



CALIFORNIA INSTITUTE OF TECHNOLOGY  
 MASSACHUSETTS INSTITUTE OF TECHNOLOGY

# INSTALLATION SPECIFICATION

E020537-04-D

DOC NO. - REV. - GID

DATE: 6/4/02

**1** SHEET **1** OF **10**

TITLE

## PEPI Installation Procedure

| APPROVALS:           | DATE   | APPROVALS: | DATE     |
|----------------------|--------|------------|----------|
| WRITTEN: Larry Jones | 6/4/02 | CHECKED:   |          |
| CHECKED:             |        | CHECKED:   |          |
| CHECKED:             |        | DCN NO     | APPROVED |
| CHECKED:             |        |            | DATE     |

## 1 SCOPE

This checklist details the steps required to remove the BSC X-Fine Assembly Replacement Weldment (aka Fine Stage Ersatz) and to replace it with the Fine X Translation Assembly (aka Fine Stage), serving as a PZT External Pre-Isolator (PEPI). These steps were chosen to minimize any resulting disturbance of optics alignment.

## 2 APPLICABLE DOCUMENTS

Listed below are all of the applicable and referenced documents for this task procedure.

|           |  |
|-----------|--|
| D972001   | BSC Top Assembly   |
| D972101   | BSC Flexure Mount Assembly (aka Fine Stage)                      |
| D972104   | Scissors Table Assembly  |
| D972105   | Translator Stack Spacer Block                                    |
| D972106   | Airbearing Assembly  |
| D972106-1 | Airbearing Base Surface  |
| D972106-2 | Airbearing Mid Surfaces  |
| D972106-3 | Airbearing Spherical Surface                                     |
| D972107   | BSC X-Fine Assembly Replacement Weldment (aka Fine Stage Ersatz) |
| D972118   | Crossbeam Weldment   |
| D972119   | BSC Airbearing/X-Y Translator Mounting Plate                     |
| D972120   | BSC Airbearing Mounting Plate                                    |
| D972127   | Scissor Table Stop Link  |
| D972141   | Flexural Pivot Assembly  |
| D972142   | Crossbeam/Airbearing Spherical Mounting Pad                      |
| D010227   | Overhead BSC Crossbeam Bracket                                   |



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|          |  |
|----------|--|
| D020246  | PEPI Retrofit Support Fixture  |
| D020280  | PEPI Retrofit Assembly   |
| T990126  | BSC Fine Actuator Stages Assembly and Installation Procedures (see Appendix in this checklist for modifications) |
| 406004LN | (Daedal) Translation Table Assembly  |

### 3 PREPARATION

- 1. Procure the following special equipment for this task:
  - a. Load cell (dynamometer) for crane, with 6000 lb maximum range and 10 lb gradations (Eilon Engineering, RON 2000 Shackle Type, Catalog no. S-03)
  - b. *Overhead BSC Crossbeam Bracket, with Shims, Eyebolt, Fasteners and Washers*  
*Unnecessary - obstructed access and could not be used*
  - c. PEPI Retrofit Support Fixture, with Fasteners
  - d. *Transfer table, for transferring equipment between the fork lift platform and the top of the Scissors Table*  
*Unnecessary - forklift alone worked fine*
  - e. Shim blocks and crowbars for separating pinned pier stack components (if needed).
  - f. Torque arm for scissors table gearbox stub shaft. *Note: this may revert to the use of an electronic driver if manual actuation of the gearbox does not work out; subsequent steps would need to be changed to accommodate this.*  
*Unnecessary*
- 2. Coordinate task schedule with the Detector Commissioning Manager (if commissioning is occurring; otherwise, coordinate with Observatory Manager).
- 3. Assemble and calibrate the appropriate quantity of Fine Stage Assemblies in preparation for installation, per T990126-A, modified by comments by Joseph A Giame, listed in the Appendix of this checklist. Mark positive side of each assembly.
- 4. Confirm shackle/clevis fit has been checked, and machine screw jack has been reworked, as called out in the Notes of drawing D020280.
- 5. Confirm all equipment to be used for this task fits and is fully functional. Confirm that the transfer table is securely attached to the fork lift platform, and that the fork lift platform is securely attached to the fork lift.
- 6. Setup beam monitors as appropriate to monitor possible shifting of the optic(s) in the BSC being worked on.



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7. Setup dial indicators at each crossbeam end for monitoring movement in all three directions: X, Y and Z. Record direction of positive indication and zero all dials (use compass directions for Pier ID reference and direction reference). **Caution: Throughout this task, take care to not disturb the Dial Indicator mounting hardware!**

*Direction of positive indication for Dial Indicators:*

*Unnecessary to record - indicators set to '0' and maintained +/- 0.004" at all times. Returned to 0.000 after installation. Only vertical displacement noted.*

*Confirmation of Zeros:*

*Unnecessary to record - indicators set to '0' and maintained +/- 0.004" at all times. Returned to 0.000 after installation. Only vertical displacement noted.*

### 4 TASK STEPS.

8. **Caution: throughout this task, take great care to not apply force or torque to the Crossbeams or anything rigidly attached to them. Do not push them, lean on or stand on them (or anything connected to them)! It is very important that the current optical alignment is not disturbed!** Refer to Drawing D020280 for an illustration of the hardware for the steps to follow. Turn the machine screw jack knob to position the clevis at 1" above the screw jack housing and install the machine screw jack on the PEPI Support Fixture; tighten the screws; mount this assembly on the top of the end of the Crossbeam with the fasteners provided. *Use the Torquing Reaction Rod in the appropriate Support Fixture hole to keep from applying net torque to the Crossbeam.* *Unnecessary - used 3/8" ratchet and resisted with hand*
9. *Install Overhead BSC Crossbeam Bracket at the BSC pier where the Fine Stage is to be installed. This will likely be an iterative process, and shims are provided to adjust the in/out position of the Bracket on the pier. Initially, install 0.50 inch of shim thickness (nominal design). Using a plumb bob, check the position of the Bracket hole with respect to the center of the screw jack clevis. Adjust the Bracket position by adding/removing shims (in/out direction) and by moving the Bracket in its slotted mounting holes (transverse direction) until the plumb bob check shows that the Bracket is centered over the Crossbeam within 0.06 inch. Tighten Bracket mounting bolts.*  
*Record BSC ID: \_\_\_\_\_ Pier ID: \_\_\_\_\_ Date: \_\_\_\_\_*  
*Unnecessary - obstructed access and could not be used*
10. *Install eye bolt and shackle on crane hook; position crane over Crossbeam Bracket hole and install the eyebolt in the Bracket hole, with a jam nut (loose) on the lower side of the Bracket plate and a full height nut above the plate at (nominally) mid screw length. This positioning is to provide for a maximum flexibility of adjustment later.*  
*Unnecessary - obstructed access and could not be used*
11. Disable crane power to preclude inadvertent operation during the remainder of this task; it will serve only as a backup in case of bracket failure.
12. *Supply 30 psig, 2 micron filtered, oil-free air to the Airbearing (only at the pier being worked) and confirm that it's floating.* *Unnecessary - removed as a unit w/o disassembly*



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- 13. Install the eye nut at the bottom of the eye bolt, with a torqued jam nut. Install the remainder of the lift chain: shackles and load cell, as shown in drawing D020280. Adjust the eye bolt to make the crane cables taut.
- 14. **Using the adjacent structure to provide torque reaction support**, loosen the bolts fastening the Airbearing Spherical Surface to the bottom of the Crossbeam. **Take care to not allow torque to be applied to the Crossbeam.** Remove these bolts.
- 15. Install the torque arm to the stub shaft at the bottom of the Scissors Table gearbox and remove scissors table stop links.
- 16. Using the machine screw jack (manually turning knob on input shaft), apply load to the bracket/ crane hook by lowering the screw jack shaft; increase this to a load of 1500 +/- 100 lb, as indicated by the load cell.  
Record this reading: Load Cell Load: \_\_\_\_\_ lb

- 17. Turn the torque arm to lower the Scissors Table, increasing the load on the load cell. **Caution: if the load decreases, reverse your direction.** Continue turning until the load cell load increases (expected maximum at the point of separation is approximately 3000 lb), **and** the Spherical Mounting Pad is sufficiently clear for removal (1/4" or greater).  
Record these readings: Load Cell Load: \_\_\_\_\_ lb      Gap: \_\_\_\_\_ inch

Record Dial Indicator Readings:  
 Pier ID: \_\_\_\_\_ X: \_\_\_\_\_ Y: \_\_\_\_\_ Z: \_\_\_\_\_  
 Pier ID: \_\_\_\_\_ X: \_\_\_\_\_ Y: \_\_\_\_\_ Z: \_\_\_\_\_  
 Pier ID: \_\_\_\_\_ X: \_\_\_\_\_ Y: \_\_\_\_\_ Z: \_\_\_\_\_  
 Pier ID: \_\_\_\_\_ X: \_\_\_\_\_ Y: \_\_\_\_\_ Z: \_\_\_\_\_

Unnecessary - also, load transferred by iterating between lowering scissor table and lifting with jackscrew. We maintained crossbeam between +/- 0.004 of initial position

- 18. If the Airbearing on this pier is a driven assembly (having translation tables), remove fasteners and remove Flexural Pivot Assembly from the top of the X-Y Translator.  
**Caution: handle this with care, as the flexures are fragile.**  
We did this first, before making up any of the lift hardware.
- 19. *Slide the Airbearing Midsurface to one side, rotate the Airbearing Spherical Surface and remove the Spherical Mounting Pad.*  
Unnecessary - airbearing removed as assembly.

20. **Caution**

**A. The surfaces of the Airbearing are very carefully formulated, machined and cleaned. Each interface bearing surface must be kept clean and must not be handled with bare hands!**

**B. Airbearings are expensive and require long lead times for replacement. Take special care in handling the Airbearing to keep from damaging it.**



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- 21. *Loosen top and bottom bands from rubber boot; remove bolts connecting pressure switch from Airbearing Mid Surface and tape pressure switch to boot; tape bands and boot together for ease in handling. Unnecessary - airbearing removed as assembly.*
- 22. *Remove bumper pins from one side of the Airbearing Base Surface, carefully restraining the Airbearing Mid Surface to keep it from slipping off of the Base Surface. Use a clean wipe with isopropyl alcohol to remove any sign of oil from the Base Surface. Slide the Mid Surface and Spherical Surface out onto the transfer table on the forklift platform. Secure them for safe lowering, lower them to floor level, separate them and set them on a foam pad under Ameristat film; shut off and disconnect the air supply. Unnecessary - airbearing removed as assembly.*
- 23. Remove the four bolts from the Airbearing Mounting Plate and remove it with the Airbearing Base Surface attached (*and Daedel Translation Assemblies and Spacer Block, if a driven unit **These removed first***) from the Fine Stage Ersatz. Check for the presence of positioning pins; take care that the Mounting Plate is not binding on its pins. If necessary, thread 1/2-13 bolts into holes from below to lift the Mounting Plate off the positioning pins. Slide Mounting Plate onto the transfer table on the fork lift platform. Secure this for safe lowering, and lower forks to floor level. Cover the Airbearing Base Surface with Ameristat film.
- 24. *Remove bolts from the Fine Stage Ersatz and remove the Ersatz (140 lb) from the Scissors Table. Take care that the Ersatz is not binding on its pins (assuming that pins are present; they may not be). If pins are present and preventing removal, use blocks and crowbars to pry off the Ersatz. Slide out Fine Stage Ersatz onto the transfer table on the fork lift platform. Secure this for safe lowering, and lower forks to floor level. **We removed the Ersatz and airbearing as a unit, and slid the airbearing right onto the fine actuator while they sat next to each other on a clean pallet. This done on the floor.***
- 25. Securely attach a calibrated Fine Stage onto the transfer table and lift it into position.  
Record S/N \_\_\_\_\_
- 26. Slide the Fine Stage onto the top of the Scissors Table. Note: if there were no pins at this interface, do not add pins; if there were, replace them if they were removed in the disassembly process.
- 27. Position the Fine Stage for bolting, after confirming that the piezo axis is parallel to the beam line and that the LIGO positive side of the Stage is toward the arm's end station.
- 28. *Install bolts at the bottom of the Fine stage, attaching it to the Scissors Table and torque them to 48 ft lb. Confirm torquing by initialing: \_\_\_\_\_  
**Only 2 holes aligned when installed, so only 1/2-13 bolts used***
- 29. *Securely attach an Airbearing Mounting Plate, with attached Airbearing Base Surface (*and Daedel Translation Tables and Spacer Block, for driven units*) onto the transfer table and lift it into position.  
**This done on floor and flexure/ airbearing installed as a unit. Translation stages not reinstalled***



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- 30. *Install the Airbearing Mounting Plate on top of the Fine Stage. If there were no pins at this interface, do not add pins; if there were, replace them if they were removed in the disassembly process. Install bolts and torque to 57 ft lb. Confirm torquing by initialing: \_\_\_\_\_*  
Pins out 90° and could not be reinstalled
- 31. *Supply air to the Airbearing Mid Surface; place Airbearing Spherical Surface in position and securely attach this onto the transfer table; lift it into position.*  
Unnecessary
- 32. *Confirm that the bearing surface of the Airbearing Base Surface is free from particles and signs of oil or grease; slide the Airbearing Mid and Spherical Surfaces onto the Base Surface and install bumper pins to limit movement.*  
Unnecessary
- 33. *Confirm that the air supply is still flowing, and that the air bearing is floating.*
- 34. *Insert the air bearing Spherical Mounting Pad into position and confirm that both it and the Airbearing Spherical Surface top are parallel with the bottom of the crossbeam. Loosely install screws at this interface.*  
Because airbearing was not disassembled, we did not supply air until installation of the unit was completed, and the load was once again on the stack.
- 35. *If the Airbearing on this pier is a driven assembly, reinstall Flexural Pivot Assembly and torque fasteners to 8 ft lb.*  
Confirm torquing by initialing: \_\_\_\_\_  
These not reinstalled
- 36. *Reinstall boot, boot bands and pressure switch.*  
Unnecessary
- 37. Raise scissors table with torque arm to decrease the load cell reading to 1500 lb. **Caution: proceed slowly; make fine adjustments at the end of the range with the machine screw jack, not the Scissors Table gearbox shaft.** Record this reading: Load Cell Load: \_\_\_\_\_ lb
- 38. Remove torque arm from Scissors Table gearbox shaft and confirm that the load cell reading has not changed. **Reinstall Scissors Table Stop Links.**  
Record this reading: Load Cell Load: \_\_\_\_\_ lb
- 39. **Using the adjacent structure to provide torque reaction support,** tighten the Crossbeam/Airbearing bolts to 10 ft lb; use a slow star pattern to prevent the Spherical Surface from being rotated out of position. Additionally, watch for lifting of the Spherical Surface out of the Mid Surfaces. This lowering, leveling, centering and torquing may require several attempts.
- 40. Using the machine jack screw, remove the load from the load cell. Take care to not increase the load!  
Record final load cell reading: Load Cell Load: \_\_\_\_\_ lb



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- 41. Shut off the air supply to the Airbearing.
- 42. Disconnect the crane, load cell, eyebolt and shackles from the Crossbeam Bracket and Support Fixture.
- 43. Disconnect the Support Fixture from Crossbeam and from Airbearing Mounting Plate. Use the torquing reaction rod in the appropriate holes to keep from applying net torque to the Crossbeam.
- 44. *Disconnect the Crossbeam Bracket from the pier.*  
*Record Dial Indicator Readings:*  
  
*Pier ID: \_\_\_\_\_ X: \_\_\_\_\_ Y: \_\_\_\_\_ Z: \_\_\_\_\_*  
*Pier ID: \_\_\_\_\_ X: \_\_\_\_\_ Y: \_\_\_\_\_ Z: \_\_\_\_\_*  
*Pier ID: \_\_\_\_\_ X: \_\_\_\_\_ Y: \_\_\_\_\_ Z: \_\_\_\_\_*  
*Pier ID: \_\_\_\_\_ X: \_\_\_\_\_ Y: \_\_\_\_\_ Z: \_\_\_\_\_*  
*Unnecessary to record, everything brought back to 0.000"*
- 45. Compare post-task beam monitoring values with pre-task and record:  
Pier:\_\_\_\_\_ Comparison: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
- 46. Repeat steps 7-37 for the remaining piers of this BSC.
- 47. Remove all Dial Indicator equipment.
- 48. Perform remaining steps of Fine Stage installation, T990126 as modified by notes in this Appendix, as applicable.
- 49. Make an E-log entry pertaining to the task completed, including any deviations, recorded values, and notes.
- 50. Sign and date at the completion of this procedure.  
Record BSC ID: \_\_\_\_\_ Task Leader: \_\_\_\_\_ Date: \_\_\_\_\_



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# APPENDIX

## Modifications to T990126-A, "BSC Fine Actuator Stages Assembly and Installation Procedures", per e-mail from Joseph A Giame of 13 Sep 1999:

I've gone through the Livingston fine actuator PZTs and controllers and have a few comments on the process and on Hytec's procedure.

I've disregarded the advice to turn the stacks off when not in use, since we intend to use them full time for 5 years (doesn't Eric know this?). I figure if any of them are going to have infant mortality, it ought to be on my bench.

As Larry noticed at Hanford, the threads in the Fine Actuator "top frame" are quite tight, and the SS stop screws tend to bind up in them, so we are using silver-plated bolts for now. Their ends are not rounded, but I doubt that it is a problem.

Section 5.2 in the procedure describes 2 ways to adjust the offset voltage of the strain gauge to account for the coil-spring preload, one using a load cell in a load frame and one using a spare flexure stage. I used the latter. The given procedure doesn't really work, since the overflow indicator light on the controller doesn't work very well. I suggest the following:

- 1) Loosen all locking nuts.
- 2) Set the PZT to 90 microns (put the meter on microns, not volts), with the loop closed.
- 3) Install the PZT, then lightly finger tighten the bearing housing.
- 4) Turn the PZT to 180 microns, which will allow easy backing off of the stop screws. (back them off now)
- 5) Restore the PZT to 90 microns.
- 6) Adjust the offset trim pot in the strain gauge controller with a small screwdriver to approximately -250 V. Then adjust the bearing housing (with a BIG wrench) to return to the 0 micron offset from the frame's rest position, as read on the dial gauge. (this zero was set earlier in Hytec's procedure).
- 7) Put a 50 mHz sine wave, 5 V peak (10 V p-p), on the Control input of the HV amplifier.
- 8) View the sensor monitor output. On the single-channel version, this is a BNC, but the three-chan version has a LEMO and comes with a matching cable with the following color code: Chan 1 = white, Chan 2 = Brown, Chan 3 = Green, braid = common. The signal on this output should be a smooth sine wave, 0-10 V. It is possible for this signal to be clipped without the overflow light coming on, unfortunately.
- 9) Set the amplifier's LCD output to volts, and after several cycles note the range needed to track the input. It should be about -700 V to + 150 V. The sensitivity of the stacks vary, so this range might be larger or smaller, but try to adjust the offset pot to center around this range. There is significant hysteresis, so the value



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of this voltage with zero input varies from -220 to -280 V.

10) If necessary, adjust the bearing housing to return to the 0 micron offset from the frame's rest position and repeat the voltage offset adjustment.

11) Label the matched set of PZT stack, controller channel and cables, so that they are all installed together.

We can use the spare actuator frame to adjust all of them.

-----

I propose the following procedure to install them in the actuator bodies in place of the piers supporting the SEI.

1) Remove all preload springs, back off stop screws on all four corners, allowing the system to find its best rest position.

2) Tighten stop screws.

3) Re-zero all dial gauges.

4) Reinstall the springs.

5) Install the PZTs in all corners, with servo on set to 90 microns.

6) Back off the stop screws, and adjust the bearing housing to bring each dial gauge to zero.

7) Apply a 50 mHz sine wave, 5 V peak (10 V p-p), on the Control input of all four HV amplifiers. Observe sensor monitor outputs and voltage ranges on the HV amplifiers and adjust voltage offset and bearing housings as necessary to center the HV range and dial gauge (as in steps 8 and 9 above). I hope that this step will be a very small tweak.

8) Position stop screws 1 mm from contact. Tighten locking nuts.

9) Tighten locking nut on bearing housing.