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Notes on Lower Quad Installation at LASTI

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1 Introduction

The purpose of this technical note is to document the experience gained during the installation of the lower section of the quad suspension into the BSC chamber at LASTI from 7 April to 17 April 2008. These notes come from the LIGO personnel involved in the installation (Derek Bridges, Ken Mailand, Brett Shapiro, Gerardo Moreno, and Mike Meyer).

The installation of the lower section of the quad suspension is broken down into 7 main steps, which will be discussed in the following sections:

1. Installation of a fixture to support the lower section
2. Detachment of the lower section from the BSC ISI/upper section
3. Assembly of the conveyor and lifter in and around the BSC
4. Placement of the lower section on the lifter and installation into the BSC
5. Reattachment of the lower section to the BSC ISI/upper section
6. Removal of the lower section support fixture
7. Disassembly and storage of the conveyor and lifter

2 Support Tooling Installation

In order to support the lower section of the quad suspension once it is detached from the upper section and the BSC ISI, a support fixture must be installed around the lower section. To install the support fixture, the sleeve around the suspension must be removed; to remove the sleeve, the earthquake stops (and brackets) on the faces of the round masses must be removed. The earthquake stops and brackets are replaced and tightened down after the sleeve is removed. The two halves of the support fixture are mounted on the lower section; each section is easily lifted by one person, with a third person to guide and join the halves together using the dowel pins. The lower section is held in the support tooling by small flanges on the lower section that fit into slots in the top of support fixture; a plate is bolted over the top of the slot, holding the flange in place. There are six places on the top of the support fixture to install these plates; only the two plates that hold the two halves of the support fixture together were used during the installation. The other four plates were not used because they are too short to extend over the flanges. According to Ken Mailand, there are also plates to hold the two halves of the support fixture together at the bottom, but these were not used during the installation.

3 Detachment of the Lower Section

Once the support tooling is installed, the lower section can be detached from the upper section. The OSEM cables and the wires connecting the first (top-most) and second masses are disconnected. A pallet covered in foil is lifted on the 5-axis table to hold the support fixture. The bolts connecting the upper section to the implementation ring are disconnected, separating the upper and lower sections. A ratchet was needed to loosen these bolts due to the tight clearances inside the structure of the upper section. The 5-axis table is lowered and the lower section is

moved out from under the BSC ISI. The implementation ring is then removed from the lower section and wrapped in foil along with the corresponding bolts for clean storage. During this step, one bolt connecting the implementation ring to the lower section was noted to be missing. This is due to a problem with a misaligned helicoil (which was unsuccessfully repaired in the past), which prevented screws from being tightened past two or three turns. Before reinstallation, this hole (and others described below) should be redrilled and retapped, and the helicoil and bolt should be replaced with a larger size.

While the lower section and support tooling was separated, a problem was found with the interface between the support tooling and the lifter; specifically, the stainless steel tubes that hold the support fixture on the long side (corresponding to the main chain) were installed incorrectly – the left and right tubes were switched and one tube was attached with the mating hole for the lifter facing upwards. An attempt was made to remove the tubes and attach them correctly, but 3 of the 4 stainless steel bolts on the first tube were galled since they were put directly into the stainless steel barrel nuts with Nitronic 60 helicoils. These bolts were broken off. Instead, two holes were drilled through the tube and the support fixture between the barrel nuts and two screws and hex nuts with rectangular “washers” were used to attach the tube to the rest of the support fixture. A drilling jig was made and used to drill the mating hole for the pin on the lifter on the bottom of the tube (6” center-to-center separation between mounting holes).

The lower section is moved from the 5-axis table using the Genie lift with the forks and the legs at widest setting. The forks are placed under the flanges on either side of the support fixture above the tubes with the mating holes for the lifter. The weight of the lower section causes the forks to droop, so ½” thick spacers are placed at the ends of the forks to keep the lower section level. The foil-covered pallet is moved from the 5-axis table to a pallet jack (which is used to transport the lower section to the BSC) and the support fixture is then lowered onto the pallet.

4 Assembly of the Conveyor and Lifter

The installation of the conveyor into the BSC generally follows the installation procedure. The tripods supporting the conveyor inside the chamber should be installed with the short legs away from the center of the conveyor. The conveyor is attached to the chamber using two hardened bolts and nuts with washers through the holes for the door bolts. Two ½” screws are also attached to the conveyor and are adjusted so that they contact the ring just inside the door of the BSC with a small amount of tension in order to support the lower section when it is over the door flange. The nuts in the feet of both sets of tripods should be locked. The conveyor is easily leveled using a clean bubble level with necessary adjustments made by turning the wing nuts on the tripods outside of the chamber.

Additional stability for the conveyor is provided by guide wires connecting the holes provided on either side near the bottom of the BSC to the eye bolts on the conveyor. The guide wires are tensioned using turnbuckles. Since the ring around the chamber that supports the floor planks is lower than expected, the two longer floor planks interfered with the guide wires and were removed until the installation of the lower section was complete.

The 5-axis table and the lifter are then attached to the conveyor as described in the installation procedure. The lifter controls are then connected to the lifter and tested before the lower section is placed on the lifter.

5 Placement and Installation of the Lower Section into the BSC

The lower section in its support fixture is transported near the BSC using a pallet jack. It is then raised onto the lifter using the Genie lift (with the ½” spacers to keep the lower section level). The Genie lift is positioned at an approximate 40 degree angle to the conveyor. With the legs of Genie lift at their widest separation, there is no interference with the tripods supporting the conveyor. The lifter is prepared by removing one of the two support plates facing the Genie lift (these plates and the lifter are marked 1 and 2 so the placed can be attached in the proper place and orientation). The 5-axis table is rotated so that the lifter is aligned with the Genie lift. The support fixture is then lifted slightly above the level of the lifter, the Genie lift is wheeled forward into place above the lifter, and the support fixture is lowered into place with the pins of the lifter placed in the mounting holes of the support fixture. To center the lower section on the lifter, the short side of the support fixture (corresponding to the reaction chain) should mate to the longer side of the lifter. The support plate that was previously removed is then reattached to the lifter.

The installation of the lower section into the BSC follows as described in the installation procedure. The 5-axis table is rotated so that the narrow side of the lifter/support fixture/lower section combination is parallel to the door opening and locked using the pin provided. The conveyor is then used to slide the lower section combination into the BSC. The entire assembly was found to be sufficiently stable as long as the lifter is not pushed or pulled. Once the lower section is in approximately the desired position, the conveyor is locked and the 5-axis table is unlocked to rotate the lifter into the proper orientation. The rotation axis of the 5-axis table is locked. The implementation ring is then reattached to the lower section. At this point, the screw mating to the hole with the “bad” helicoil was able to be tightened completely. The lifter is used to raise the support fixture/lower section (first using the coarse adjustment, followed by fine adjustment) until the implementation ring can be mated to the upper section. Small adjustments in pitch were made using the tilt feature of the 5-axis table.

6 Reattachment of the Lower Section

Once the implementation ring can be mated to the upper section, the two sections are joined using the screws that were previously used. Once again, a ratchet was needed to tighten some of the screws due to restricted clearance. When the implementation ring was attached to the upper section, one screw was found to be unable to fit. The screw could be turned once to catch the threads, but would then “pop out” of the hole. This was not the hole with the “bad” helicoil. The other screws were loosened and retried, but the screw still would not fit. Consideration was given to clamping the upper and lower sections together using a clean clamp, but the lower section has no horizontal clamping surface. If a small flange is added to newer support fixtures, clamping the sections could be a possibility. It was also noted that there is not much material on the lower section where the screws attach the lower section to the implementation ring; if structural frequency requirements permit, the supports at the top of the lower section should be more substantial. In addition, some screws through the implementation ring connect the upper and lower sections, which seems to be overly complicated. Either the implementation ring should be connected to the upper and lower sections using separate screws, or the ring could be eliminated entirely with the upper and lower sections connected directly. Any modification should not increase the height of the lower section, since there is very little clearance when moving the lower section through the chamber door.

7 Removal of the Support Fixture

Once the upper and lower sections are reattached, the lifter is lowered to its lowest position. The two support plates are detached and removed from the chamber, and the 5-axis table is unlocked and rotated 90 degrees so the tooling can be moved out of the chamber using the conveyor.

The support fixture is then removed from the lower section using three people: two to hold each side of the support fixture and one to remove the plates holding the lower section in the fixture. Once the plates are removed, the two halves are pulled apart and removed from the chamber one half at a time.

The sleeve is then reinstalled over the lower section. Only one orientation of the sleeve is correct, so care must be taken to install it correctly. As before, the earthquake stops on the faces of the round masses must be removed before installing the sleeve and replaced after the sleeve is in place. Two of the earthquake stops on each of the two penultimate masses cannot be replaced due to the crossbrace of the sleeve. There is a significant amount of space between the lower section and the sleeve at the points where the two parts are bolted together. In this installation, washers around the screws were used to fill this space; in the future, shims should be used.

Once the sleeve is replaced, the OSEM cables and the wires between the first and second masses can be reconnected.

8 Disassembly of the Conveyor and Lifter

The tooling is disassembled in reverse order of the assembly process: the lifter controls are disconnected, the lifter is removed, the 5-axis table is removed, and finally the conveyor is removed. Once the tooling is removed, the longer two flooring planks can be placed in the BSC if needed. The tooling was cleaned, repacked, and labeled; special care should be taken to make sure that the special equipment (wrenches, spring pullers and lifting straps for the 5-axis table, and other hardware) is kept with the tooling.