Phase 1 of the assembly sequence installs and positions the hardware external to the vacuum system; this includes the Piers, the Actuator Stack components, and the Crossbeams. This phase will take place with the chamber closed.

1 INSTALL PIER ANCHOR BOLTS

The BSC SEI Pier anchor bolts will be located by means of the Pier Centering Jig. The jig has registration surfaces that will contact the "D" Nozzles for position.

1.1 SET UP PIER CENTERING JIG

Setting up the Pier Centering Jig involves positioning the registration surfaces to insure proper position of the jig relative to the BSC chamber. Also, the Jig must hang level when lifted. Referring to drawing D972376, check the y (zone C6) dimension. This can be lost during transport etc. and should be checked and set as required. *The position of the side stage has been scribed on the Jig.* The vertical registration surface of the jig will not be used and the Elevation Stage Subassemblies should be removed from the jig to prevent interference with the chamber.

1.1.1 Y-dimension: Position a framing square on top of the pier lifting weldment perpendicular to the line between the two plumb bob holes. This should allow the checking and setting of the distance from the plumb bob hole's centerline to the vertical surface of the Side Stage Weldment (D972409), to 15.75".

1.1.2 Level: Position and connect the 10' Strong-Bac to the Jig using 6' straps; use the no-pier lift slots. Thread 4 gammon reel strings through the plumb bob holes and connect to 4 plumb bobs. Raise the Jig, hang the plumb bobs and check the level of the 'A' surfaces with two levels along the x-axis and an 8' level spanning the y-axis between the weldments. Adjust the level with weights, e.g. C-clamps. Mark positions for reference.

1.2 LOCATE ANCHOR BOLTS

1.2.1 With the Pier Centering Jig set as detailed above, move the Jig into position with the Point Contacts lightly touching the Conflat cover faces and the Side Stage Weldment lightly touching the outboard side of the Conflat flange. The vertical position is not critical, only insure that the Side Stage Weldment is tangent to the flange.

1.2.2 Extend the plumb bobs to the floor and raise enough to hang just above the Drill Template. Adjust the position of the Template such that the scribes of the Template are under the plumb bobs. Mark the four bolt holes, the center of the template, and the circumference with a permanent marker. Repeat for the other side of the Jig.

1.2.3 After moving the Jig out of the way, use a circle scribe and mark the limits for the grout area. This will be ~3.5" beyond the jig circumference and is not critical.

1.2.4 Make check measurements between marks on the floor that are accessible. Nominal should be 114" in both x and y.

1.3 DRILL FOR & INSTALL ANCHOR BOLTS

The Anchor Bolt hole-drilling and bolt installation will be contracted out. The contractor is directed to the *Anchor Bolt Installation* document and manufacturer's instructions for equipment and procedures.

1.4 PREP SURFACE FOR GROUT

The contractor installing the Anchor Bolts will roughen portions of the area defined above (~4 ~4x4) per the grout manufacturer's requirements.

2 INSTALL PIERS

The position of the Piers is important to many later stages of the installation with the elevation and levelness especially critical. The installer is urged to recheck positions before grouting proceeds. The BSC Piers will be installed individually around each chamber. All four piers will then be elevated wrt to the BSC 'D' Nozzle ports and to each other. Finally, pairs of Piers will be positioned horizontally relative to the Chamber using the Pier Centering Jig.

2.1 POSITION GROUT PLATE

By measuring down to the floor from the bottom of the 'D' Nozzle flange, the approximate height of the Grout Plate above the floor can be determined. This may be different for each pier given the variability of the floor levelness. At LHO, the base of the Pier or the top of the Grout Plate is 106.596" below the bottom of the 'D' Nozzle flange. At LLO, it is 105.596".

2.1.1 Screw four Flange Nuts, flanges up, on the four Anchor Bolts of a given pier. Place a Grout Plate over the bolts onto the Flange Nuts.

2.1.2 Level the Grout Plate and recheck the height.

2.2 INSTALL PIER

2.2.1 Using two swivel lifting eyes and two equal length slings, hoist a Pier. The lifting eyes should be installed in opposite sides of the Pier top so that it will hang level; this will cause the Pier to rotate while raising from a horizontal attitude so use caution. Also, use care to prevent the cable from jumping out of the grooves in the crane sheave and that the base of the Pier does not fall off its support when rotating.

2.2.2 Set the Pier over the Anchor bolts and rest on the Grout Plate using caution not to damage bolt threads; this may require the moving of cable trays. Face the opening in the top, side of the Pier axially inward aligned with the axis of the 'D' Nozzle.

2.2.3 Secure with heavy-duty flat washers and SST nuts; remove the lifting gear.

2.3 ELEVATE PIER

Unlike the lighter HAM Pier, the heavy BSC Pier should have no problem with flattening the Grout Plate. However, the Pier may be resting on only three of the four Flange Nuts with the fourth nut only snug against the downward deflected Grout Plate. To insure the level will be maintained while torque is applied, the installer must insure that all four Flange Nuts are raised, compressing the Grout Plate to the bottom of the Pier. The top nuts may need to be tightened down when checking final level.

2.3.1 Using differential leveling with the optical level, find the average level of the four 'D' Nozzle flange bottoms.

2.3.2 Then, again with differential leveling, position the tops of the Piers 8.166" ±0.080" below the average found above. Despite this generous tolerance, the four Piers must be within ±0.020" of each other. Take multiple readings on the tops of each Pier (above each anchor bolt is most efficient) and level to within ±0.010" (1mrad).

PIERs Elevated/Leveled:

Date: _____Initial: _____Comment: _____

2.4 LOCATE PIER

The position of the Pier will now be set relative to the 'D' Nozzles of the BSC Chamber using the Pier Centering Jig. The level of the Pier has been set previously and should not be disturbed by this process. Set the horizontal position of the Pier to ±0.250".

2.4.1 Remove the ½" dowel pins in the tops of the piers.

2.4.2 Move the Pier Centering Jig into position over the two Piers in front of opposite 'D' Nozzles and adjust the position of the jig so that the registration surfaces of the Jig contact the 'D' Nozzles.

2.4.3 Move the Piers under the jig to align the dowel pin holes of the Pier with the receiving holes of the jig. Record off-nominal positions.

PIERs Located:

Date: _____Initial: _____Comment: _____

2.5 TORQUE ANCHOR BOLTS

2.5.1 Move the Jig just out of the way and torque the top nuts down to 150 ft-lbs.

2.5.2 Recheck the level of the Piers to insure 1mrad tolerance is maintained. Make level adjustment if required and reposition the jig to check horizontal position.

2.5.3 When the position and elevation of the Pier has been maintained after torquing, repeat for the other two Piers.

PIER Anchor Bolts Torqued:

Date: _____Initial: _____Comment: _____

2.6 GROUT PIER

A contractor will do the grout work in accordance with standard practices and the grout manufacturer's instructions.

3 INSTALL ACTUATION SYSTEM

The Actuation Stack consists of the vertical motion Scissors Table, D972104, the X-Fine Translation stage, D972101, and the Coarse X-Y stage D972102. To insure correct movement of the Optics Table in the Chamber and to prevent the driven stages' motor drives from being overloaded, the stack must be aligned to be square within 1mrad. The alignment will be established on the Adapter Plate; further components of the system will in turn be pinned to this plate. During each component's installation, clean the mating surfaces for a solid connection.

3.1 ESTABLISH OFFSET BEAMLINES

Two offset lines parallel to the main beamline are needed to align the actuation stacks. Having these offset lines parallel to each other is more important than being absolutely parallel to the actual beamline; however, that is also desirable. The theodolite will be positioned to sight across the beamline in two positions in the approximate center of the Piers; additionally, a third setup of the theodolite will be needed to sight over the two Piers on the same side of the beamline. (See Figure 1.) At LHO, 124" and 61" offset from the main beamline have provided good focusing and clear visibility.

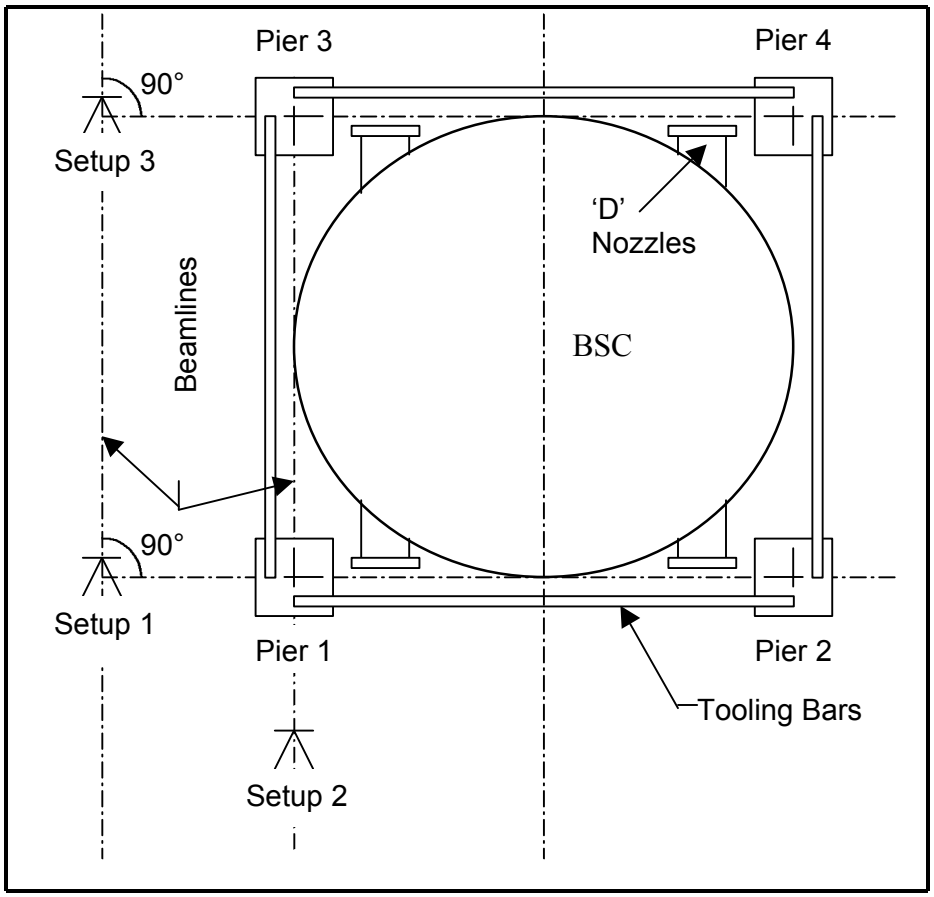

Figure 1. Adapter Plate alignment sketch.

3.2 INSTALL & ALIGN ADAPTER PLATE

3.2.1 Referring to the BSC Installation logbook, choose a Pier that was nominally located as the reference Pier (Pier #1), preferably a Driven Stage Pier. Because only two of the four Adapter Plates will house a Driven Translation Stage, the rotation of the other Adapter Plates will not be critical. The Tooling Bars will suffice for alignment; the Driven Stage is mounted on the left end of a Crossbeam when looking at the Chamber.

3.2.2 Position Adapter Plates in the center of the Piers. Insure the Adapter Plate is right side up; this is based on the inserted helicoils. Bolt an Optics Plate onto each Adapter Plate.

3.2.3 Buck the Theodolite onto the offset beamline at Setup 1.

3.2.4 Pin the first Adapter Plate to the reference Pier for rotation. The pins will keep the Adapter Plate in the center of the Pier during its rotation and during the positioning of the other three Adapter Plates.

3.2.5 Turn 90° from the offset beamline and rotate the #1 Adapter Plate so that the scribe on the Optics Plate is parallel to the Theodolite vertical crosshair. If the crosshair is offset from the scribe, this same offset must be used on the #2 Adapter Plate; this can be measured reading a fine scale through the Theodolite. The goal should be to achieve a 1mrad alignment: for rotation ±0.005" over 10" of the Optics Plate and for translation ±0.028" over the 114" Pier center to center. Fix the Adapter Plate to the Pier with Adapter Plate Mounting Clamps.

3.2.6 Install a Tooling Bar in the #1 Adapter Plate and position the #2 Adapter Plate to receive the other end of the Tooling Bar. The Tooling Bar will get the Adapter Plate close but may need adjustment in both rotation and translation. Again using the crosshair site from Setup 1, translate and rotate the #2 Adapter Plate as required and bolt down.

3.2.7 **Measure and record the horizontal distance from the Tooling Bar to either the face or the flange of the 'D' Nozzle, depending on the orientation of the chamber.**

3.2.8 Install a Tooling Bar from the #1 Adapter Plate and adjust the #3 Adapter Plate to receive the tooling bar.

3.2.9 Move the Theodolite to Setup 2 where a sight can be taken over plate #1 to plate #3 and buck-in to the offset beamline. The first Tooling Bar between plates #1 and #2 may need to be removed.

3.2.10 Translate plate #3 to be along the same offset as plate #1. Rotate Adapter Plate #3 as required and bolt down to the Pier.

3.2.11 **Measure and record the horizontal distance from the Tooling Bar to either the face or the flange of the 'D' Nozzle, depending on the orientation of the chamber.**

3.2.12 Install Tooling Bars in Adapter Plates #2 and #3 and position Adapter Plate #4 to receive the two Tooling Bars. If Adapter Plate #4 is a Floating Stage, alignment with the Theodolite is not necessary and the next step may be skipped.

3.2.13 Move the Theodolite to Setup 3, buck in on the offset beamline and turn 90° to Adapter Plate #4. The Tooling Bar between plates #1 and #3 may need to be removed for visibility. The translation position of plate #4 should be good *i.e.*, the scribes should be offset from the crosshair the same amount; if not the Tooling Bars or Setup 1 is suspect. However, the plate may require rotation. Once rotated, bolt the plate to the Pier.

3.2.14 **Measure and record the horizontal distance from both Tooling Bars to either the face or the flange of the 'D' Nozzle, depending on the orientation of the chamber. Compare the measurement with the similar value made on the opposite side of the Chamber. These readings must be equal (nominal ±3/16") in transverse and ±3/8" in axial.**

3.2.15 **If discrepancies were found in the previous step, the Adapter Plates will need to be translated using the Teflon guide bars to retain the orientation and the Theodolite to monitor the translation amount.**

3.2.16 Alignment is now complete; the Tooling Bars and Optics Plates may be removed.

ADAPTER PLATES Aligned:

Date: _____Initial: _____Comment: _____

3.3 INSTALL SCISSORS TABLE

The Scissors Table will be received at the facilities ready for installation with the motor installed. They will have stop links installed to hold the nominal height. Dowel pins in the base of the Tables will register in the Adapter Plate.

3.3.1 Lift the Scissors Table using two ½-13 lifting eyes installed diagonally in the top of the Table.

3.3.2 Check to insure the dowel pins do not protrude greater than 3/8"—the Adapter Plate is only ½" thick.

3.3.3 Lower the Table to register the dowel pins in the bottom of the Table in the hole and slot of the Adapter Plate.

3.3.4 Clamp the Scissors Table to the Pier with eight Scissors Table Mounting Clamps. Torque the bolts.

3.3.5 Repeat for the other three Piers.

MOUNTING CLAMPs Torqued:

Date: _____Initial: _____Comment: _____

3.4 INSTALL X-FINE TRANSLATOR

The X-Fine Translator stage will be received at the observatory assembled and ready to install. The stage will *not* have the PZT drive used for motion installed. There will be stop screws holding the flexure in nominal position with dial indicators installed for monitoring. The PZT drive will be installed later. The four Fine stages of a BSC are mounted oriented in the same direction, unlike the Scissors Table which are mounted in opposite directions. To accommodate this, there are two sets of receiving holes in the base of the Fine stage. In the corner station, the X-Fine stage will be replaced with the Fine Stage Ersatz.

3.4.1 Mount all Fine stages in the same direction according to detector protocol **TBD**.

3.4.2 Hoist the Fine stage with lifting strap through the bottom frame. The replacement Ersatz will need two angle brackets bolted into the ½-20 holes.

3.4.3 Lower the stage onto dowel pins installed in the top of the Scissors Table; then, install and torque down the mounting bolts.
3.4.4 Check that the dowel pins in the top of the Fine stage are protruding ≤ 0.25".

FINE STAGEs Torqued:
Date: _____Initial: _____Comment: _____

3.5 INSTALL COARSE X-Y TRANSLATION STAGE

The Coarse X-Y Translation Stage is comprised of the Airbearing mounted on the Airbearing Mounting Plate (D972119 and D972120) and for the driven assembly, an x-y translator mounted on the mounting plate and connected to the Airbearing. The x-y translator, comprised of the Translator Stack Spacer Block D972105 and the two cross mounted Daedel Translation Assemblies, will be shipped as a unit and are pinned to the Airbearing Mounting Plate.
For each BSC Chamber there will be two driven assemblies and two floating assemblies diagonally arranged. The driven assemblies will be installed on the left stack as one looks at a given Crossbeam, and the translators will be mounted between the Crossbeams. The Mounting Plate will be lifted up to its position on the stack with the Airbearing Base Surface and the x-y translator already attached.
The surfaces of the Airbearing are very carefully formulated, machined, and cleaned. The top of the Base Surface, the bottom and top of the Mid Surfaces, and the base of the Spherical Surface must *not* be handled with bare hands. As long as the surfaces are kept oil/grease free, the air flowing through the bearing will keep the surfaces free of dust. If required, the surfaces may be cleaned according to the Specialty Components, Inc *LIGO BEARING—HANDLING AND INSTALLATION INSTRUCTIONS* document provided with each Airbearing shipped.
In general, all handling of the Airbearing should be done wearing gloves, frocks, masks, and caps. Additionally, any time there is risk that an assembled Airbearing may move, <85% relative humidity, 2μm absolute filtered, oil/resin free, 30 psi air must be supplied to prevent damage. This pressure is for no load only, refer to the above document when floating loads.
The Airbearing Base Surface will be oriented to have the two Pneumatic Mounting Block flats (D972151, zones A-7 and A-6) facing outward from the beamline and away from the chamber axially.
The production unit Airbearings are being shipped with the Mid-Surfaces bolted to the upper Spherical Surface. This will allow the Airbearings to be installed using lifting eyes and the crane.
3.5.1 Check for dowel pins in the top side of the Driven Airbearing Mounting Plate used for aligning the Translation Stage and install if not present. The bottom of the Plate has the holes and slots for the dowel pins in the top of the Fine Stage.
3.5.2 Install the x-y translator unit on the above dowel pins and bolt down from the underside. Do not use the two countersunk holes for this connection; use only the four thru holes. The countersunk holes will not be accessible after build-up of the stack and the translators could not be removed if the bolts were not accessible.
3.5.3 With the required cleanliness precautions observed, place an Airbearing Base Surface on the Airbearing Mounting Plate (dowel pin holes and slots facing down), orient as noted above and bolt down with twelve ¼-28x2.0 bolts. Torque to 7 ft-lbs.

AIRBEARING BASEs Torqued:

Date: _____Initial: _____Comment: _____

3.5.4 With hoisting brackets attached to the mounting plates, lift the mounting plates into their position on the X-Fine Translation Stage.

3.5.5 Torque the mounting plates down to the fine stage with ½-20 bolts to 57 ft-lbs.

MOUNTING PLATES Torqued:

Date: _____Initial: _____Comment: _____

3.5.6 Install the tubing coated dowel pin bumpers around the top of the Base Surface.

3.5.7 Install two eyebolts into opposite ½-13 holes in the top of the Spherical surface. Hoist into position with crane.

3.5.8 With ~ 30 psi air attached and flowing, carefully place the Airbearing Mid Surfaces onto the base.

3.5.9 Loosen and remove the center bolt holding the surfaces together.

3.5.10 Install an Airbearing Bellows.

3.5.11 Place a Crossbeam/Airbearing Spherical Mounting Pad (D972142) on the Airbearing Spherical Surface. Turn off air to conserve it.

3.5.12 Repeat for the other three stacks.

4 INSTALL CROSSBEAMS

The Crossbeams will be installed in a level attitude onto the Airbearing. If the Crossbeam puts a load on the Airbearing before it is level, the Airbearing Spherical Surface will be rotated out of position as the Crossbeam is leveled. The Translation Flexural Pivot Assembly, D972141, will be replaced by the Assembly Flexure Jig, D972492, during installation. This will insure that the Airbearing Spherical Surface will line up with the Flexural Assembly when it is later installed. Further, until the Crossbeam is connected to the Support Tubes via the *V-Blocks*, Crossbeam Bracket Assemblies D972388 & 389 will support the Crossbeam. This procedure is for the installation of *one* Crossbeam.

4.1 POSITION AIRBEARING

To provide the complete range of motion required of the actuation system, the floating portion of the Airbearing (Mid Surfaces) must be positioned in the center of the Base Surface. This will be accomplished with jigs. Be sure to use washers on the holes sized for shoulder bolts; there is less material for the bolt to hold on, especially the slots, and the material can be damaged.

4.1.1 Install the Assembly Flexure Jig, D972492 on top of the X-Y Translation assembly with shoulder bolts & cap screws.

4.1.2 Supply air to the Airbearing being positioned.

4.1.3 Using the two Pneumatic Mounting Block flats (see § 3.5), install the Airbearing Centering Jigs, D972488. Repeat for the non-driven stack.

4.1.4 On the driven actuation stack (left), install alignment pins in the two center holes of the four ¼-20 holes on the edge of the Airbearing Spherical Surface (D972106 zone D-5).

4.1.5 Move the Airbearing Spherical Surface to register the alignment pins in the Flexure Jig; bolt the jig to the Spherical Surface using appropriate shoulder and regular bolts. Adjust the positions of the two translation stages to register the Airbearing Mid Surfaces on the Centering Jigs.

4.1.6 Turn off the air to conserve it.

4.2 INSTALL CROSSBEAM BRACKETS

There are left and right Crossbeam Brackets; install the left bracket on the left Pier as you look at the chamber for a given Crossbeam. Install the bracket without the Clamp Weldment (D972434 & D972438); it will be installed after the Crossbeam is in position.

4.2.1 Hoist a Crossbeam Bracket using two ½-13 lifting eyes and equal length slings. Bolt the Crossbeam Bracket in its central position to the side of the Pier with four ½-13x1.25 bolts and extra large washers; repeat for the other Pier.

4.2.2 With the Crossbeam Bracket Shim in place, adjust the height of the Adjustable Locating Button so that the top of the shim is ~1.5" above the top of the Airbearing Spherical Mounting Pad.

4.3 LEVEL CROSSBEAM

There are two special situation installations. They occur at the vertex side of WBSC7 & 8. The framework of the 48" gate valve is less than 6" away from the final installed position of the Crossbeam. This is not sufficient room to install the 10" wide Support Tube Mount Base. In these two occurrences, the Crossbeam will be installed with the 2 Support Tube Spherical Mounts and the Support Tube Mount Bases attached.

4.3.1 Install three Swivel Lifting Eyes into the level crossbeam lifting holes, D972118 zones D-4, 6, & 8, of the Crossbeam. Hoist the spreader beam with the overhead crane. Hang the three Crossbeam Leveling Chains from the appropriate hooks of the spreader beam and connect to the lifting eyes. Raise the Crossbeam to a comfortable working level using caution not to bend any hardware.

4.3.2 Attach Support Tube Spherical Mount D972123 and Support Tube Mount Base D972125 to the Crossbeam in the special situation noted above.

4.3.3 Symmetrically place two magnetic base levels diagonally across the reference surface (A) mounting pads. Level the Crossbeam using the turnbuckles.

4.4 INSTALL CROSSBEAM

Once the Airbearing carries the load of the Crossbeam, it will be very difficult to adjust the position of the Spherical Mounting Pad between the Crossbeam and the Airbearing—be sure to keep the bolts free as the Crossbeam is lowered.

4.4.1 Bring the Crossbeam into position just above the Airbearing.

4.4.2 Turn the Airbearing air on; set for 50 psi.

4.4.3 Lower the Crossbeam close enough to the Spherical Mounting Pads such that bolts can be loosely installed through the Crossbeam and Mounting Pads and into the Airbearing Spherical Surfaces. One side will be closer so watch both sides.

4.4.4 Bring the Crossbeam down so the first Mounting Pad makes contact; raise the Adjustable Locating Button so that the Crossbeam Bracket Shim contacts the Crossbeam and counteracts the overturning moment of the Crossbeam. Keep the mounting bolts from binding. As the load transfers from the crane to the Airbearing and the Crossbeam Bracket, monitor the levelness of the Crossbeam and adjust the Buttons as needed to maintain the pitching level of the Crossbeam.

4.4.5 Continue lowering until the second Mounting Pad just makes contact with the Crossbeam. If it is much lower, the Crossbeam was not level, the Scissors Tables are not both at nominal height, or the Piers were not properly leveled. Investigate and correct as required.

4.4.6 Again, raise the Adjustable Locating Button so that the Crossbeam Bracket Shim contacts the Crossbeam. Be sure the mounting bolts remain free in the thru holes.

4.4.7 Tighten the Crossbeam/Airbearing Bolts to 10 ft-lbs.; 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.

4.4.8 Install the Clamp Weldments by first bolting to the Crossbeam using just 2 of the 4 bolts (which ever pair makes contact) and then fixing to the Crossbeam bracket with two c-clamps.

4.4.9 Repeat § 4 as required for the second Crossbeam of the Chamber.

CROSSBEAMS Torqued (10 ft-lbs.):

Date: _____Initial: _____Comment: _____

Phase 2 of the assembly sequence will require the vacuum chamber to be open. To keep as much potential contamination from the interior of the vacuum system, Open the Installation sock only when the open chamber is covered.
Installation will include the insertion of the Support Tubes into the chamber; the installation of the Support Table/Downtube onto the Support Tubes; and sealing the Bellows onto the Support Tube. The Support Tubes will then be connected to the Crossbeams with the V-Blocks; and the Bellows can then be connected to the chamber. Once the V-Block connection is made, the chamber may be closed and leak checked if required.

5 PREPARE FOR CLEANROOM WORK

The size, weight, and complex nature of moving the Roller System and the Cleanroom may require different sequences for each chamber.

5.1 Clean Area

Following standard LIGO protocol, clean the chamber, beamtube, and surrounding areas.

5.2 Position Roller System

The Roller System will hold the Support Tubes as they are moved into the BSC Chamber until they can be lifted by the crane and moved into final position.

5.2.1 The Roller System Assembly D972390 needs some preparation before use. Adjust the individual rollers as required to provide support to the Tube as it rolls along using the Roller System Tube Jig D972444.

5.2.2 Position the Assembly with the extended rollers facing the 'D' Nozzle Ports; locate the rollers as close to chamber as other items allow.

5.2.3 The varying floor will require both elevation and leveling adjustments using the adjustable feet. Elevate the Assembly with the tube jig as a guide to put the Support Tube several mm high in the 'D' Nozzle Ports. This is done due to downward flexing of the Roller System from the load of the Support Tubes. Level the Assembly to keep the Tube from rolling.

5.3 Position/Power-up Cleanroom

Following standard LIGO protocol, move the Cleanroom into position around the chamber and power-up.

5.4 Remove BSC Top

Once the Cleanroom has been running for at least 24 hours and the particle counter is reading less than 100 (>0.5μ) /m^3, and the volume affected is vented, the BSC top may be removed (Check w/vacuum equipment subsystem). The bolts may be loosened ahead of time to allow o-ring expansion (after venting.)

5.4.1 Insure all vacuum system hardware and conduit has been removed as required.

5.4.2 Position the Cleanroom 'sock' around the dome below the lifting lugs and cinch snug.

5.4.3 Connect the appropriate spreader bar to the crane and connect to the lifting lugs. Remove any remaining bolts in the chamber/lid flange leaving two bolts only to prevent sideways motion. Apply small amounts of lift with the crane and wait for the o-rings to expand. Repeat until the seal comes free. Check that the o-rings are not coming off with the Dome and slowly raise the top off the chamber.

5.4.4 Once safety and room permit, slide a lid cover between the chamber and the lid, and secure to the chamber.
5.4.5 Check the surface of the Dome Flange and clean as required. Secure another lid cover into place on the Dome.
5.4.6 Disconnect the velcro of the Cleanroom sock from the Cleanroom. The Cleanroom sock as designed will not allow the Dome to pass through it. The sock will just come off with the Dome. Watching for clearances raise the Dome out of the Cleanroom rotating and translating as needed and lay down.
5.4.7 Position and attach an Installation Sock onto the Cleanroom Frame.
5.4.8 Suspend the Installation Sock.

5.5 Install Work Platform

Only part of the Work Platform can be used before the Support Tubes are connected to the V-Blocks and the Jib Cranes removed. Be mindful of the cleanliness of the chamber and keep dust and debris from getting into the chamber. Shoes should be changed whenever going from the floor area or higher to a level above the open chamber. Also, keep the chamber opening covered unless access is required.
5.5.1 Remove the partially and protect the O-ring with foil.
5.5.2 Repeat this exposing and protecting until complete.
5.5.3 Expose just enough of the protected flange and install side (long) platform sections aligning with the 'D' Nozzle axis. Secure with bolts and wide washers--snug only.
5.5.4 Install the side rails.

5.6 Remove Conflat Covers

5.6.1 Loosen bolts and with hoist, remove Conflat Covers.
5.6.2 Install Conflat Covers, D972465, with the flat trimmed edge vertical and outboard; use a length of soft wire to limit risk to the Bellows knife edge during installation.
5.6.3 Cover the opening with clean Al foil.

6 INSTALL SUPPORT TUBES

In the special case noted in § ***4.3***, the Support Tubes will have to be installed through the Bellows. The Bellows will need to be in their compression clamps, D972396, and suspended between the Crossbeam and the Chamber. In none-special cases, all four Bellows will be installed just prior to V-Block connection in §**8**.

6.1 Position Jib Cranes

Hoist the Jib Cranes onto the Crossbeam and attach with four ½-13x1.25 bolts to the Crossbeam.

6.2 Position Bellows

In the special case, hang a Bellows in its Compression Clamp from the Cleanroom hoist between the Chamber and the Crossbeam. The Bellows must be raised from underneath rather than lowered from above.

6.3 Position Support Tubes

With the forklift if possible or the crane if necessary, place both Support Tubes on the Roller System. Watch tube orientation—threaded mounting holes go up and in, with extra holes at ±11" from center going up. Position the Tube as close to the chamber as possible and watch the CG for tipping and rolling of the Tube.

6.4 Position Support Tube Spreader

6.4.1 With chamber cover closed, open the cleanroom sock and bring Support Tube Spreader inside keeping crane hook out.

6.4.2 Zip the sock closed and align spreader with Support Tube.

6.5 Move Support Tube In

As the Support Tube is rolled into the chamber, elevation and level adjustments of the Roller System may be needed to keep the Tube from contacting the chamber or nozzle port.

6.5.1 Roll a Support Tube into the chamber far enough to be hoisted by the spreader bar spanning the Crossbeam. The Tube must be hoisted on center to allow the transfer in §6.5.4.

6.5.2 Using wire rope slings around the milled-down diameter of the Tube suspended on the ends of the spreader, lift the Tube with the crane to take the load—watch clearance on the nozzle ports.

6.5.3 Continue moving the Support Tube into the chamber using the crane until the Crossbeam prevents further advance.

6.5.4 Install brass inserts with eyebolts in the holes 11" off the center of the Tube. Connect the eyebolts to the inner lugs on the spreader bar via turnbuckles.

6.5.5 Adjust the turnbuckles to take the load from the end suspension points.

6.5.6 Disconnect the sling connection and continue moving Tube into chamber.

6.5.7 In the special installation case, guide the Tube end through the Bellows with **both Conflat gaskets** in place.

6.5.8 In the special case, make up the custom conflat seal and torque the bolts.

6.5.9 Continue moving the Support Tube into place until the jib Cranes can be employed.

6.6 Hang Tubes from Jib Crane

6.6.1 Install the custom eyebolts through the Jib Crane Weldment and thrust bearing and secure with brass nuts.

6.6.2 Measure the gap between the top of the small diameter on the end of the Support Tube and the Crossbeam Pad and set to ~155 mm using the crane.

6.6.3 Adjust the brass nuts to take the load of the Support Tube from the crane maintaining the attitude of the Tube.

6.6.4 Disconnect the spreader bar from the Support Tube and remove the brass inserts with eyebolts.

6.6.5 Repeat for the other Support Tube starting at § ***6.1***.

7 INSTALL SUPPORT TABLE/DOWNTUBE

The size of the Support Table/Downtube Weldment will require very careful crane work. The Weldment weighs ~1500lbs and will clear the cleanroom by only a few inches. Also, the introduction of structures into the vacuum plenum that will reside *above* the laser beamline necessitates the utmost in cleanliness precautions. Every effort to eliminate dust settling on the weldment must be taken—limit exposure time and unnecessary activities.

7.1 Remove the BSC 60" door or Chamber adjacent Spool

Following standard LIGO procedure, remove the 60" door or spool as appropriate.

7.2 Move Downtube Assembly In

7.2.1 Maintaining cleanliness, connect a short (four links) ½" SST chain to the main crane with the necessary shackles.

7.2.2 Using aluminum foil, make a debris shield just below the crane hook.

7.2.3 Keeping as much of the Weldment as possible protected in its bags, connect the chain to the eyebolt in the top of the Weldment with the jaw/jaw swivel shackle.

7.2.4 Remove the outer bag and hoist the Weldment into position above the cleanroom sock being mindful of the clearance to the cleanroom.

7.2.5 Open the cleanroom sock from below and with adequate personnel hold the sock open while the Weldment is lowered into the cleanroom. Once clearance allows, zip the sock closed above the swivel shackle but below the debris catch.

7.3 Connect Support Table to Support Tubes

During this process at least one person will be required to be inside the BSC Chamber to assist guiding the Weldment into place and bolting the Weldment to the Tubes. The BSC Stool will assist in gaining adequate height to the work area. This person must use the strictest of care to prevent dirtying the chamber—new boots for entry and new gloves immediately upon entry. Also, this person must limit exposure time to the overhead load of the Support Table/Downtube Weldment.

7.3.1 Remove the inner bag and foil from the Weldment.

7.3.2 Pull back the chamber cloth cover being careful to keep particulate accumulated on the cover from falling into the chamber.

7.3.3 Lower the Weldment between the two Support Tubes—the Tubes may need to be separated slightly to allow clear access.

7.3.4 Keeping the Weldment just off the Tubes to allow relative movement, install silver-plated SST cap screws with vented washers through the Weldment into the Tubes. Iteratively, snug the side bolts, lower the Weldment onto the Tubes, and snug the top bolts, until the load of the Weldment is completely supported by the Support Tubes. The Downtube may not hang level and the attitude of the Support Tubes may need to be adjusted with the Jib Crane eyebolts and by manually rotating the Tubes using BSC Torque Bars, D972486.

7.3.5 Torque the bolts to 23 ft-lbs.

SUPPORT TABLE/TUBES Torqued:

Date: _____Initial: _____Comment: _____

7.4 Rotate Downtube

7.4.1 Unbolt the ½-13 bolts through the angle brackets holding the Downtube to the Support Table; do not unbolt the bracket from the Downtube.

7.4.2 Raise the Downtube/Optics Table off the Support Table. Now unbolt the brackets from the Downtube and reconnect in similar holes 45° from the previous locations.

7.4.3 Rotate the Downtube Assembly ~45° and lower the Assembly back to the Support Table. No need to reinstall bolts into the Support Table.

7.4.4 Disconnect the Crane from the lifting eye and raise the hook sufficiently to allow the installation of the Downtube/Chamber cover (BSC Fitted 2). Install the cover to completely protect the chamber.

7.4.5 Open the cleanroom sock, raise the hook, and then close the sock.

8 INSTALL BELLOWS

The Bellows will be installed in two phases. The first will bolt the custom conflat of the Bellows to the end of the Support Tube. Once this connection is made the Support Tube can be connected to the Crossbeam via the V-Block. The Bellows will not be connected to the chamber until after the V-Block connection. This will allow nominal positioning to be maintained between the Tubes and the ports. To maintain this nominal positioning, Centering Blocks will be bolted to the nozzle flanges registered against the Support Tubes.

8.1 Center Support Tubes

8.1.1 If the Support Tubes were moved from their nominal 155 mm location set in § ***6.6***, Position the Support Tube just below (~0.10") its nominal vertical position to allow the Mounting Base and the Spherical Mount to be slid between the Crossbeam and the Support Tube.

8.1.2 Loosely attach Support Tube Centering Jigs to the nozzle flanges. Using a plunge micrometer, measure and balance the horizontal offsets from the vertical tangents of the Support Tubes to the vertical tangents of the nozzle flanges.

8.1.3 Once balanced to ±0.030", snug and then tighten with the jig contacting the Tube and with the jig alignment edge vertical. A torpedo level on the opposite parallel surface will suffice for this task.

SUPPORT TUBES Centered:

Date: _____Initial: _____Comment: _____

8.2 Install Support Tube Extension

Attach a cleaned Support Tube Extension to the end of Support Tubes where Bellows and V-Blocks still need to be installed.

8.3 Install Bellows on Custom Conflat

8.3.1 Install the Bellows into the Bellows Compression Clamp Assemblies with the leak notch on the bottom.

8.3.2 Hoist Bellows with hoist system to position Bellows over the end of the Support Tube Extension. A large diameter copper gasket must be positioned on the Tube at this point; it will be installed after the V-Block connection is made. Also, the custom conflat gasket must be installed at this time in its final position on the end of the Support Tube.

8.3.3 Slide the Bellows over the Extension using caution to not dislodge the custom conflat gasket. Once supported by the extension the lifting bar of the Bellows Compression Clamp will need to be removed.

8.3.4 Continue sliding the Bellows in its Compression Clamp onto the extension and then the Tube itself until the custom conflat makes contact. Maintain pressure/contact between the parts while an assistant gets the seal's bolts snug.

8.3.5 Torque the custom conflat seal following LIGO-M980086-00-M.

8.3.6 Repeat until all four Bellows are in place.

CUSTOM CONFLATS Torqued:

Date: _____Initial: _____Comment: _____

9 INSTALL V-BLOCKS

The Support Tube Mounting Base and Cap, or V-Block, will make the solid connection between the external and internal hardware. This connection will be made while maintaining the Support Tubes in the center of the nozzle ports and the Airbearing in the center of its travel area. This will allow complete range of motion from the actuation system without interference. Additionally, to insure a stress free connection, the mounting hardware must remain loose until all slack in the connections is removed.

9.1 Position Mounting Base with Spherical Mount

9.1.1 With a Spherical Mount in place on the Mounting Base, hoist the assembly with a strap through the cutout in the base. Position the assembly on the Support Tube Extension and keeping a hold on the assembly, remove the strap.

9.1.2 With the strap out of the way, slide the Mounting Base along the extension and onto the Tube under the Crossbeam. When the holes line up, install bolts into the Crossbeam and raise the assembly off the Tube.

9.1.3 The Support Tube Extension may now be removed.

9.2 Raise Tubes into Mounting Bases

9.2.1 Using the Jib Crane eyebolts, evenly raise the Support Tubes into the Mounting Bases, adjusting the Mounting Base mounting bolts to prevent any rotation of the Mounting Bases from binding up the Spherical Mount. Continue raising until the last crank of the eyebolt snugs the Spherical Mount to the Crossbeam. Do not tighten one of the yokes to this point while others still need adjustment. Take the last crank on all four at the end.

9.2.2 Position the Mounting Cap over the Mounting Base and install the four bolts. The long thru hole of the Cap and the long helicoil in the Base make a connection vulnerable to cross-threading—use caution.

9.2.3 Snug, then tighten the Mounting Cap bolts maintaining an even gap between the Cap and Base to prevent bolt binding. This will help prevent rotation of the Base on the Spherical Mount.

9.2.4 Torque the Mounting Base mounting bolts to 114 ft-lbs. in sufficiently small increments to eliminate rotation of the Base on the Spherical Mount.

MOUNTING BASES Torqued:

Date: _____Initial: _____Comment: _____

9.2.5 Torque the Cap mounting bolts to 200 ft-lbs.

MOUNTING CAPS Torqued:

Date: _____Initial: _____Comment: _____

9.2.6 Remove the Jib Crane hardware and Weldments.

9.3 Install Bellows to Chamber Conflat

9.3.1 Remove the Support Tube Centering Jigs and the Conflat Covers.

9.3.2 Clean the ‘D’ Nozzle’s and Bellow’s knife-edges.

9.3.3 Clean the 16.5” gasket and position on the nozzle conflat.

9.3.4 Expand the Bellows by loosening the 1” nuts on the Compression Clamp.

9.3.5 Once free of the Clamp, the Bellows will sag and need manual support best provided from underneath.

9.3.6 From this vantage point, rotate the Bellow’s flange to align with the conflat, then bring the flange into contact with the nozzle flange. While maintaining pressure to not lose the gasket, have an assistant install and snug the bolts and plate nuts.

9.3.7 Torque the rotatable seal following LIGO-M980086-00-M.

ROTATABLE SEAL Torqued:

Date: _____Initial: _____Comment: _____

With the internal hardware now supported by the external structure, the BSC’s dome may be reinstalled for leak checking of the Bellows.

Phase 3 of the installation builds the isolation core of the SEI. The Isolation stacks are made up of the coiled Springs and the Leg Elements. This four layer spring/mass system isolates the Optics Table, where optics are mounted, from the Support Table which is connected to the nonisolated external structure.

10 INSTALL ISOLATION STACKS

Record the serial numbers of the springs noting in which layer and stack they are placed.

10.1 Install Work Platforms

10.1.1 Keeping as much of the chamber opening/Downtube assembly covered as possible, reinstall the Work Platforms if previously removed and/or install the end sections that could not be used because of the Jib Cranes.

10.1.2 Install the hand-rails.

10.1.3 Move the crane into position over the cleanroom and suspend the Three-Legged Chain inside the cleanroom via a long 3/8" SST chain and SST swivel.

10.2 Check Support Table Perpendicularity

Install the BSC Leg Location Pin, D972217-7, into the 3/8-24 holes in the Support Table counterbore. Measure the distance between the top centers of the pins and record. If the measurements are >±4mm of the 286 nominal, investigate and contact Hugh Radkins or Larry Jones.

10.3 Position Springs

The Spring Positioning Fixtures, D972469, 70, and 71, designed by HYTEC are not perfect in design and should be used thoughtfully. Non-epoxy springs will be used in all but the top layer.

10.3.1 Locate the Spring Positioning Fixtures around the counterbore/cutout in the Support Table or the Leg Element edge. Position the fixtures so that one spring is located at the closest point to the Downtube.

10.3.2 The spring located closest to the Downtube will be a right-hand spring with others alternating handedness around the layer.

10.3.3 The individual springs will be oriented with the ends of the springs facing inward closest to the center of the layer.

10.3.4 Inspect and insure that the springs are properly located in their seats while positioning. Position a vented washer near the Locating Pin hole to be moved into position when installing the Safety Pins.

10.4 Install Leg Elements

Two sizes of locating pins are used to position the Leg Elements relative to each other. The first two Leg Elements use the "BSC" pins but the third layer of the BSC Stack is too thin to use this design. The "HAM" locating pins, D972715-7, are just right though and are used on this layer.

10.4.1 Screw a Locating Pin into each of the three 3/8"x24 holes of the Support Table or Leg Element.

10.4.2 Meanwhile, pull the 'next' Leg Element out of the shipping box using the fixture provided by Allied. The 'wing bolts' Allied supplied may become worn after repeated use and can be replaced with a class B brass bolt.

10.4.3 'Rotate' the Leg Element to the horizontal and place on the Leg Element Tray attached to the Forklift Boom Extension.
10.4.4 Move the Element into the cleanroom where it can be stripped of foil and cleaned if required. Install Leg Element Hoist Plug Adapters (D972982) with ½-13 eyebolts, into the Leg Element. Transfer the Leg Element from the Tray to the Three Legged Chain. Be sure to hang the Leg Element as level as possible by watching the rotation of the chains.
10.4.5 Carefully position the Leg Element over the locating pins and evenly lower the element to contact the spring seats uniformly.
10.4.6 Verify that the springs and seats are OK and then disconnect the crane and remove the Locating Pins.

10.5 Install Safety Pins

10.5.1 Move the vented washers over the three 3/8"-24 threaded holes and install three Safety Pins, D972217-9, -1, or -3, into the layer below.
10.5.2 Apply some torque to the pin with a wrench or screwdriver to prevent a loose pin from rattling.
10.5.3 Inspect the clearance between the Safety Pin and Leg Element.

10.6 Repeat

Repeat the sequence for the remaining Leg Elements using the appropriate Spring Positioning Tools, Locating Pins and Safety Pins.

SAFETY PINS Checked and Snugged:
Date: _____Initial: _____Comment: _____

11 POSITION DOWNTUBE ON STACKS

11.1 Position Springs

The last layer consists of just four epoxy springs. They are arranged in a tight group separated enough so as not to touch but not so far as to extend past the Shim. As with previous layers, position a right-handed spring closest to the Downtube and then alternate.

11.2 Position Shims

On top of each group of four springs place a shim of appropriate thickness. Check that the springs do not protrude past the shim's edge. Place a Viton Shim on top of the metal shim.

11.3 Install Locating Pins

In the top Leg Element of each stack install a single Downtube Centering Pin, D972493. The choice of position on the Leg Element is not important but one might want to be orderly in some way. Position a vented washer nearby.

11.4 Rotate Tube & Place on Stacks

11.4.1 Connect the crane to the Downtube with ½" hardware and lift the Downtube from the Support Table.
11.4.2 Remove the angle brackets from the sides of the Downtube.
11.4.3 Clean the Downtube and Support Table where the bracket was installed.

11.4.4 Rotate the Downtube and move the crane as required so the Downtube is over the alignment pins.
11.4.5 Lower the Downtube slowly and evenly so as to not bounce on the springs.
11.4.6 Remove the Centering Pins and snuggly install Safety Pins, D972217-5.
11.4.7 Inspect the springs and their seats for proper seating, and the Safety Pins for grounding, *i.e.,* touching the Leg Elements.

SPRINGS, SEATS, & PINS Checked and Snugged:

Date: _____Initial: _____Comment: _____

11.4.8 Disconnect the crane and remove the pin and lifting eyebolt assembly from the top of the Downtube.

11.5 Install Counterweights and Cabling

Following plans provided by other subsystems, install counterweights and electronic controls cabling onto the Seismic Isolation platform.

11.6 Remove Installation Fixtures

Remove the work platforms and other fixtures remaining in the work area.

11.7 Replace Dome

Following Vacuum subsystem procedure, reinstall the chamber Dome and Door.