LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

*LIGO Laboratory / LIGO Scientific Collaboration*

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# Enhanced LIGO ISI Installation into LHO HAM6 Chamber Hazard Analysis

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Distribution of this document:
Advanced LIGO Project

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Each of the undersigned has carefully reviewed the contents of this hazard analysis and believes it has adequately identified potential personnel safety hazards and risks. The safety of the personnel carrying out the procedures or using the equipment addressed by this hazard analysis is considered to be at an acceptable level.

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## 1. Executive summary:

This document covers safety concerns for the installation of the HAM ISI into the HAM6 chamber for Enhanced LIGO at LHO. It must be read before beginning work on the HAM ISI installation and used in conjunction with the Procedure Document for Installing the ISI into the HAM Chamber, LIGO document number E080012-00-D.

The document is intended to point out safety hazard peculiar to this project only. For LIGO general site safety and safe work practices in the lab the site safety coordinator must be contacted and personnel must have appropriate safety training.

The LIGO System Safety Plan (LIGO-M950046) must be read beginning work on the HAM ISI installation. It always takes precedence over this document.

The LIGO document LIGO-M070360-04-M, Advanced LIGO Safety: Processes and Guidelines, contains important informations that may be necessary to understand the details of this hazard analysis.

Details about the dimensioning and components specification are presented in the LIGO document LIGO-E080053-00-D, HAM ISI Installation Fixture - Dimensioning and Components Specifications.

Summary of Hazards for HAM ISI Installation

The third section of this document details the specific hazard possibilities. The highest mitigated Hazard Analysis Severity Table rating is a “2E”. The installation has five “2E” ratings and three “4E” ratings.

The first three unmitigated hazards are critical and it’s important that the procedure is exactly followed:

3.1 Collapse of installation stands when loading them

3.2. Failure of Anchor Shackles

3.3. Failure of lifting connectors

Section 3.6. (Strain or impact injury while pushing the ISI into chamber) highlights that personnel must be extremely careful to fingers and hands while moving the loads.

## 2. Overview of the HAM ISI Installation into Chamber:

The HAM ISI will be moved from the test stand into the HAM chamber using a combination of rolling cart, crane and trolley system.

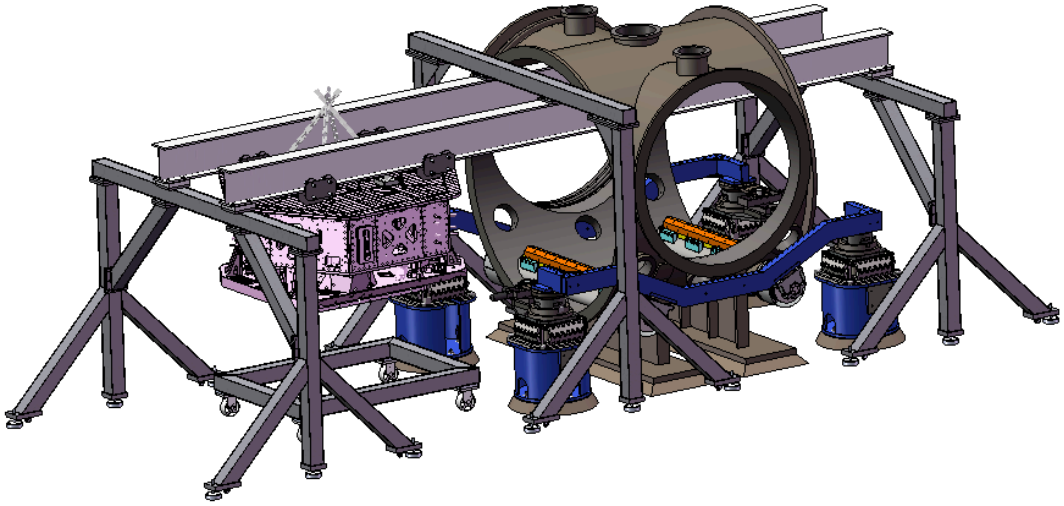
This installation requires overall common sense and good lab practices including continual communication with fellow workers when you may be around, under or over the ISI. Personnel must have good knowledge of how to safely use tools associated with the installation. Lab work on LIGO projects often involves working in the same area as the vacuum system and lasers. All personnel must have appropriate safety training to work at a LIGO facility. A single foreman must be designated for the installation team. This foreman has command authority and responsibility. The foreman directs all steps in the installation.

*Structure:*

A set of three stands will be built on either side of the HAM chamber as pictured below. Two parallel I-beams will be supported by these stands and pass through the HAM chamber. Two rolling trolleys will be attached to each I-beam.

*Process:*

A crane will be used to lift the ISI from a test stand and place it on a rolling cart. This cart will be rolled into place under the I-beams outside the HAM chamber.
The crane will lift the ISI from the rolling cart to the I-beam trolleys. The ISI is fastened to these trolleys and released from the crane.
The trolleys then roll the ISI into the HAM chamber.
Once the ISI is within the chamber the crane's chains will drop down through and opening in the top of the chamber and be used to lift the ISI from the I-beams and lower it to the support tubes at the bottom of the chamber. The ISI is then released from the crane and fastened to the support tubes.

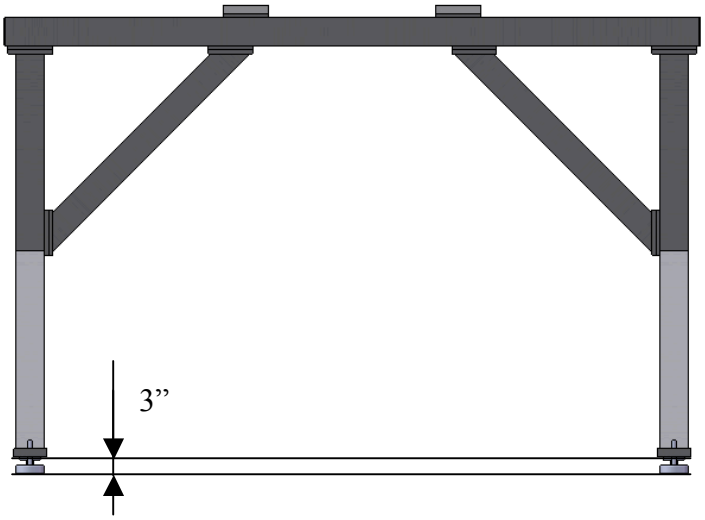


*HAM ISI Installation Fixture*

## 3. Specific Hazard Possibilities:

3.1. Collapse of installation stands upon loading

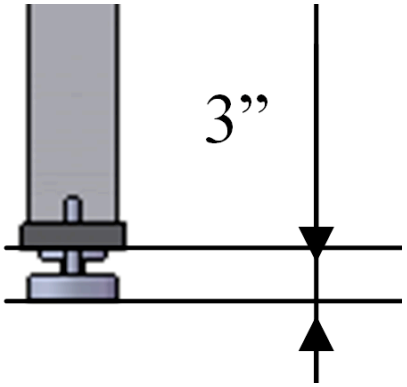
Each of the three stands has wheels to position the stands at the right place. These wheels are not designed to carry more than the load of the stands and the two I beams. They can NOT carry the load of the ISI. The ISI must NOT be connected with the trolleys if the wheels of the stands are in contact with the ground. The height of the leveling pads must be adjusted prior to loading. The nominal height of the leveling pads prior to loading is 3". This dimension ensures that the wheels are not in contact with the ground (Wheel mount height is 2.5"). The ISI must not be loaded while the stands' wheels are contacting the ground.




A requirement to check the leveling of the pads is included in the installation procedure. To mitigate the risk, it would be desirable to place adhesive labels on the stands. On the labels should be written: "The ISI must NEVER be loaded prior to setup the leveling pads to their nominal height", with an explicit drawing below the text:

**- CAUTION -**

**The ISI must NEVER be loaded prior to setting the leveling pads to their nominal height:**



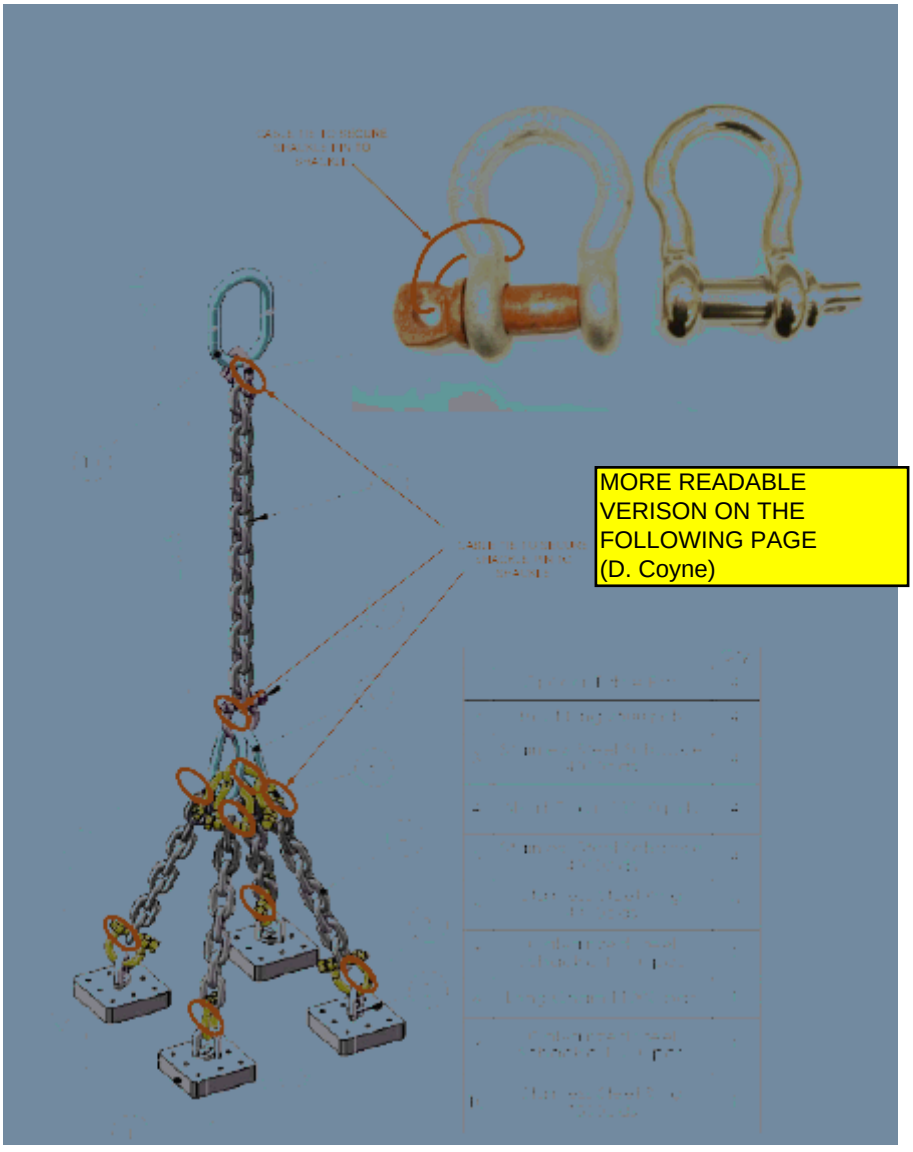
3.2. Failure of Anchor Shackles

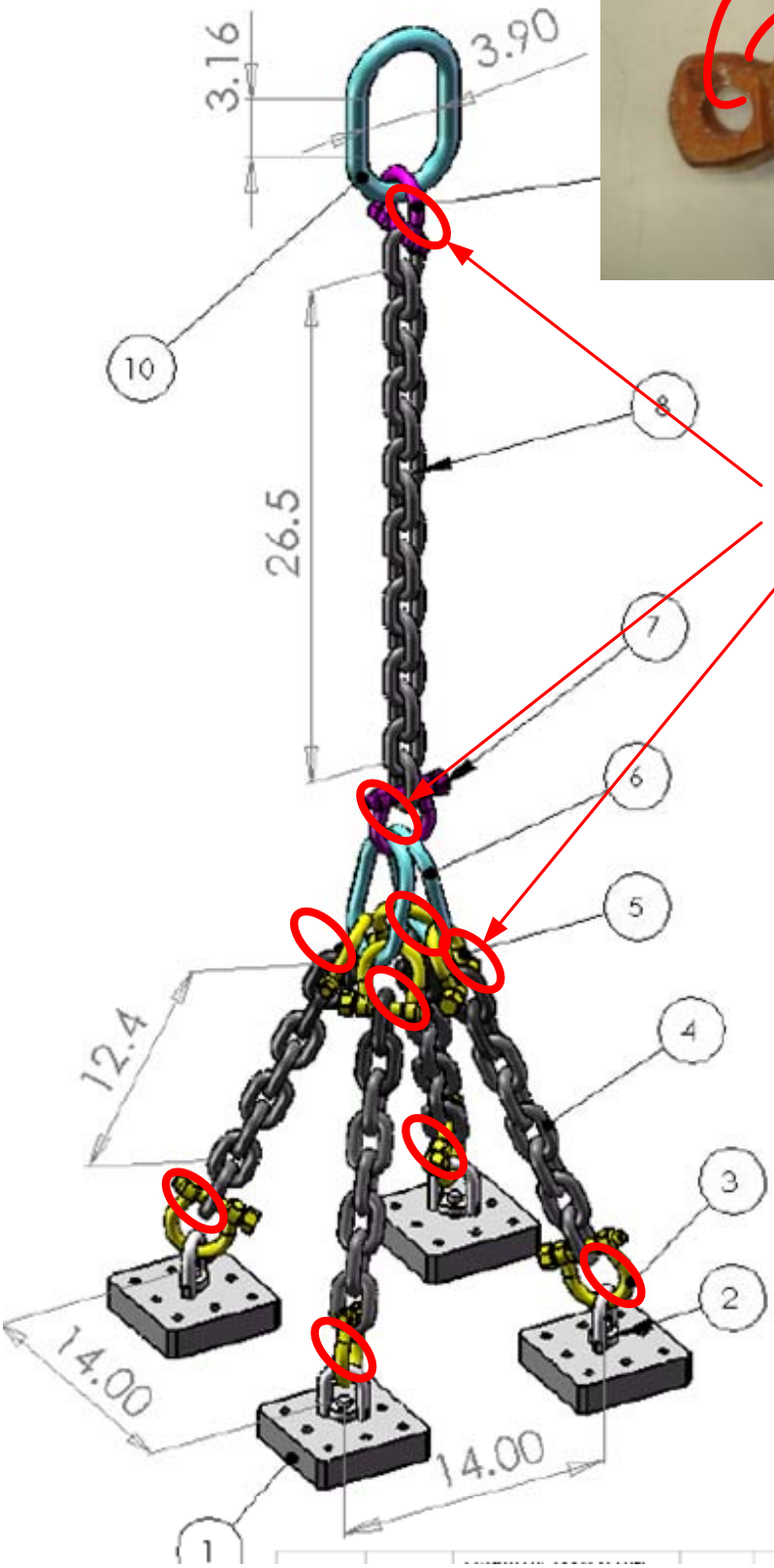
Two types of anchor shackles are used. Stainless steel shackles are used to connect the chains with the optical table. Galvanized Alloy Steel shackles are used to connect the chain with the hook. They have the same dimensions but different load limits:

- "Stainless Steel 316" Shackles, limit load is 4000 pds
- "Galvanized Alloy Steel" Shackles, limit load is 10000 pds (5 ton limit is engraved on this type of shackle)

The Stainless steel shackles are designed to carry a quarter of the load. They can NOT carry the full load. Don't use them where the galvanized are supposed to be used. Follow the installation procedure exactly.

To mitigate the risk, the entire lifting chain/shackle assembly will be built and "lock" so that it can't be dis-assembled. The shackles pins will be locked in place with either aluminum or stainless steel cable ties through the eye of the shackle pin and around the pin's shackle:




| | | Qty |
|---|---|---|
| 1 | Optical Table Pad | 4 |
| 2 | Hoist Ring 2500 pds | 4 |
| 3 | Stainless Steel Schackle 4000pds | 4 |
| 4 | Short Chain 11000 pds | 4 |
| 5 | Stainless Steel Schackle 4000pds | 4 |
| 6 | Stainless Steel Ring 4400pds | 2 |
| 7 | Galvainzed Steel Schackle 10000pds | 1 |
| 8 | Long Chain 11000 pds | 1 |
| 9 | Galvainzed Steel Schackle 10000pds | 1 |
| 10 | Stainless Steel Ring 7500pds | 1 |

3.3. Failure of lifting connectors

The following components are tightened on the optical table:

- Table to Hoist connector, D070574-00-D
and
- Table to Trolley connector, D070573-00-D

These components carry the full load of the ISI, therefore high strength screws Bumax 88 Stainless Steel must be used. NEVER use any other screws than those specified.

All the Bumax screws are labeled on their head either:

- BUMAX A4-316L

Or

- SA A4-316L

3.4. Accidental release of ISI from crane

The ISI will be lifted with the crane three times during the installation.

-Lifting hooks and chain must be properly rated per the Installation Procedure document.

-Lifting hooks and plates must be securely fastened to the ISI according to the installation procedure.

-All personnel must stand clear of the path of the craned part; no one must ever stand/sit directly under the part while on the crane in case of failure of crane, tapped hole, or lifting hook.

-When lifting or lowering the ISI to the installation structure or supports be careful to NOT pinch fingers etc.

3.5. Accidental release of ISI from trolleys

The ISI will be transferred from the crane to the trolley and then back to the crane.

- Make sure trolleys are securely attached to beam and to ISI before the crane is released.

-Make sure connector plates securely fastened to the ISI.

- No personnel must stand/sit directly under the ISI while it is being transferred from crane to trolleys or while on the trolleys.

3.6. Strain or impact injury while pushing the ISI into chamber

The ISI will roll along the I-beams as it is moved into the chamber. Several people must be involved in this process in order to ensure the ISI is moved steadily.

-Personnel not directly involved must stand clear of the path of the ISI as to avoid impact should the ISI break free or move more easily or less smoothly than anticipated.

-Personnel must not be touching the I-beam or the trolleys while the ISI is in motion to avoid pinched fingers.

- Personnel must watch their footing as the ISI enters the chamber as this will be a tight space; tripping and falling under or against the ISI is a possibility.

-Personnel must keep clear of the chamber door opening when the ISI is entering the chamber to avoid being pinched between the door opening and the ISI.

3.7. Drop of ISI from crane onto support tubes / fastening ISI to support tubes

While the ISI is lowered by crane from the I-beams to the support tubes personnel must keep themselves and any tooling clear of the mating surfaces between the ISI and the support tubes/risers. This will be tight and precise fit so more than one person must steer the ISI onto the beam tubes/risers as it is lowered.
Personnel will need to access the support tubes and risers in a tight space under the ISI in order to insert fasteners. The ISI will be partially supported by the support tube structure, partially by the trolleys/I-beams at this point.

3.8. Slipping of ISI on cart or cart getting away from personnel

The ISI will be placed on the specially made rolling cart and rolled into place under the I-beams of the installation fixture. The ISI must be well centered on the cart (it will however not be fastened to the cart). The cart must be rolled slowly and carefully so that the cart does not stray from the intended path and hit equipment or personnel. Personnel must not be in the path of the rolling cart.

## HAM ISI Installation into LHO HAM6 Hazard Analysis Severity Table

| TEM # | Hazard | Cause | Effect | Un-mitigated Severity | Un-mitigated Probability Level | Un-mitigated Risk Index | Comment | Mitigation | Mitigated Severity | Mitigated Probability Level | Mitigated Risk Index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Collapse of installation stands when loading them | Forgetting to adjust the height of the leveling pads | Injury to personnel, damage to equipment | Critical | Remote | 2D | Once the height of the leveling pads is adjusted to the nominal position structure will have the designed strength | Remember to follow procedure document and adjust the height of the leveling pads to their nominal position | Critical | Im-probable | 2E |
| 2 | Failure of Anchor Shackles | Using the Stainless Steel shackles where the Galvanized Steel shackles are supposed to be used. | Injury to personnel, damage to equipment | Critical | Remote | 2D | Once using each shackles where it is supposed to be used, the structure will have the designed strength. Make sure that the cable ties which lock the pins to the shackles are in place (not cut or removed) | Remember to check in the procedure document where to use each shackle | Critical | Im-probable | 2E |
| 3 | Failure of lifting connectors | Using low strength screws where high strength screws must be used. | Injury to personnel, damage to equipment | Critical | Occasional | 2C | once using the high strength screws the structure will have the designed strength | Remember to check in the procedure document where to use each fastener | Critical | Im-probable | 2E |
| 4 | Dropping of craned ISI | Failure of lifting hooks, chains or crane; failure to use proper lifting hooks | Injury to personnel, damage to part | Critical | Remote | 2D | cranes have regular inspection and sudden failure is unlikely | The floor path of a craned parts kept clear of personnel; lifting hook rating must be checked | Critical | Im-probable | 2E |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Accidental release of ISI from trolleys | failure of trolleys, ISI fastener plates, or I-beam flanges | injury to personnel, damage to part | critical | remote | 2D | if properly used trolley structure was designed to hold weight of ISI in motion | Make sure ISI is secured properly to trolleys; no personnel must be in the path of the ISI while in motion | critical | im-probable | 2E |
| 6 | Injury while pushing the ISI into chamber | ISI moves more quickly or less smoothly than anticipated; personnel not standing clear of doorway of chamber; not keeping clear of trolley path or ISI path | injury to personnel | marginal | occasional | 3C | the ISI has the potential to knock down personnel while it is in motion or if it "gets away" from personnel | Several people must be involved to ensure steady movement; no touching the I-beam while ISI is in motion; no standing near chamber door opening | minor | im-probable | 4E |
| 7 | Sudden drop of ISI from crane to support tubes / tight space to fasten ISI to support tubes | ISI drops to quickly from lack of fine adjustment on the crane; small space to access the support tubes under the ISI once ISI is in place | injury to personnel | marginal | occasional | 3C | As the ISI is lowered, personnel will guide the ISI into position, but there is no need for personnel to place themselves (e.g. fingers) between the ISI and it's mating riser on the support tube. | Keep hands clear of mating surfaces between ISI and support tubes as the ISI is being lowered. | minor | im-probable | 4E |
| 8 | Dropping of ISI off of the cart or cart rolling into equipment or personnel | The ISI not securely fastened to the cart or the cart being pushed too quickly or unevenly | injury to personnel or eqipment | marginal | occasional | 3C | The cart is specifically designed to hold the weight and shape of the ISI structure | ISI needs to be properly fastened to the cart and personnel must stay clear of the path of the cart- Make sure there are no obstructions in the path of the wheels, e.g. nuts, bolts, which could jam or stop the wheels | minor | im-probable | 4E |

**Hazard Severity and Probability Categories from LIGO document number: M070360**

| *Table 1: HAZARD SEVERITY CATEGORIES* | | |
|---|---|---|
| **Hazard Severity** | **Category** | **Definition** |
| Catastrophic | 1 | Death or permanent total disability, system loss, major property damage or severe environmental damage. |
| Critical | 2 | Severe injury, severe occupational illness, major system or environmental damage. |
| Marginal | 3 | Minor injury, lost workday accident, minor occupational illness, or minor system or environmental damage. |
| Minor or Negligible | 4 | Less than minor injury, first aid or minor supportive medical treatment type of occupational illness, or less than minor system or environmental damage. |

| *Table 2: HAZARD PROBABILITY LEVELS* | | |
|---|---|---|
| **Probability** | **Level** | **Individual Item** |
| Frequent | A | Likely to occur frequently or continuously experienced. |
| Probable | B | Will occur several times in the life of an item. |
| Occasional | C | Likely to occur some time in the life of an item. |
| Remote | D | Unlikely but possible to occur in the life of an item. |
| Improbable | E | So unlikely, it can be assumed occurrence may not be experienced. |