WORK PERMIT #1888

submitted by brian.oreilly@LIGO.ORG

Date: 2014-02-21 09:02:01
Facility: LLO
Task Leader: Jeremy Birch
Work Location: Y end station
Facility Liaison:
System/Subsystem: Install

After Hours: No. **Buddy System Partner(s):**

Period of Work Activity: 2/21/14 through 2/21/14

Description of Activity: Install BSC5 cartridge. The checklist is E1400069, Install procedure is E1200344, Hazard Analysis is E1200925

Team Members: Jeremy Birch (Lead) Joe Hanson (Crane) Celine (Top Spotter, Tag Line) Danny (Top Spotter, Tag Line) Mike V. (Top Spotter, Tag Line) Gary (Inside Spotter) Matt (Inside Spotter) Bryan (Contamination Control, Tag Line, Legs, Lower Support) Tomeeka (Leg, Upper Support) Myron (Top Spotter, Tag Line) Richard (Safety) Mike F. (Photos) Ray (Leg, Support) Jesse (Leg, Support) Brian (Leg Controls)

Personal Protective Equipment: Hard Hat, Steel Toe

Activity Hazards: Vacuum, In-Chamber, Contamination, Cuts or Pinch Points, Slip or Trip, Falls, Ladders, Rigging, Crane, Critical Lift

Activity Required Documents: E000065, E0900047, F1100001, M1000367, F1100034, M980242, T1000629

Other Relevant Documents: E1200925, E1200344

Authorization to Begin Work

Installation Manager: Brian O'Reilly	Date: 2/21/14
System Manager:	Date: 2/21/14
Site Safety:	Date: 2/21/14
Vacuum Engineer: David McCoy	Date: 2/21/14
Operator: Jon Evans	Date: 2-21-14

Work Completed

Task Leader: Jeremy Birch	Date: 2/25/14

DCC Document Reference
Work Permit #1888

DCC Number	Document Title
E000065	Chamber Entry/Exit Checklist
E000065	initial LIGO Chamber Entry/Exit Checklist
E0900047	Adv LIGO Contamination Control Plan
E0900047	LIGO Contamination Control Plan
F1100001	LLO Overhead Crane Inspection Checklist and Lift Plan
M1000367	LLO Gantry Crane Rules
F1100034	LIGO Lab Critical Lift Plan
M980242	LIGO Observatory Operational Safety & Environmental Protection Manual
T1000629	aLIGO General Safety Rules for De-Install Activities
T1000629	aLIGO General Safety Rules for De-Install/Installation Activities
E1200925	BSC Cartridge Installation Hazard Analysis, aLIGO
E1200925	BSC Cartridge Installation (Universal) Hazard Analysis, aLIGO
E1200344	BSC Cartridge General Install Procedure aLIGO
E1200344	All BSC, Cartridge Into Chamber, Basic Install Procedure, aLIGO
E1200344	All BSC, Install Competed Cartridge Into Chamber Procedure, aLIGO
E1200344	All BSC, Install Completed Cartridge Into Chamber Procedure, aLIGO

OVERHEAD CRANE INSPECTION CHECKLIST

LIGO

Date: 2/21/14

Location: Y End

Operators Name: JHanson

Crane Used: Y End

Weight of Load: 9480

Circle One: (Verified) / Estimated

Load Cell Used YES_____ NO_____

Crane Capacity: (circle one or fill in)

(5 Tons) / 10,000 lbs.

1.5 Tons / 3,000 lbs.

Other _____

Operator Overhead Crane Inspection Checklist

Put "OK" in the correct columns if the item has no defect.

ITEM	INSPECTED	COMMENTS IF NOT OK
Certified/Trained Operator	✓	
Labels for Controls	✓	
Controls Functioning	✓	
Upper Limit Switch	✓	
Lower Limit Switch	✓	
Trolley Operation	✓	
Cable Condition	✓	
Hook & Safety Latch	✓	
Load Rating On Hook	✓	
Gantry Condition	✓	
Certified Rigging Used	✓	
Rigging Condition	✓	
Other		
Critical Lift Plan Needed:	(Yes) No	Exceed 75% of Crane Capacity or System Critical Components (Complete Page 2)

Crane Operator Signature: (required)

System Representative Signature: (required)

Safety Reviewer Signature: (required)

(Cont) CRITICAL LIFT PLAN

Lifting & Rigging Equipment to Be Utilized: (specify type and capacity)

BSC Lifting Fixtur

Communication Method: ☑ Radio ☑ Verbal ☐ Hand Signals

Steps taken to eliminate personnel danger and property damage:

Hats + Shoes

Description of Lift:

Instalation of BSC IST

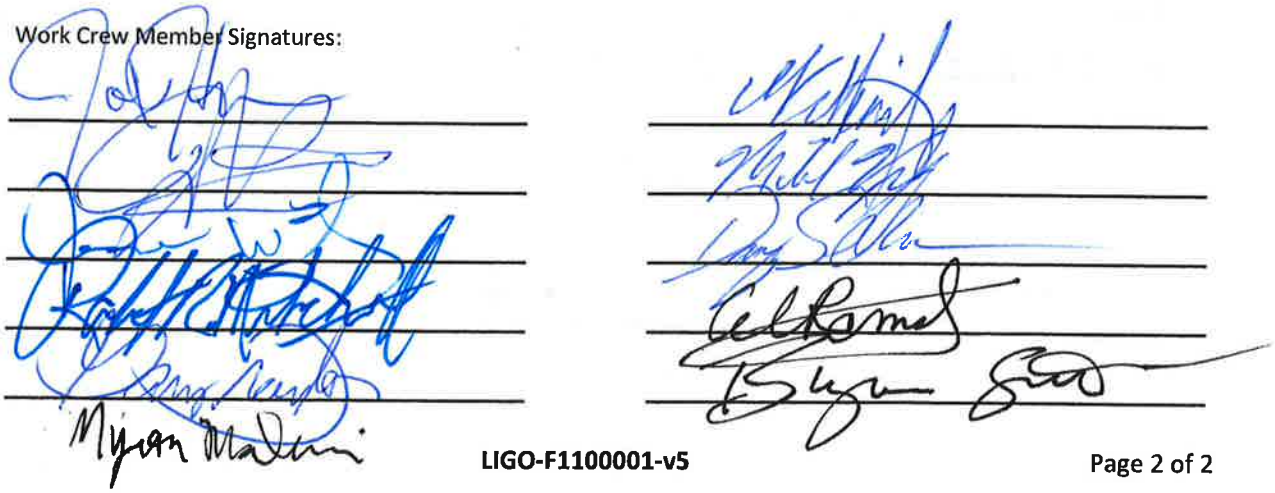
All lifting operations should consider the following:

* Communication and language difficulties
* Environmental conditions
* Weight, size, shape, and center of gravity of load.
* Lighting of work area
* Availability of lifting points
* Proximity of obstructions, hazards, and path of load travel.
* Method of slinging and detaching the load.
* Working under suspended loads.
* Use of tag lines
* Access and emergency escape routes.
* Inspection record for crane being used.

Annual and Daily

* Experience of operator and riggers
* Initial and final load positions.
* Number of personnel required for task
* Lifting over live equipment.
* Visibility of load and travel path
* Other workers in immediate lift area

Work Crew Member Signatures:



LLO APPROVAL SIGNATURES FOR CHAMBER CLOSURE
CHAMBER/VOLUME : BSC5

Gary Traylor, LLO SUS INS lead/LLO IAS lead — Date 4/1/2014

Stuart Aston, LLO SUS Test lead — Date 4/1/2014

Jeremy Birch, LLO SEI INS lead — Date 4/1/2014

Celine Ramet, LLO SEI Test lead — Date 04/01/2014

Matt Heintze, LLO IO INS lead/ Contamination Control / TMS — Date 4/1/2014

Chris Guido AOS lead (Viewports, TCS, PCal) — Date 4/1/2014

Mike Vargas, AOS lead (SLC, OpLev) — Date 4-1-14

Harry Overmier, LLO Vacuum — Date 4-1-14

Valera Frolov, LLO ISC/Integration lead — Date 4/1/14

Brian O'Reilly, aLIGO LLO Installation Lead — Date 4/1/14

BSC5 Cartridge Flight Check List

2/21/14

~~11/5/13 9:09 AM~~

- Lock ISI
- Lock Quad
- Remove clean cables
- Remove air side cables
- Remove 600# mass
- Install lifting pads
- Get baseline particle count for clean room and in chamber(1/0, x/x, 2/0)
- Crane inspection/Critical lift plan
- Move clean room away from test stand
- Install lift fixture debris catch
- Fix lift fixture to the cartridge. Double check bolts
- Test lift with load cell. Balance if needed
- Set load down on test stand and remove load cell

TEST
ISI Room
Chamber
during walk 1/0
0/0
ISI
5/0
14/2 IN Chamber
FLIGHT
Final count. In chamber 2780/570

- Safety meeting
- Begin flight to chamber
- Open clean room soft cover and install second cover
- Once load is clear, the clean room should be returned over test stand
- The load should be positioned over chamber opening
- Remove the BSC dome cover and lower cartridge to the lowest safe point
- Cover the load with the two clean room covers
- Leg crew may start elevation of clean room (Approx. 40 minutest)
- Before the last move on legs the upper spotters and inside crew should prep
- Install transition plate between E-module and work platform
- Particle counts should be taken before continuing; Record results (14 / 2)
- Increase purge air
- Remove BSC dome tall
- Lower cartridge enough for bolts to start
- Once all bolts are in, rest load fully on support tubes and torque bolts
- Remove lifting fixture
- Reinstall the single clean room cover
- Cover ISI

Team

Jeremy Install lead

Joe ~~Harry~~ Crane operator/MMC Rep

Celine ~~Joe~~ Top spotter/test lift/tag line

Danny Top Spotter/tag line

Bryan Contamination Control/tag line/legs/lower support for inside team

Mike V Top spotter/tag line

Gary Inside spotter/SUS rep

Matt Inside spotter/TMS rep

Tre ~~Celine Test lift/SEI rep~~/Legs/upper

Brian Legs

Myron Top/test Lift/tag line

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-E1200344-v4 *Advanced LIGO* 1st Nov 2012

All BSC, Install Completed Cartridge Into Chamber Procedure, aLIGO

Sam Barnum, Hugh Radkins, Ken Mason, Richard Mittleman

Distribution of this document:
Advanced LIGO Project

This is an internal working note

of the LIGO Laboratory

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**Note v3 (update by CIT) includes equipment list from v1 and note to take teams back to Top Level install procedures.*
**Note v2 had 31st Oct 2012 as date, this was typo. v3 (this doc) is more up to date than v2.*

1 Overview

This document covers the procedure for the installation of a BSC Cartridge into a BSC chamber at either the Hanford and Livingston facilities. This document along with the respective "BSC Cartridge Installation Hazard Analysis" must be read before beginning work on the installation.

Each of the BSC chamber installations will differ somewhat depending on the orientation and payload. A separate document for each chamber will be required to outline the variations in weight, CG, and the flight path for insertion (Requirements and Procedure, Cartridge Flight and Insertion into BSC Chamber).
For example LIGO document E1101016 contains BSC8 specific requirements and must be read prior to insertion of BSC8 ISI and payload into the H2 BSC8 chamber.

A note about clean room standards

For a clean procedure all LIGO standards should be followed. Clean room garb including gloves should be worn when working with parts. Parts should be cleaned and handled according to the standard in LIGO document number E960022. Class A and Class B cleaning procedures and requirements on garbing and handling parts are specified in the LIGO documents M990034-C, LIGO Contamination Control Plan.

All tools that come in contact with the ClassA assembly should be cleaned to LIGO ClassB standards. The ISI should be handled under a portable clean room. Any time a part of the ISI assembly is not covered by the portable clean room or not being actively worked on it should be covered with appropriate clean covers. (C3 polyester or equivalent).

Required Equipment List:

(Assume quantity of one (1) unless noted)
BSC Dome Cover for Dome
BSC Dome-Tall for Chamber
BSC-ISI C-3 Cover
Wire Ties for Cabling (many)
D1000753—Lift Hook Receiver (3)
Bumax-88 3/8-16x2" SHCS & Washers (18)
D1101583—BSC Cartridge Cover
D1101836—Crane Debris Cover
ELT 3pt Spreader Lift & Counterweight
Grade 8 5/8-11x2" 12pt CS (3)
12pt 5/8x3/8 offset wrench
3/8"x125 ft-lbTorque wrench
3/8" breaker
Load Cell, Shackles, & Hook
D1102282--Alignment Pins (4) & 1/8" Hex Key
Spring Clips (Many)
Stage0/Support Tube Attach Hardware: Ag-Plated 3/8-24x2" SHCS & Washers(NAS 1149 3/8x.625x.063"thk flat washers) (14 each)
5/16 Hex Key wrench, sockets, & ratchets
Inspection Mirrors (2)
Headlamps, Flashlights, & Floodlight

2 Related documents:

LIGO-E1200023: aLIGO Chamber Installation Procedures.
LIGO-E1200900: aLIGO BSC Installation Procedures (from sub-systems)
LIGO-E1200901: aLIGO BSC Safety Procedures(associated with install)

3 General Process of Installation

3.1 Pre-Flight

Tasks here can be done with Cleanroom in place

3.1.1 Cover suspended items from below with covers provided by Sub System Teams.

3.1.2 Position C3 cloth Cartridge Cover on top of cartridge. (D1101583)

3.1.3 Position C3 cloth 3pt-Lifter undercover over cartridge cover. (D1101836)

3.1.4 Attach 3pt-Lifter (D1003140) to Crane with Load Cell in line.

3.2 Test-Flight

These tasks require the cleanroom to be moved to use the crane. The Cartridge while clothed in C-3 will be accumulating dust and efforts should be made to expedite this period.

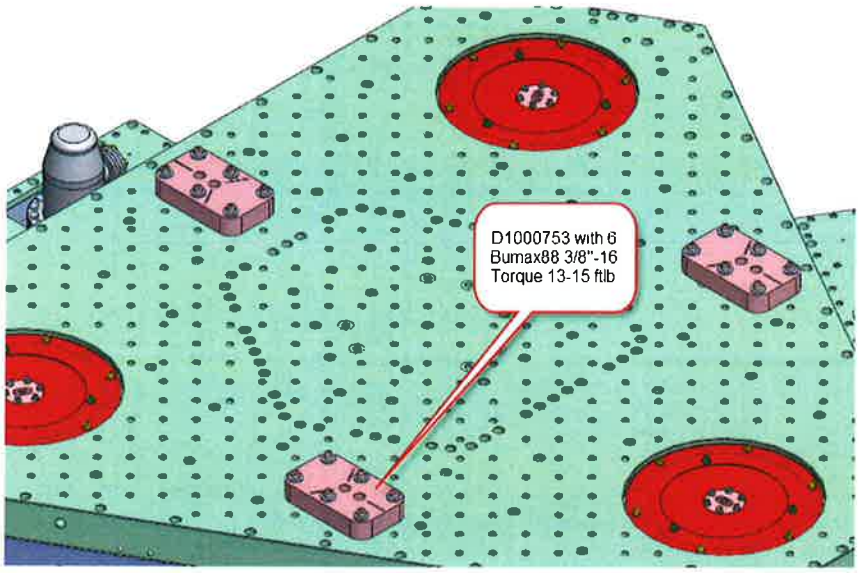
3.2.1 Move Cleanroom to allow clear lift of Cartridge.

3.2.2 Move (crane) 3pt-Lifter (D1003140) to Cartridge.

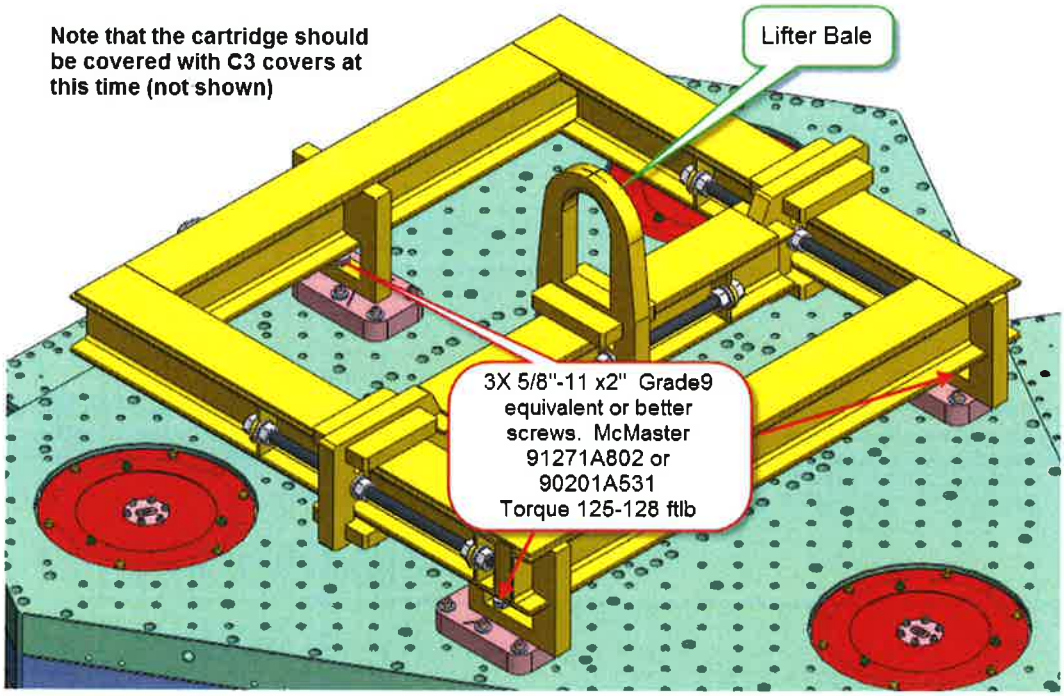
Useless Drawing

3.2.3 Attach the three (3) Lift Hook Receivers (D1000753) on the ISI Keel-plate, if not already present (See D1000756 for layout and use Bumax-88 3/8"-16 Screws, Torque, 13-15 ft-lb).

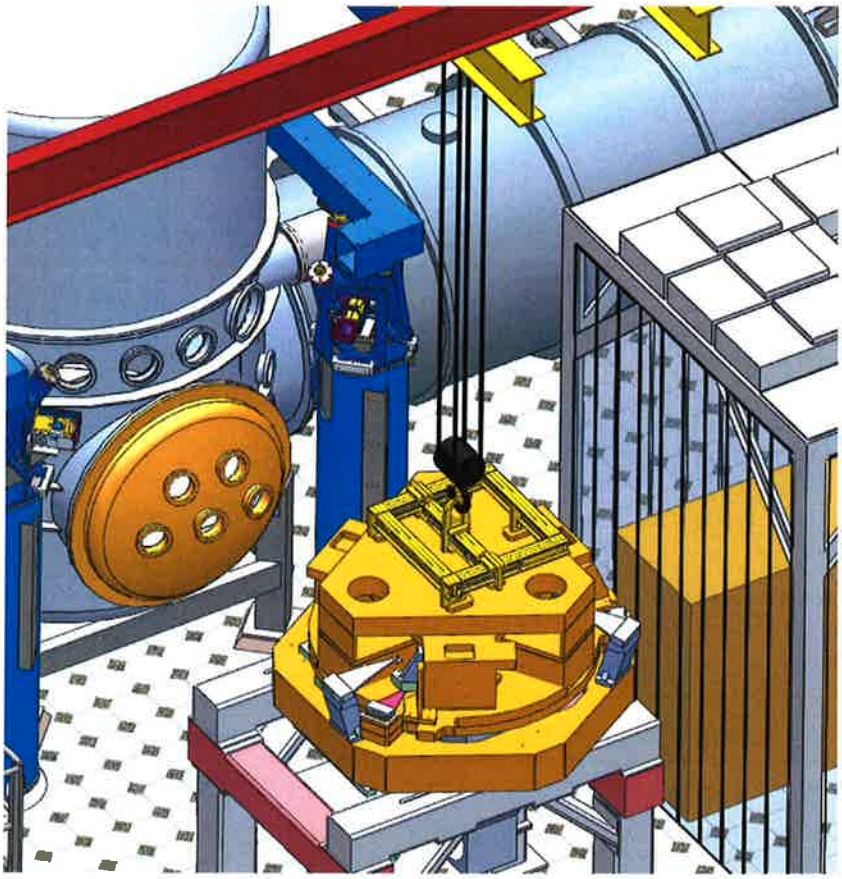
(Note: all pictures are examples from BSC6, but are applicable to all BSC)



3.2.4 Attach 3pt Lifter to Lift Hook Receivers (*D1003140*), use 5/8"-11 Grade9, equivalent or better (91271A802, 90201A531), 125-128 ft-lb



3.2.5 Adjust 3pt lifter bale to predicted X-Y CG location (some keel plate hole patterns are rotated by 120deg from the that shown in the assembly documentation, adjust x-y of the lifter bale to compensate for rotation.)



3.2.6 Remove counter weight from 3pt-Lifter, if used to balance the lifter during flight.

3.2.7 Lower crane enough to remove tension from cable and adjust crane position to TDC above cartridge.

3.2.8 Level the Cartridge: Lift cartridge slowly and stop if any point in the Stage0-Test Stand contact area exceeds a ¼" gap while any other point remains in contact. Visual inspection is sufficient. If visually not level within the needed ¼", set the cartridge back down and adjust 3pt-Lifter bale location to compensate. Repeat as necessary until level within ¼".

3.2.9 Check Cartridge weight: Lift cartridge from test-stand with load cell and crane approximately 1-2 inches, If load cell starts to exceed 10,000lb, stop, and set cartridge back down. Remove weight and try again. Note final total weight, set back down and remove load cell.

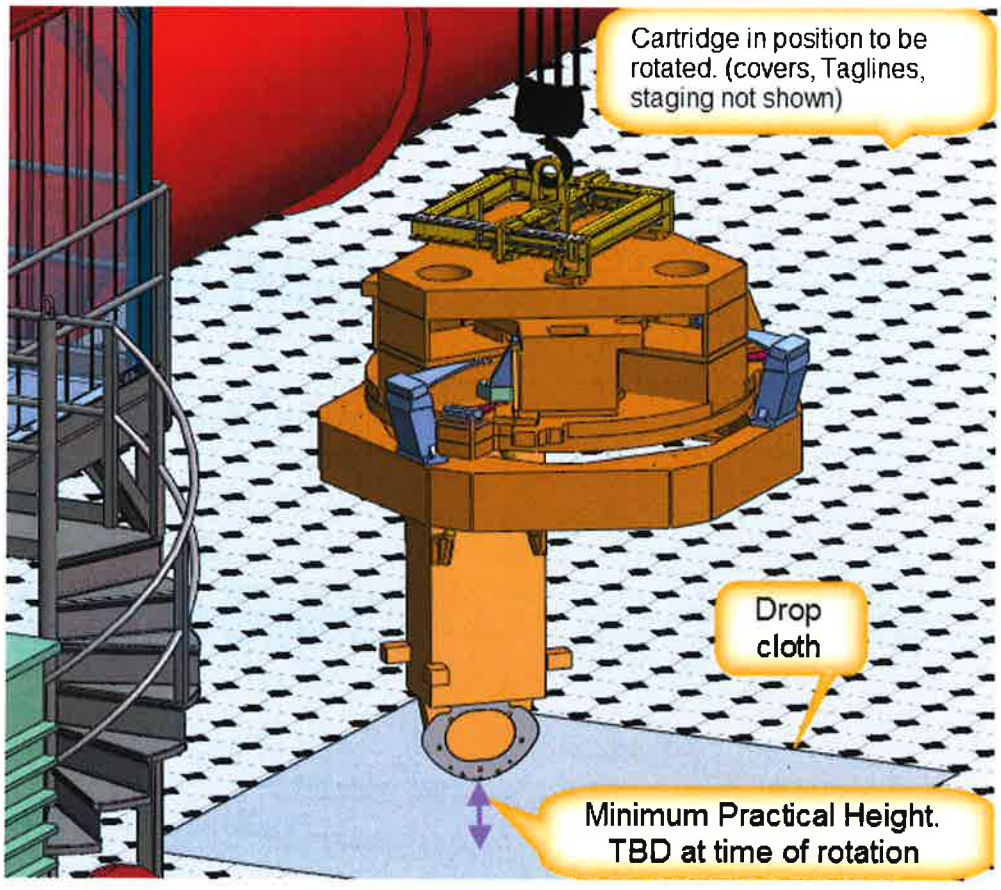
3.2.10 Flight to Chamber

Remove load cell and reconnect Crane to 3pt-Lifter with just the crane hook, get to TDC position.

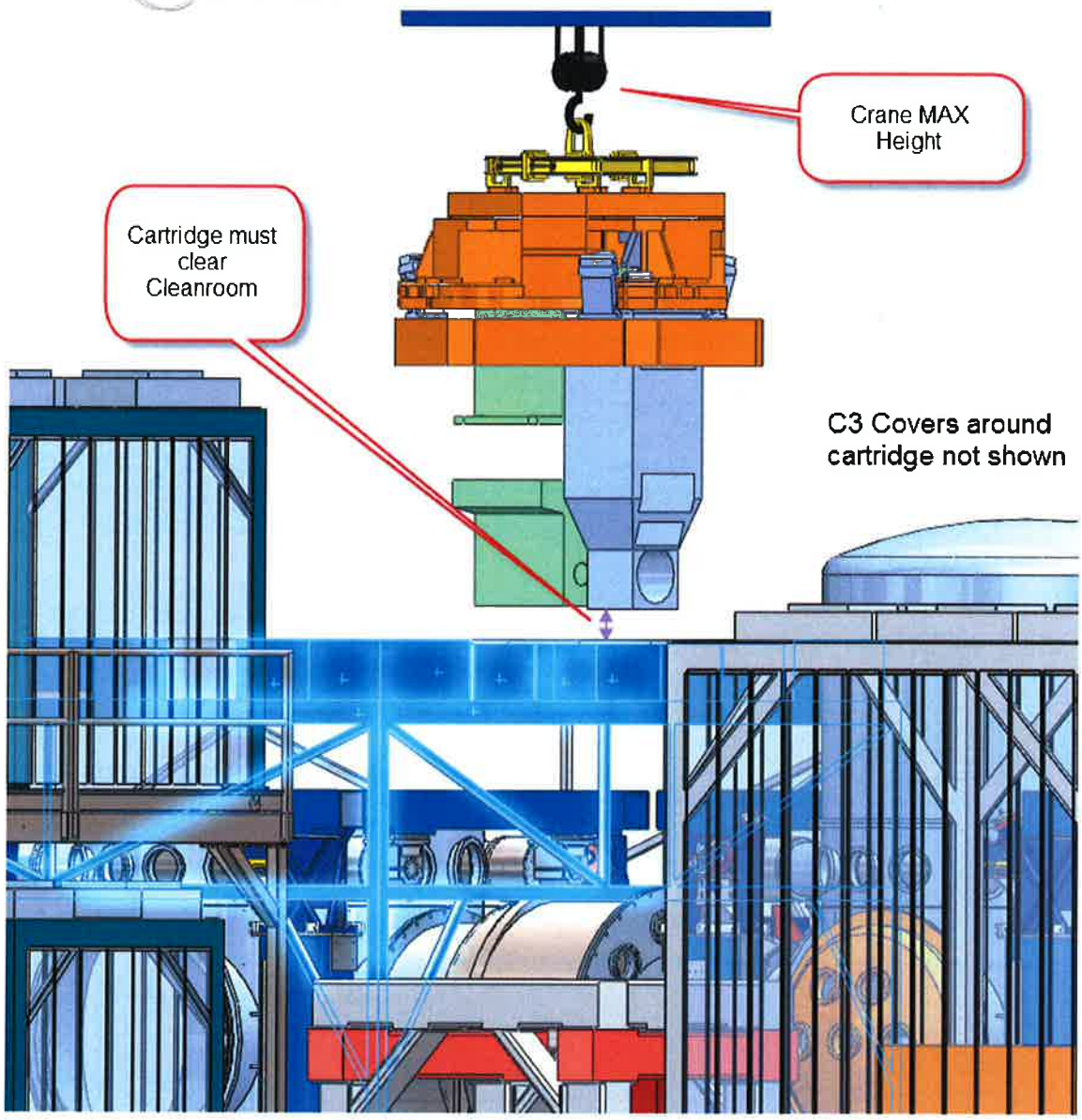
3.2.11 Hoist a few inches. Hold in this position for several minutes and watch for drifting, creep, or any other unsafe condition.

3.2.12 Lift Cartridge high enough to pull big cover down around cartridge and between the cartridge and test stand. This may require stages of raising the Cartridge and pulling down the cover so that the cover does not touch the floor. Tie off open end of cover under the full Cartridge.

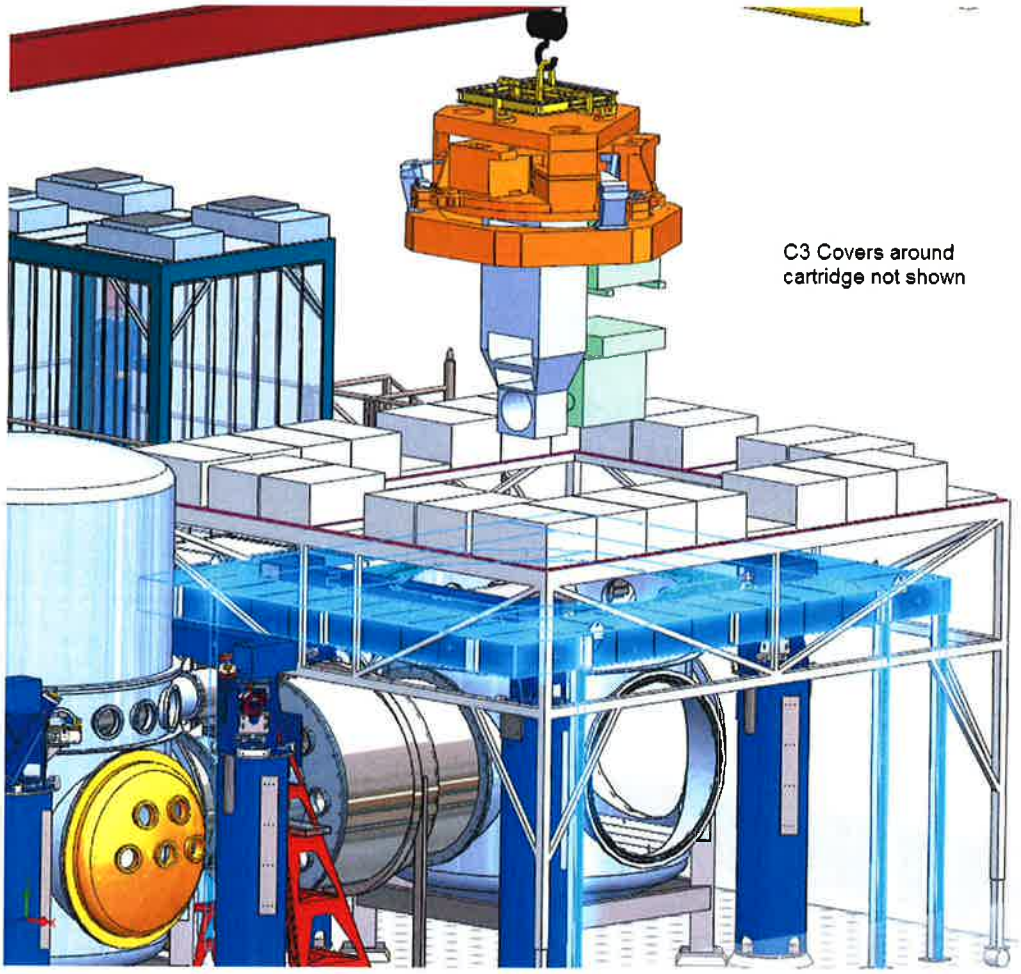
3.2.13 Orient the Cartridge as required for installation per G1000125. Do this away from the Test Stand at a minimum height above the floor. Insure a protective tarp with clean side up has been placed on the floor in the rotation area, otherwise cartridge cover may contact floor. Attach 2 to 4 taglines to 3pt lifter (to rotate cartridge, or serve as backup) Lift cartridge to clear the Test Stand. Move it to designated area over tarp. Lower cartridge to minimum practical height without suspensions contacting the floor. If rotating "by hand" Move staging from around test stand and place around cartridge with access to stage0, or use taglines. Using either taglines or the "by hand" method, rotate cartridge to align with chamber orientation. If pivot on hook becomes jammed, return cartridge to test stand and repair. There is clearance to allow this.



3.2.14 Raise cartridge up to height to clear BSC Clean-room (max height) Insure BSC Clean-room is at minimum height (just above spools), Walking Plates (D1002410) and Platforms (D1001990) are in place without railings, around chambers (See install procedure E1101051). Clean-room clearance should be ~8" or more.



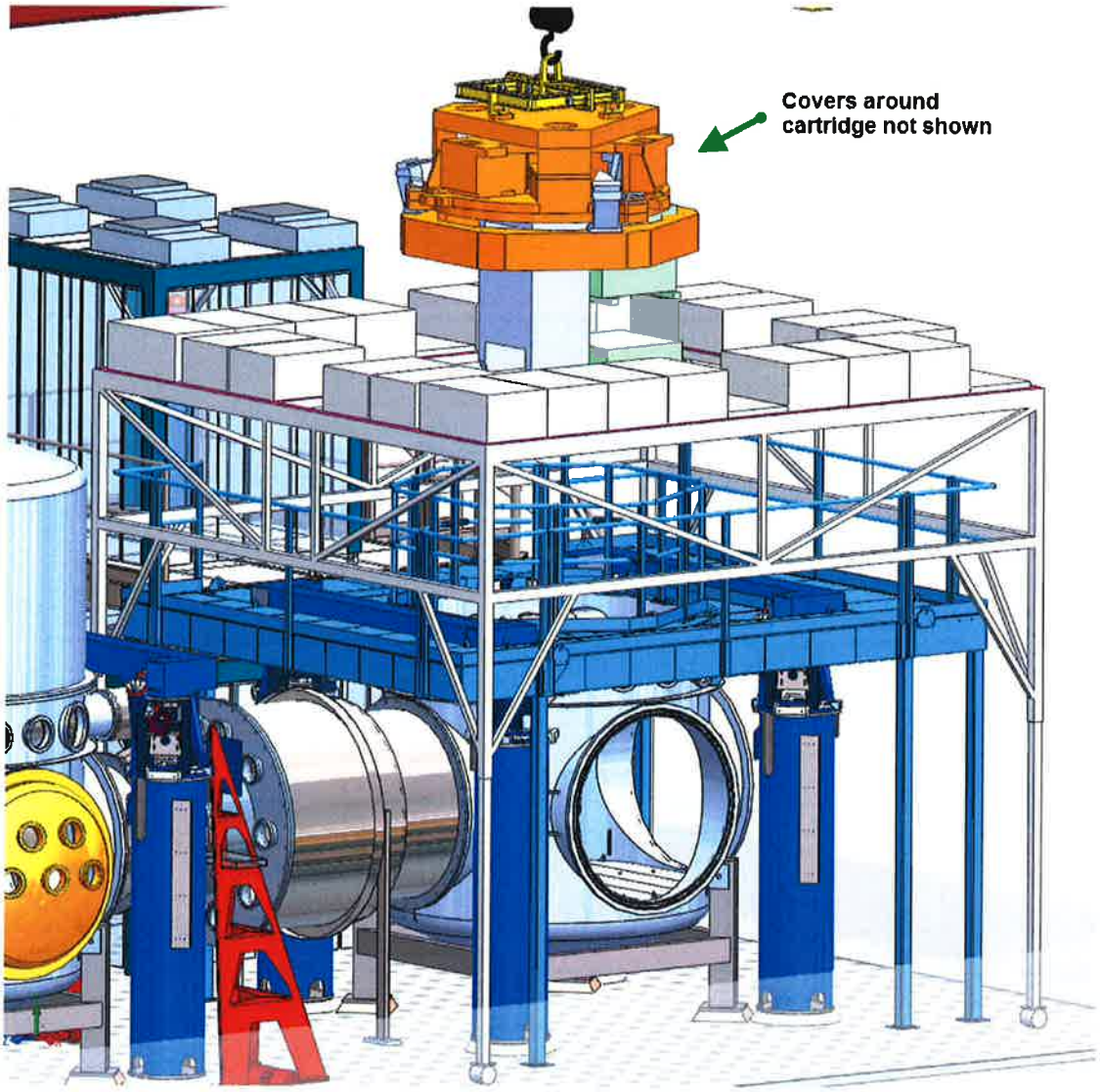
3.2.15 Move crane to a point centered above BSC chamber and clean room as shown in Fig. bellow.



3.3 Flight Path at the Chamber

3.3.1 This requires personnel in the Cleanroom on the Walking Plates wearing fall arrest equipment. The raising of the cleanroom, lowering of the Cartridge, and opening of the sock may be iterative. The intent is to not have the BSC chamber uncovered when the cleanroom ceiling is open.

3.3.2 With the fabric cover on the chamber, open the top of the chamber and raise the BSC clean room back up around the cartridge to max height. *It will not be possible to install walking plate railings as shown bellow due to lack of clearance.*



3.3.3 Lower the cartridge just far enough that the cleanroom ceiling can be secured around the lift hook sealing the cleanroom.

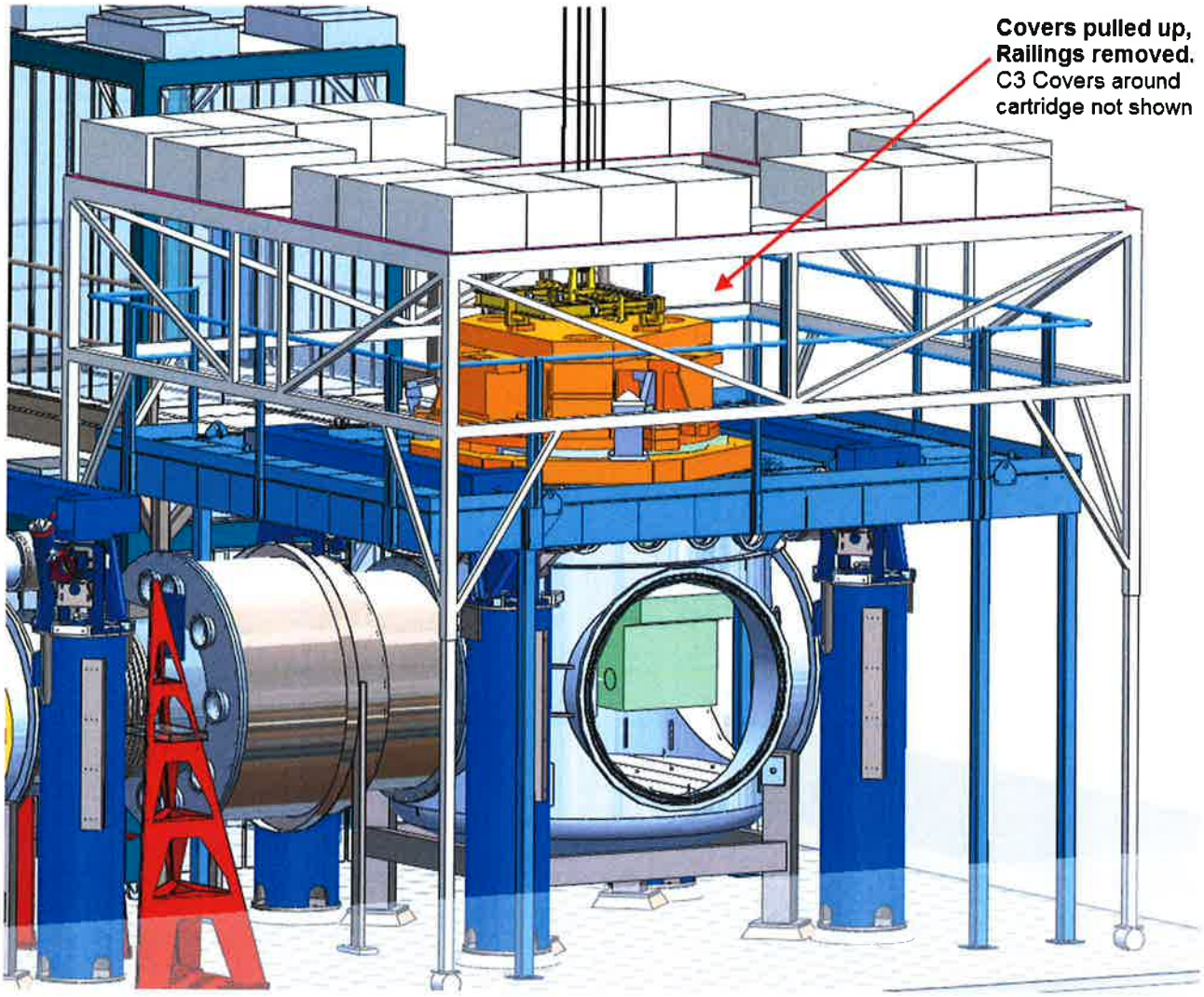
3.3.4 When dust counts are low enough, pull up covers as needed to expose ISI Stage0/Support Tube contact. This should only be the Cartridge Cover which is tied below. Roll this up as possible, raising and then lowering the Cartridge as required.

3.3.5 Raise the cartridge enough to remove the chamber cover. Maneuver the Cartridge to avoid contact with the chamber.

3.3.6 Lower the cartridge enough to evaluate its position wrt the chamber and potential interferences.

3.3.7 Continue lowering the cartridge, shifting horizontally as required in Chamber specific *Cartridge Flight & Insertion* Document until all obstructions are cleared. Someone will be needed in the chamber assisting in guiding.

3.3.8 Center position and continue lowering adjusting position as proximity to Support Tubes improves feedback.



3.4 Flare, Rollout, & Tiedown

View of the alignment pins mounted in the Stage0 holes will not be easy from above. Someone will be needed in the chamber assisting in guiding the landing. Two people will be required, and should stand in the chamber door flanges outside the Support Tubes.

3.4.1 Slip ISI Stage0 ever so smoothly over alignment pins and hold ISI just above the tubes to allow movement.

3.4.2 Install (14) 3/8-24 x 2" silver plated SST cap screws with washers through stage 0 into the tube removing the guide pins last. It will be necessary to install these screws from inside the BSC chamber. Remove the alignment pins and replace with screws. Try to lower the cartridge in small increments such that the screws can all be threaded in by hand

3.4.3 Lower the cartridge until it is supported by the support tubes. If gaps remain between the Support Tubes and ISI Stage0 (might be difficult to assess) raising a Support Tube with HEPI 'Set Screws' may be called for. When all gaps are closed, torque bolts to 23 ft-lbs. Remove all load from Crane and do final torquing.

3.5 Debrief

3.5.1 Break loose but don't remove the three (3) 5/8-11 bolts from 3pt-lifter/base plates

3.5.2 Disconnect Base Plates (D1000753) from Keel and lift high enough to cover ISI with C3 (BSC Dome Tall). Use the Crane Debris Cover to cover the lifter by folding it up over the lifter. Open cleanroom ceiling and hoist 3pt lifter clear. Close up clean room and finish removing C3 covers. Secure 3pt lifter, Base Plates and hardware.

It is now time to move back to Top Level install procedure i.e. relevant link from related documents in LIGO-E1200023: aLIGO Chamber Installation Procedures folder e.g. Section 5.5 of LIGO-E1200634: aLIGO Installation Procedure: LBSC1 (added by CIT, 29th Oct 2012)

It is now time to move back to Top Level install procedure i.e. relevant link from related documents in LIGO-E1200023: aLIGO Chamber Installation Procedures folder e.g. Section 5.5 of LIGO-E1200634: aLIGO Installation Procedure: LBSC1 (added by CIT, 29th Oct 2012)

3.6 Post Install

Work in progress below as evident--HR

3.6.1 Check level of stage 0 using a clean precision level. Adjust with HEPI if necessary until stage 0 is level to within .4 mrads.

3.6.2 Replace keel masses and viton pads on top of stage 2 per E0900357.

3.6.3 Attach in vacuum cabling to all sensors, actuators and payload. Be careful not to bend pins or put force on feed-thrus.

3.6.4 Install other payloads as specified in the chamber specific procedure.

3.6.5 Unlock all six lockers between stage0 and stages 1 & 2.

3.6.6 Rebalance and continue testing per LIGO E1000304.

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO- E1200925-v1 | *Advanced LIGO* | 25 Oct. 2012

BSC Cartridge Installation Hazard Analysis

Sam Barnum, Dennis Coyne, Brian O'Reilly, Norna Robertson, Calum Torrie

Distribution of this document:
LIGO Science Collaboration

This is an internal working note
of the LIGO Project.

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http://www.ligo.caltech.edu/

CHANGE LOG

Date, version	Summary of Changes
18 Oct 2012	Initial release for comment (modified from E1200327 BSC2-L1)
25 Oct 2012	1) BIG ONE - is this is now a general HA for ALL Cartridge installs. 2 have now been completed at LHO and one at LLO. As part of this change to general we clarified, noted and identified the following: - 2) Identified risk for damage to Gate-Valve Plumbing and Gate Valve (section 2 and hazard 9) 3) Noted that some keel plate hole patterns are rotated by 120deg from the that shown in the assembly documentation, adjust x-y of the lifter bale position to compensate for rotation. (section 3.4) 4) Spelled out that there is a need to rotate Cartridge to align with chamber, if a rotation of the cartridge is required to align it to the chamber (BSC1,2). (Section 3.5) 5) Updated related documents (section 4) 6) Identified clearly that the cleanroom will be fitted with a 4" spacer between the two halves to provide clearance for the gate-valve motor box. A narrower version of Platform-C will be used in place of the original Platform-C to avoid contact with the gate-valve plumbing (Section 5.9) 7) Walking Plate railings will not be reinstalled, due to lack of clearance between them and the incoming Cartridge. (3.8)
26 Apr 2013	Added hazard associated with moving cleanroom while people are resident on work platforms.
29 April 2013	Modified signature page as per D. Nolting

1) Scope

This document covers safety concerns related to the installation of the BSC cartridge from the Test/Assembly stand into the BSC Chamber. The cartridge is comprised of the BSC Internal Seismic Isolation (ISI) with all of the optics table payloads which can be lifted and inserted without interference into the chamber.

The scope includes:

1) Preparation and liftoff of cartridge from the Test/Assembly Stand.
2) Flight of the cartridge from the Test/Assembly stand to the Chamber.
3) Insertion of the Cartridge into the chamber.

This document does not cover the issues associated with the individual suspension and seismic systems that are part of the cartridge. Nor does it cover aspects specific to the crane, or handling of optics. These are covered by other documents.

2) Summary of Hazards

The hazards in this work can be broadly divided into the following areas:

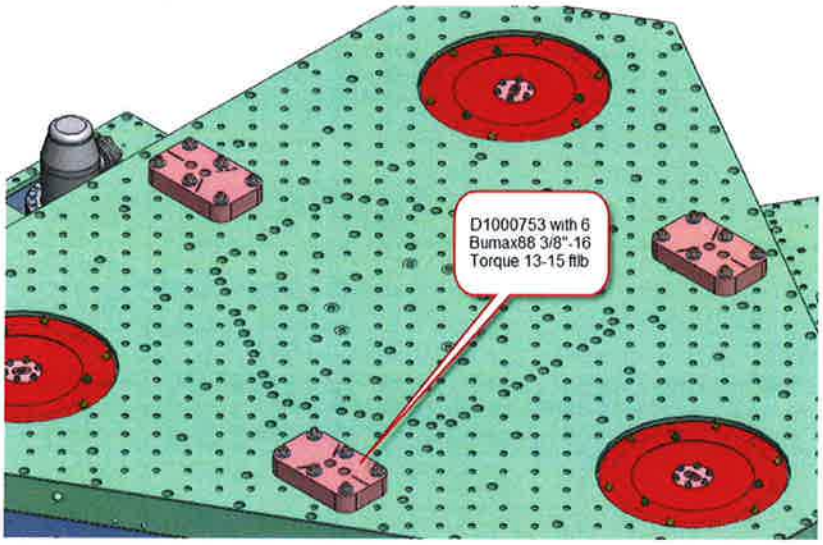
1) Moving of heavy, delicate and valuable structures with lifting and moving equipment, with potential for shock/impact if dropped or bumped, leading to the following potential failures/hazards:
   a) Personnel injury (crushing, pinching, falling).
   b) Damage to equipment, such as:
      - failure/stretching of wires and/or fibers.
      - misalignment of suspension elements.
2) Damage to the suspensions or isolation system,
   a) Impact against the Test/Assembly Stand.
   b) Impact against the BSC Chamber and Support Tubes.
3) Particulate contamination,
4) Cartridge dropped,
5) Crane failure (without drop) or Power Failure during operation,
6) Crane/Structural failure (Overload crane),
7) Drop/fall hazard of tools, etc. due to assembly of components at height,
   a) While putting covers over cartridge.
   b) During attachment of 3pt Lifter to cartridge.
   c) When attaching Cartridge to Chamber support tubes
8) Crane rotation failure while cartridge suspended.

9) Damage to Gate-Valve Plumbing and Gate Valve.

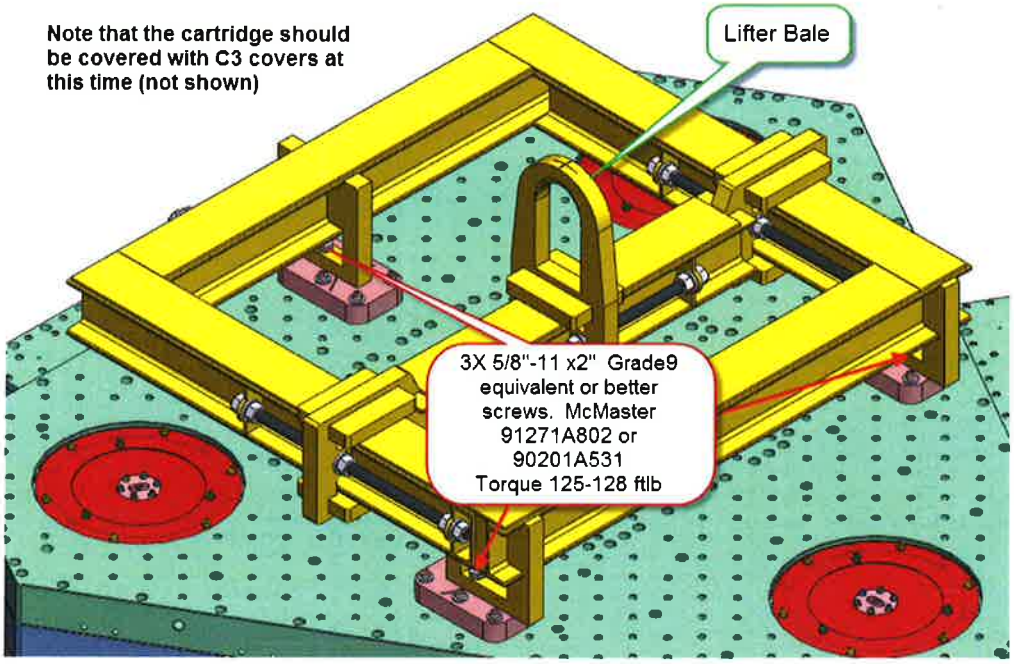
10) Personnel injury (strike or fall) when working on test stand platforms while cleanroom is moved away from test stand area.

3) Overview (Note: all pictures are examples from BSC6, but are applicable to BSC2)

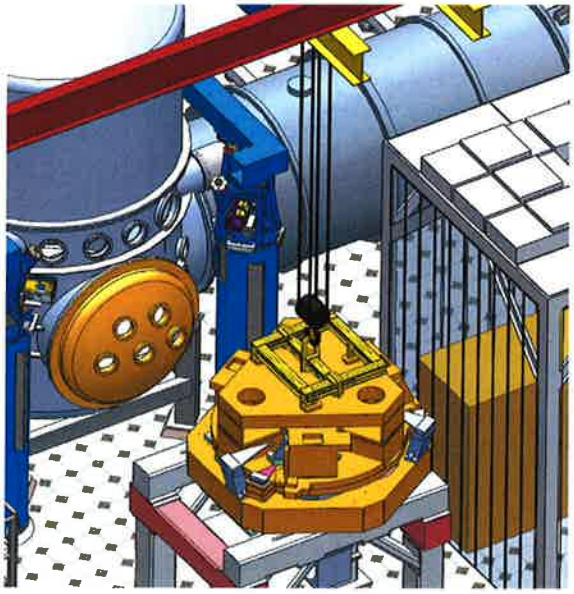
3.1 Attach the three (3) Lift Hook Receivers (D1000753) on the ISI Keel-plate, if not already present (See *D1000756 for layout and use Bumax-88 3/8"-16 Screws, Torque, 13-15 ft-lb*).



3.2 Attach 3pt Lifter to Lift Hook Receivers (*D1003140*), use 5/8"-11 Grade9, equivalent or better (91271A802, 90201A531), 125-128 ft-lb



3.3 Crane In position above Cartridge and Test Stand

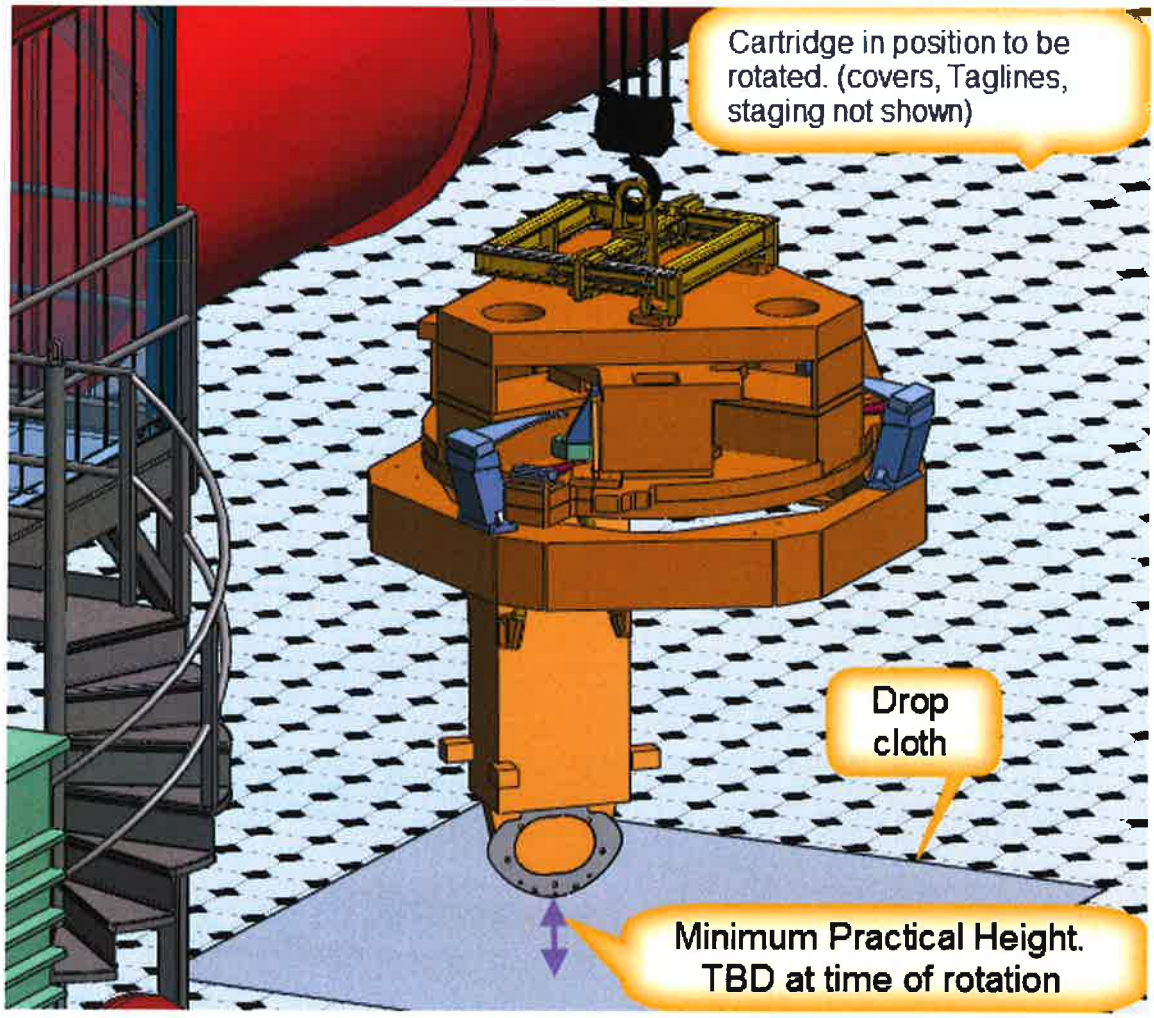


3.4 **Adjust 3pt lifter bale** (shown below with load cell attached) to predicted X-Y CG location (some keel plate hole patterns are rotated by 120deg from the that shown in the assembly documentation, adjust x-y of the lifter bale to compensate for rotation.) Then **Check Cartridge weight:** Lift cartridge from

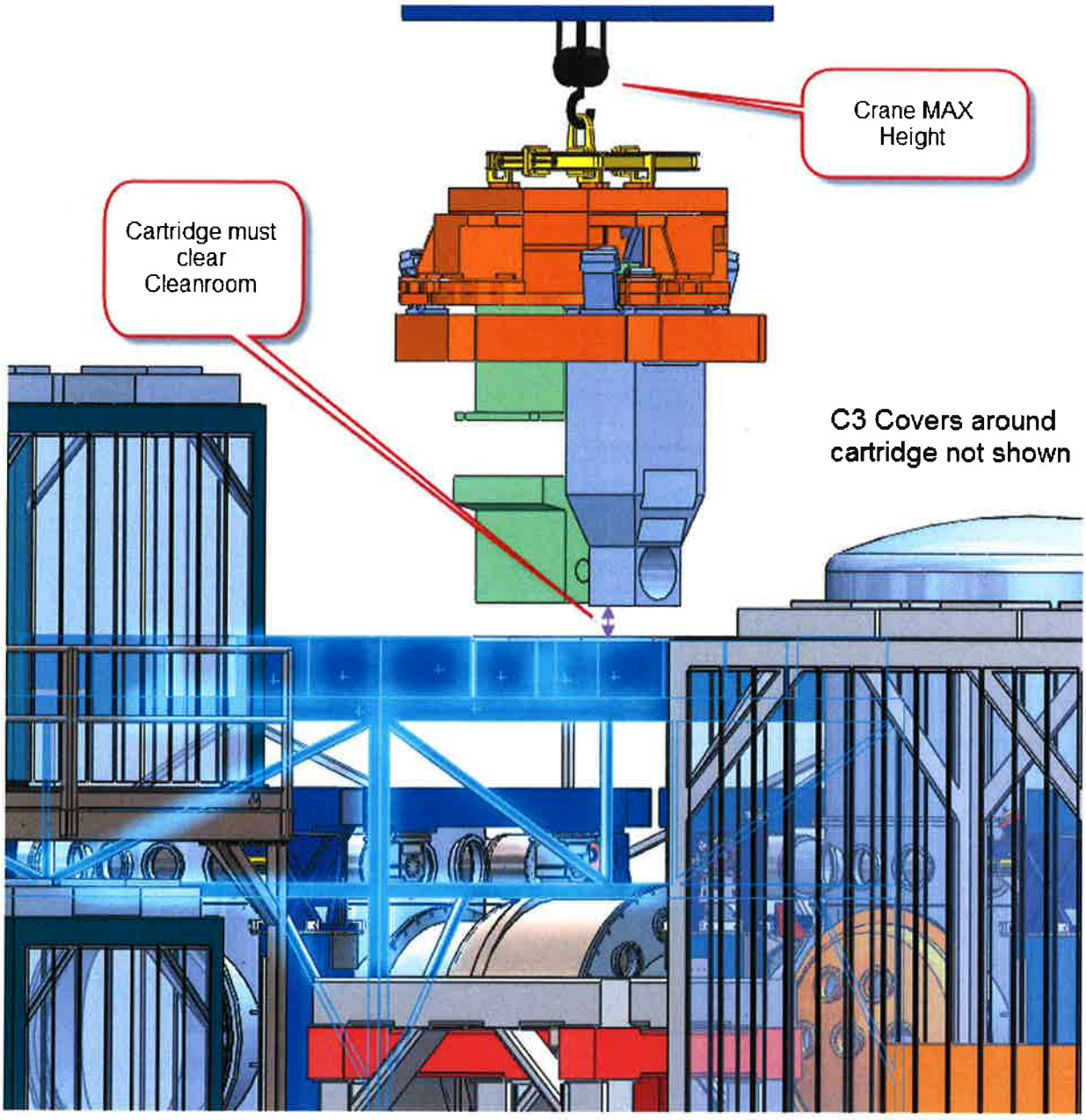
test-stand with load cell and crane, If load-cell starts to exceed 10,000lb, stop, and set cartridge back down. Reduce cartridge weight and try again. Record the final total weight, set back down and remove load cell. Record the specific load cell and any needed deviations in the intended payload for the cartridge. If there is a 2" or more gap at any point between the mounting surface of the Test Stand and the mounting surface of the cartridge, the cartridge must be re-leveled. Target gap at any point will be ~ 1/4"

(3pt. Lifter & Load Cell, shown while not attached to cartridge)

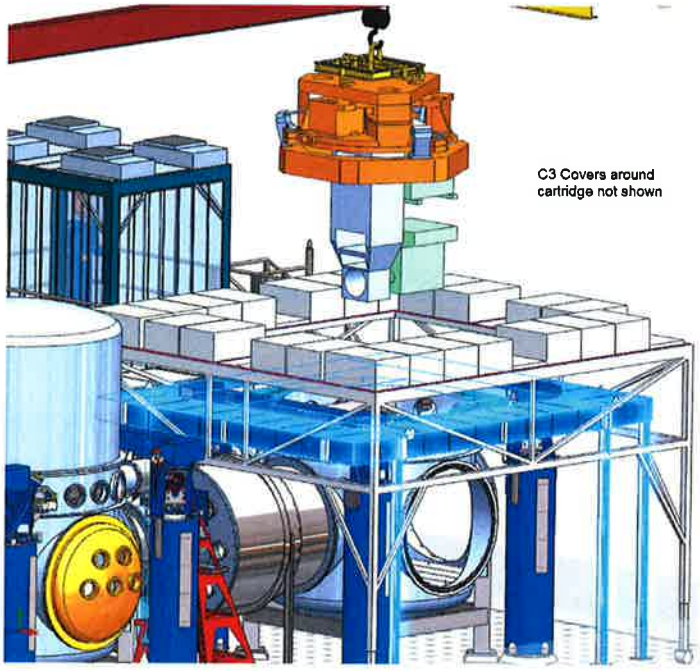
3.5 Rotate Cartridge to align with chamber, if a rotation of the cartridge is required to align it to the chamber (BSC1,2): Insure a protective tarp with clean side up has been placed on the floor in the area where the cartridge rotation will take place (cartridge cover may contact floor otherwise). Attach 2 to 4 taglines to 3pt lifter (to rotate cartridge or serve as backup) Lift cartridge to clear Test Stand and move to designated area over tarp. Lower cartridge to minimum practical height without suspensions contacting the floor. Move staging from around test stand, into place to access stage0 if rotation "by hand" is to be done. Using either taglines or the "by hand" method, rotate cartridge to align with chamber orientation. If pivot on hook becomes jammed, return cartridge to test stand. There is clearance to allow this.



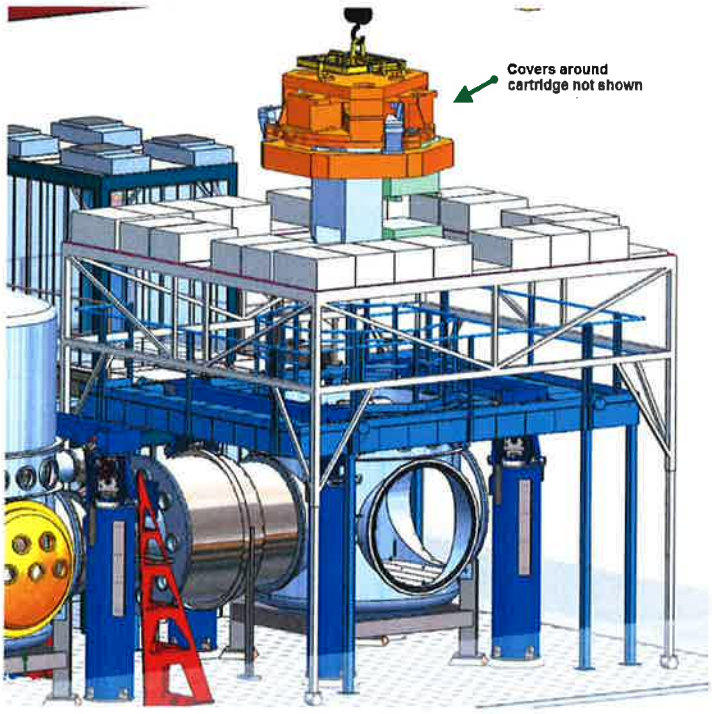
3.6 **Lift** cartridge up to height to clear BSC Clean-room (max height). BSC Clean-room should already be at minimum height (just above spools), Walking Plates (D1002410) and Platforms (D1001990) should be in place without railings, around chambers (See install procedure E1101051). Clean-room clearance ~8"



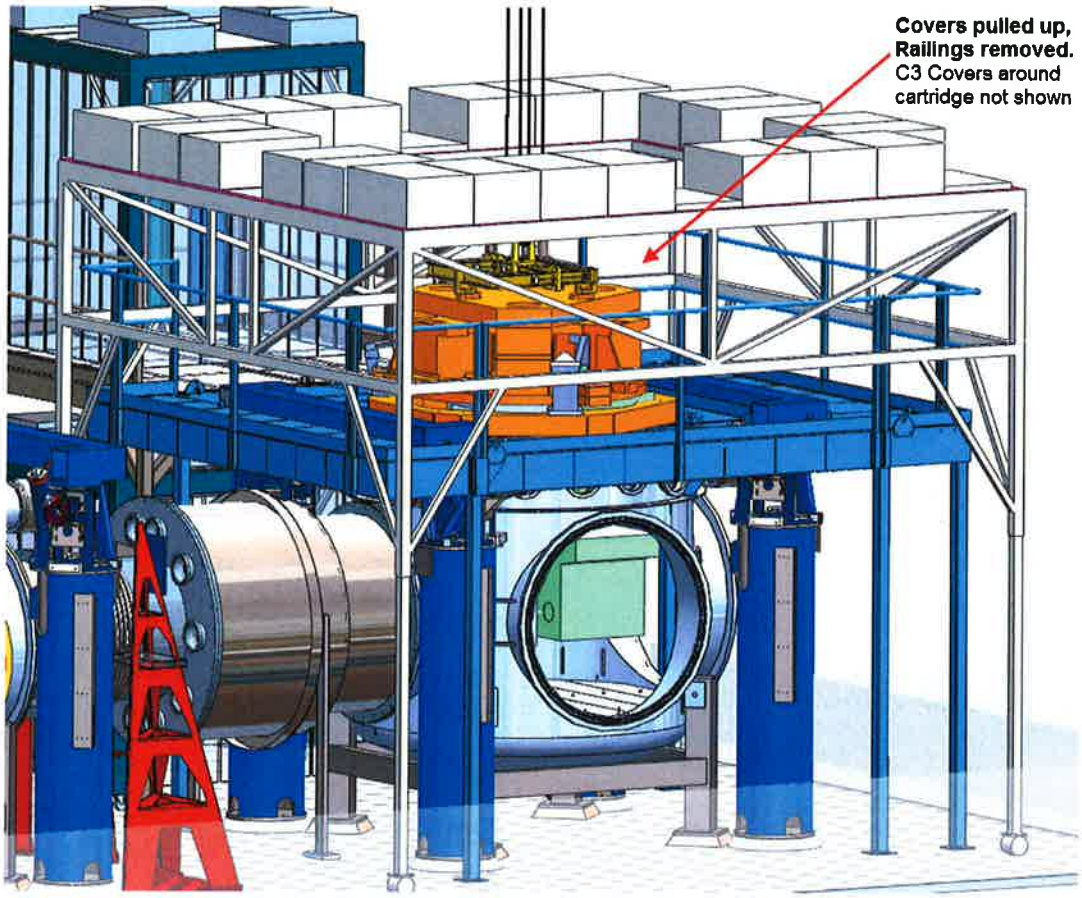
3.7 Move crane to a point centered above target BSC chamber, and BSC Clean-room



3.8 Raise BSC Clean-room back up to max height, Walking Plate railings will not be reinstalled, due to lack of clearance between them and the incoming Cartridge. Fall arrest system will be used (personal harness, lanyard, anchor points,) to prevent falls.



3.9 Lower cartridge to just above chamber, and role up outside cover to expose stage0, remove fabric cover from chamber. Continue to lower cartridge onto support tubes in chamber.



3.10 Insert 3/8"-24 x 2" screws into all 14 holes. Torque 21 ft.lb, Then remove 3pt Lifter, close up clean room, finish removing C3 covers.

4) Related Documents

- LIGO-E1200023: aLIGO Chamber Installation Procedures.
  (See related documents specific to the BSC Cartridge being installed)
- LIGO-E1200900: BSC Installation Procedures (from sub-systems)
- LIGO-E1200901: BSC Safety Procedures(associated with install)
- LIGO-E1101051: BSC Work Platforms Assembly Instructions
- LIGO-E1200344: All BSC, Basic Cartridge Install, aLIGO
- LIGO-E1101017: Cartridge Lifting Hardware, Loading Analysis.

5) Hazard Analysis

Each hazard, and mitigation approach or measure, is listed in the severity table in the next section

5.1 While moving heavy, delicate and valuable structures using lifting and moving equipment, there is potential for injury, shock and/or impact if structures are dropped or bumped.

- Personnel injury (crushing, pinching, falling)

  A minimum number (4) of personnel must be trained for, and follow safety rules of the lifting equipment to be used. Safety glasses, shoes, and hardhats must be worn by personnel involved in the lifting and transporting of the Cartridge. At no time should work be done above head height while people are directly below.

- At no time should any person be beneath a suspended cartridge.
- Damage to equipment (from shifting or vibrations)
- Vibrations, Accelerations and Decelerations during liftoff, transport, and placement have the potential to damage items held in the suspensions or between the stages of the ISI. Therefore the ISI and items in the SUS frames must be locked down per the checklists and references in LIGO-E1200900 & LIGO-E1200344

5.2 Damage to the suspensions or isolation system from Impact

- Impact can cause damage directly to the suspension frames, Test Stand, or Chamber. Resulting movement of the suspended items in the frames during an impact can cause secondary damage. Chances of contact with optics table payload is significantly reduced by removing any items that might interfere with the Support Tubes or Chamber. In addition there are lateral moves (laid-out in BSC Requirements and procedures.. in: LIGO-E1200900) to avoid contact with potentially interfering items. The ISI and items in the SUS frames must be locked down per applicable checklists and references in LIGO-E1200900 & LIGO-E1200344.

5.3 Particulate contamination

- To protect delicate optics and other components, all guards, covers and caps, must be in place. All personnel must be trained and follow the detailed procedure and checklist to ensure all of the required items are in place
- Fabric covers are used over the entire cartridge assembly to catch particulates generated by the crane.

5.4 Cartridge Drop

- Failure of the lifting apparatus causing the cartridge to drop, could result in serious injury and loss of a significant portion of the cartridge hardware. Thus no person will be allowed below the cartridge or within a safety radius of it during liftoff, transport or

set-down. Only the crane operator and persons watching for close encounters and/or providing hand signals, shall be allowed in the area where the lift is being made. All others shall stay at a safe distance (20-feet minimum) away from lift activities. The exception to this is in the very early and late stages of liftoff and set-down while the cartridge is only a few inches away from the support tubes, which would shield anyone from the short drop of the cartridge. The cartridge will need to be inspected and guided at these two times. The dropping hazard is mitigated overall by the use of lifting hardware that has a 3 times yield, designed-in, safety factor. It should also be noted that it is recommended that bystanders refrain from talking/making noise that may disturb the concentration and communication of the personnel involved in the lift.

5.5 Failure of crane to operate or power failure during operation

- A failure of the crane lifting mechanism, or power loss during transport will result in the crane locking in place. This is not a safety problem, and covers will prevent contamination. See critical lift plan in LIGO-E1200901.

5.6 Structural failure of Crane

- The crane will not be operated beyond rated capacity. All items will be pre weighed, and must only be the ones expected per plans (LIGO-E1200900 and LIGO-E1101017) to be part of the cartridge (no additional unexpected parts).

5.7 Drop/fall hazard due to assembly of components at height

- To prevent falls and dropped items from height, platforms and walking plates with kick panels and railings will be in place as needed around the BSC chamber. Also a Fall Arrest System will be used when railings cannot be used.

5.8 Crane does not allow cartridge to rotate, or jams at partial rotation

- Cartridge can be returned to test stand if hook pivot becomes stuck.

5.9 Cleanroom or platforms impact the Gate-Valve or plumbing.

- The cleanroom will be fitted with a 4" spacer between the two halves to provide clearance for the gate-valve motor box. A narrower version of Platform-C will be used in place of the original Platform-C to avoid contact with the gate-valve plumbing. Reference LIGO-E1101051 (BSC Work Platforms), for setup and configuration of the platforms round the BSC Chambers.

5.10 Personnel strike hazard while moving cleanroom when people are resident on test stand work platforms.

- The test stand cleanroom is moved to allow crane access to the 3pt lifter and cartridge, when readying the system to be checked with a load cell and subsequently flown to chamber for install. Workers on test stand work platforms will typically hold curtains open to ensure the clear plastic drapes do not touch the ISI. However, cleanroom gussets

(cross-bracing) located at the corner of the ceiling (where the legs are affixed) has some chance to strike a worker when the cleanroom begins to clear the test stand. This puts the worker at risk for injury due to the strike, and due to a potential fall from the test stand that could follow (see Fig 5.10). The risk can be exacerbated if the cleanroom sits off-center relative to the test stand (which may happen owing to nearby interferences).

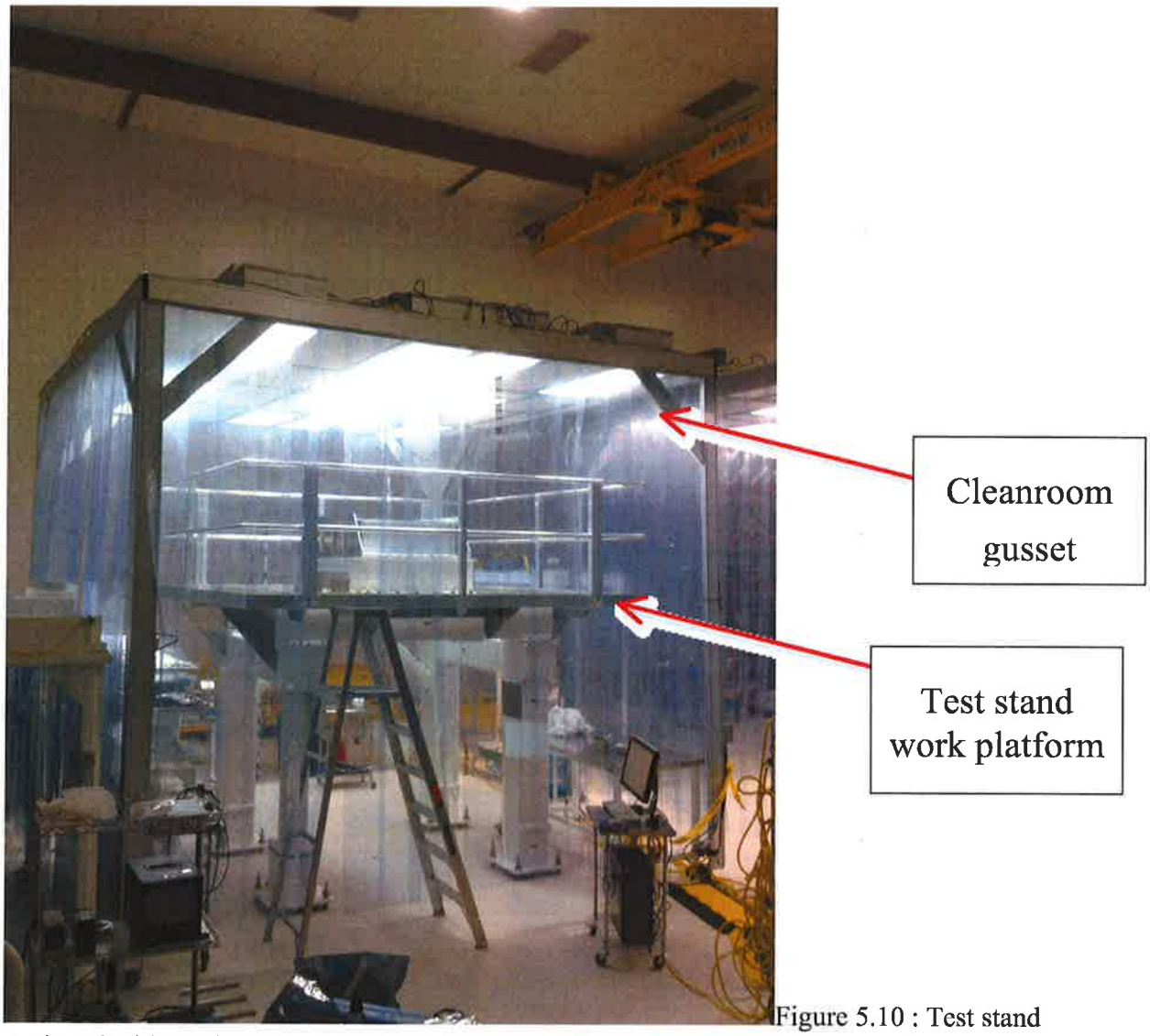


Figure 5.10 : Test stand equipped with work platform. When being moved for crane access, gussets on cleanroom can interfere with workers on platform (in particular, if the cleanroom is offset from test stand center).

6) Hazard Analysis Severity Table (The number in brackets is a reference back to section 2 summarizing the hazard)

Item (Ref)*	Hazard	Cause	Effect	Unmitigated Severity	Unmitigated Probability Level	Unmitigated Risk Index	Comment	Mitigation	Mitigated Severity	Mitigated Probability Level	Mitigated Risk Index
1 (2.1)	Fingers/hand/arm pinching/crushing hazard	Between Cartridge and Support tubes on Test Stand or in Chamber	Injury to personnel	Critical	Occasional	2C		A minimum number (4) of personnel must be trained for and follow safety rules of lifting equipment being used	Negligible	Remote	4D
2 (2.2)	Cartridge impact anywhere other than mounting surfaces.	Interference with support tubes, Test Stand or chambers	Damage to mostly suspended items.	Critical	Probable	2B	Damage concern mostly to suspensions during lift or lower, to stand or chamber	Remove interfering items & lateral moves of cartridge to clear obstacles.	Marginal	Remote	3D
3 (2.3)	Particulate contamination	Debris falling from above: crane etc. Removal of covers/caps	damage to environment	Marginal	Probable	3B		C4 Cloth covers for cartridge and suspended components	Marginal	Remote	3D
4 (2.4)	Payload drop hazard	Improper use of interface tooling, linkages, crane	Injury to personnel; damage to equipment	Critical	Remote	2D	3X or better safety factor on all lifting equipment (Industry standard)	Personnel must be trained and follow detailed procedure and checklist.	Critical	Improbable	2E
5 (2.5)	Failure of lifting mechanism, power outage	Lifting equipment not serviced or used as per instructions, power outage	Nuisance, lost time	Marginal	Remote	3D	Final weight of cartridge measured, insure crane within operating spec. at all times.	lifting equipment should be inspected and maintained, so that a failure is unlikely. Do not operate at time when a power outage is likely.	Negligible	Improbable	4E
6 (2.6)	Crane, structural failure	Overloaded crane, poor crane related maintenance	Injury to personnel; damage to equipment	Critical	Remote	2D		All items to be lifted pre weighed, Test lift, Proper crane maintenance	Critical	Improbable	2E
7 (2.7)	Assembly of components at height	On top of, or below Cartridge and above Support tubes	Injury to personnel; damage to equipment	Critical	Remote	2D		Use barrier plates and railings as instructed, and personnel must wear safety glasses ,shoes ,hard hats	Critical	Improbable	2E
8 (2.8)	Crane rotation failure	Hook Binds	Wrong orientation	Marginal	Remote	3D		Return cartridge to test stand, repair crane	Negligible	Improbable	4E

Item (Ref)*	Hazard	Cause	Effect	Unmitigated Severity	Unmitigated Probability Level	Unmitigated Risk Index	Comment	Mitigation	Mitigated Severity	Mitigated Probability Level	Mitigated Risk Index
9 (2.9)	Gate Valve or plumbing damage	Impact with cleanroom/platfom	X/Y arm Vacuum leak	Critical	Remote	2D	Spacer added to cleanroom to clear gatevlave	New platform -C to clear plumbing/vlave, close gatevalve at cryopump	Marginal	Remote	3D
10 (2.10)	Strike from cleanroom when on test stand	Moving cleanroom without alerting workers on test stand	Injury to personnel	Critical	Occasional	2C	Risk is exacerbated by off-center cleanroom	Good communication from crew moving cleanroom to personnel on test stand	Marginal	Improbable	3E

7) Key

Key to table in section 6

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	4	Less than minor injury, first aid or minor supportive medical treatment type of occupational illness, or less than minor system or environmental damage.

Probability	Level	Definition
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.

SEVERITY OF CONSEQUENCE	PROBABILITY				
	E Improbable	D Remote	C Occasional	B Probable	A Frequent
1 Catastrophic					
2 Critical					
3 Marginal					
4 Negligible					

Hazard Risk Index	Risk Code Criteria
1A, 1B, 1C, 2A, 2B, 3A	Unacceptable
1D, 2C, 2D, 3B, 3C	Undesirable (Directorate decision required)
1E, 2E, 3D, 3E, 4A, 4B	Acceptable with review by Directorate
4C, 4D, 4E	Acceptable without review

Checklist for the aLIGO LBSC5 Cartridge Installation

AUTHOR(S)	DATE	Document Change Notice, Release or Approval
Brian O'Reilly	17 Feb 2014	V1

Objective and Scope

This document addresses critical issues in the lift of the cartridge (SEI/SUS/AOS) payload from LLO test stand, to insertion in BSC5. Further documentation on overarching cartridge procedures can be found in related documents below. The critical lift document is not intended to supersede E1200322, aLIGO Installation Procedure: BSC5 (or documents called out therein), but instead to call out critical safety items on the lift from test stand to chamber.

1. Related documents

LIGO-E1200344: BSC Cartridge General Install Procedure aLIGO

LIGO-E1200925: BSC5-L1 Cartridge Installation Hazard Analysis (Signed version V1, see notes)

2. Required Personal Protection Equipment (PPE)

1. Hard hat
2. Steel toe shoes/boots

3. Procedure

1. Hold a pre-lift team meeting ensuring that all personnel have reviewed and understand the procedure, hazard analysis, and this lift plan for the ISI lift from the test stand to the chamber.
2. Task leader should verify that all persons involved with the lift are wearing the appropriate PPE assigned for the lift.
3. Task leader should ensure that all necessary tools and equipment should be staged and ready in the work area prior to any lift being made.
4. Task leader and safety officer shall ensure that all personnel not involved in the lift leave the area or stay at a safe distance until the lift has been completed. If necessary, barricades and safety warning personnel can be used to control access to the area.
5. Verify that the lift area, path of load travel, and BSC5 chamber areas are clear of extraneous equipment and personnel. Particular attention must be paid to the flight path of the cartridge, owing to potential interferences from neighboring cleanrooms, chambers and vacuum equipment such as annulus ion pump tubing.
6. Verify that the crane is in a safe working condition and the critical lift documented by completing F1100001-v5 / LLO Overhead Crane Inspection Checklist and Lift Plan
7. Verify that the associated lifting spreader bars and shackles are load rated for the lift. Verify that fasteners associated with the 3pt lifter are appropriate.
8. *Task Leader should complete pre-lift checklist, below.*

Checklist for the aLIGO LBSC5 Cartridge Installation

9. Make the "Test-Flight" lift as described in section 3.2.1-3.2.9 of E1200344
    a. Note that for BSC5 we will lift the cartridge and place it back on the test stand in a different position. This is to allow attachment of some safety restraints for the TMS assembly.
10. *Complete the post-load checklist, below.*
11. Make the "Flight to Chamber" lift as described in section 3.2.10 *et seq.* of E1200344
12. *Complete the post-fight checklist, below.*

4. Hazard Analysis

1. Reference LIGO-E1200925: BSC5-L1 Cartridge Installation Hazard Analysis

5. Contamination Control

1. Reference LIGO-E0900047: LIGO Contamination Control Plan
2. Reference LIGO-E1201035: aLIGO Chamber Entry & Exit Guidelines

Checklist for the aLIGO LBSC5 Cartridge Installation

Task Leader: Jeremy Birch (Print Name) (Initial all items once completed)

Pre-load-test checklist:

1. Verbally confirm that team members have introduced themselves to each other and that all have read the procedure, are aware of the hazards and are wearing correct PPE. ____
2. Verbally remind team members of the stop work policy. ____
3. Verbally remind team members to not stand under or place limbs under the load once it has been lifted. ____
4. Confirm that the crane and lifting gear have been inspected and documentation completed. ____
5. Confirm that the cartridge is cleared and disconnected from any cables, locking fixtures are in place etc. ____
   a. **BSC5-ISI:**
      completed, approved or checked by:
      date: 2/20/14
      comments (optional):
   b. **ETMY QUAD:**
      completed, approved or checked by:
      date: 2/20/14
      comments (optional):
   c. **TMSy:**
      completed, approved or checked by:
      date: 2/20/14
      comments (optional):
6. Confirm that all personnel not involved in the task have been removed from the work area and that the control room operator has been notified of the impending lift ____

Post load-test checklist:

1. Confirm with team members than no interferences were noted during the short lift. ____
2. Have at least two team members verbally confirm reading from load cell ____ 9130165
3. Verify that lift area, path of travel, and landing area is clear of extraneous equipment and personnel. ____
4. Remind personnel again not to stand of place limbs while the load is suspended with the crane. ____

Checklist for the aLIGO LBSC5 Cartridge Installation

Pre-lift checklist:

1. Verbally confirm that team members have introduced themselves to each other and that all have read the procedure, are aware of the hazards and are wearing correct PPE. _____
2. Verbally remind team members of the stop work policy. _____
3. Verbally remind team members to not stand under or place limbs under the load once it has been lifted. _____
4. Confirm that the crane and lifting gear have been inspected and documentation completed. _____
5. Confirm that the cartridge is cleared and disconnected from any cables, locking fixtures are in place etc. _____
   a. **BSC5-ISI:**

   completed, approved or checked by:
   date: 1/21/14
   comments (optional):

   b. **ETMY QUAD:**

   completed, approved or checked by:
   date: 2/21/14
   comments (optional):

   c. **TMSy:**

   completed, approved or checked by:
   date: 2/21/14
   comments (optional):
6. Confirm that interior of chamber is clear of other assemblies and ready for cartridge _____
7. Confirm that all personnel not involved in the task have been removed from the work area and that the control room operator has been notified of the impending lift _____

Post-lift checklist:

1. Check that all lifting equipment has been removed from the cartridge. _____

LIGO

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-E1101063

Advanced LIGO

28 Oct. 2011

Clean Room Heights, Cartridge Install, BSC Chamber, aLIGO

Sam Barnum

Distribution of this document:
LIGO Science Collaboration

This is an internal working note
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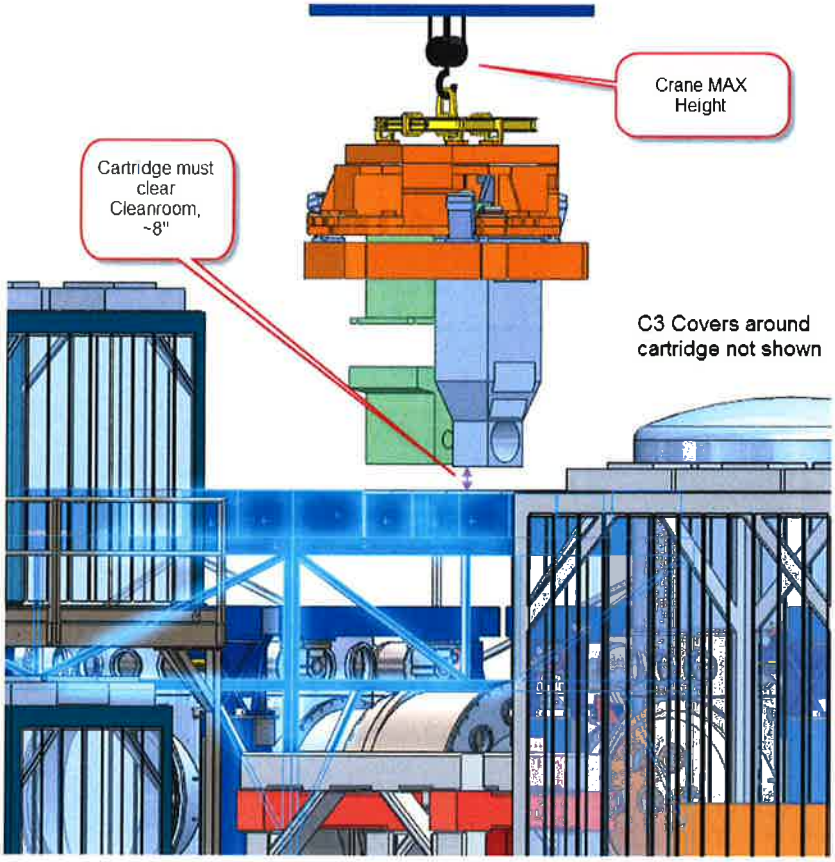
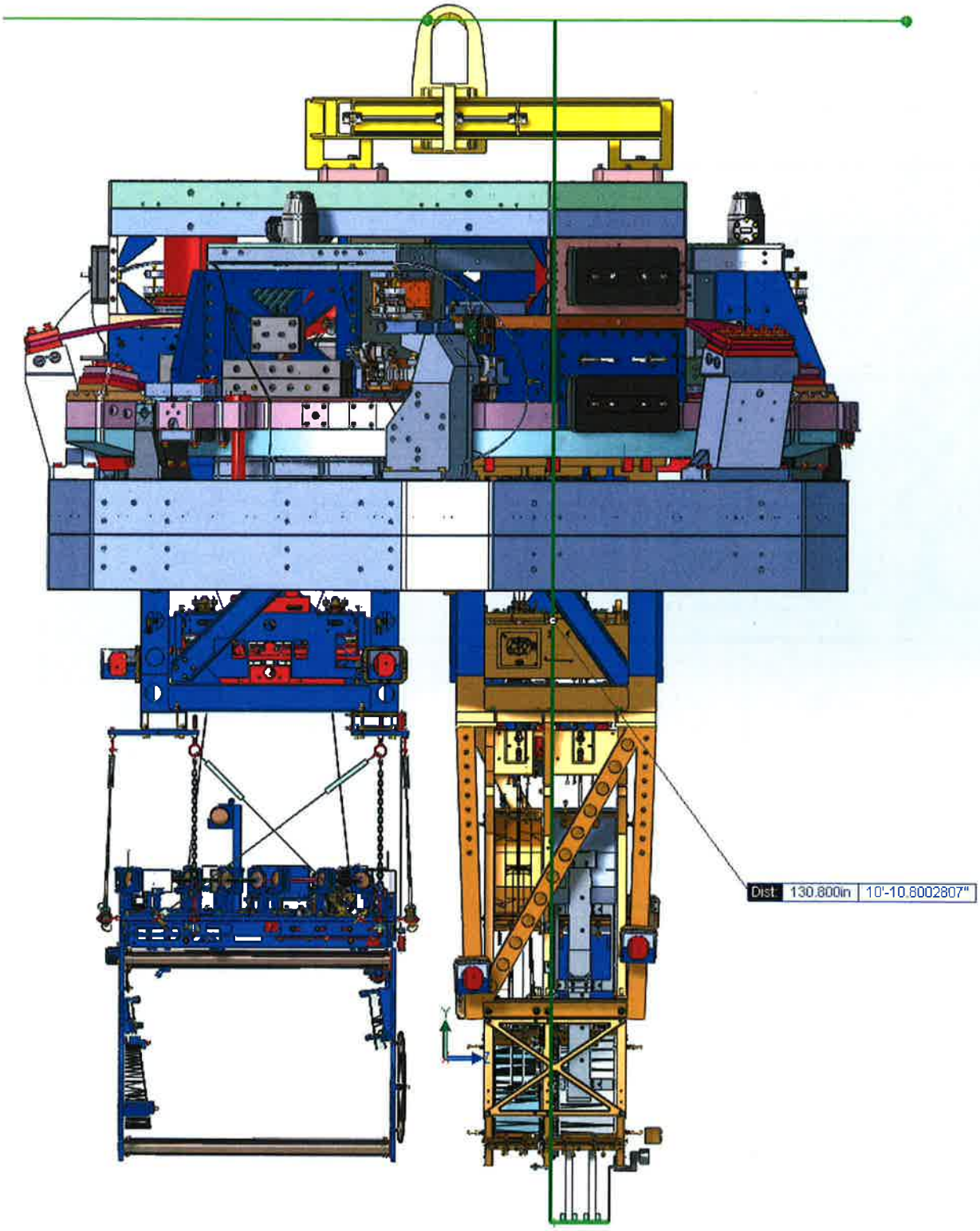
Hook heights at LHO:

Y-end = 26' 4 1/2",
X-end = 25' 9 1/2",
Main North-0 = 26' 5",
Main North-1 = 26' 5",
Main North-2 = 26' 5",
Main North-3 = 26' 4 1/2".

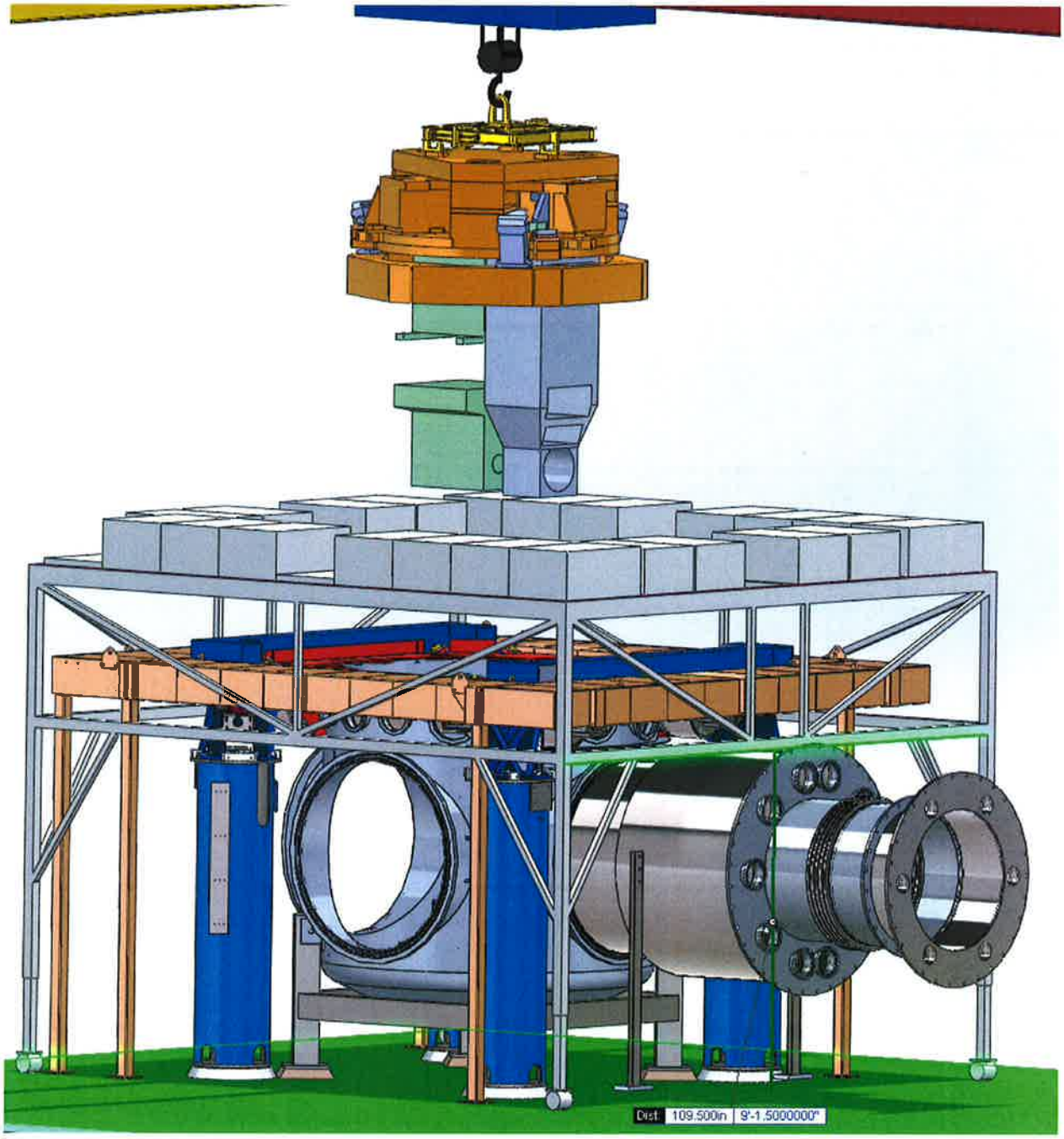
Hook heights at LLO:

Y-End - 26' 8"
X-End - 26' 2"
LVEA North - 26' 3"
LVEA East - 26' 1"
LVEA South - 26' 8"
LVEA West - 26' 5"

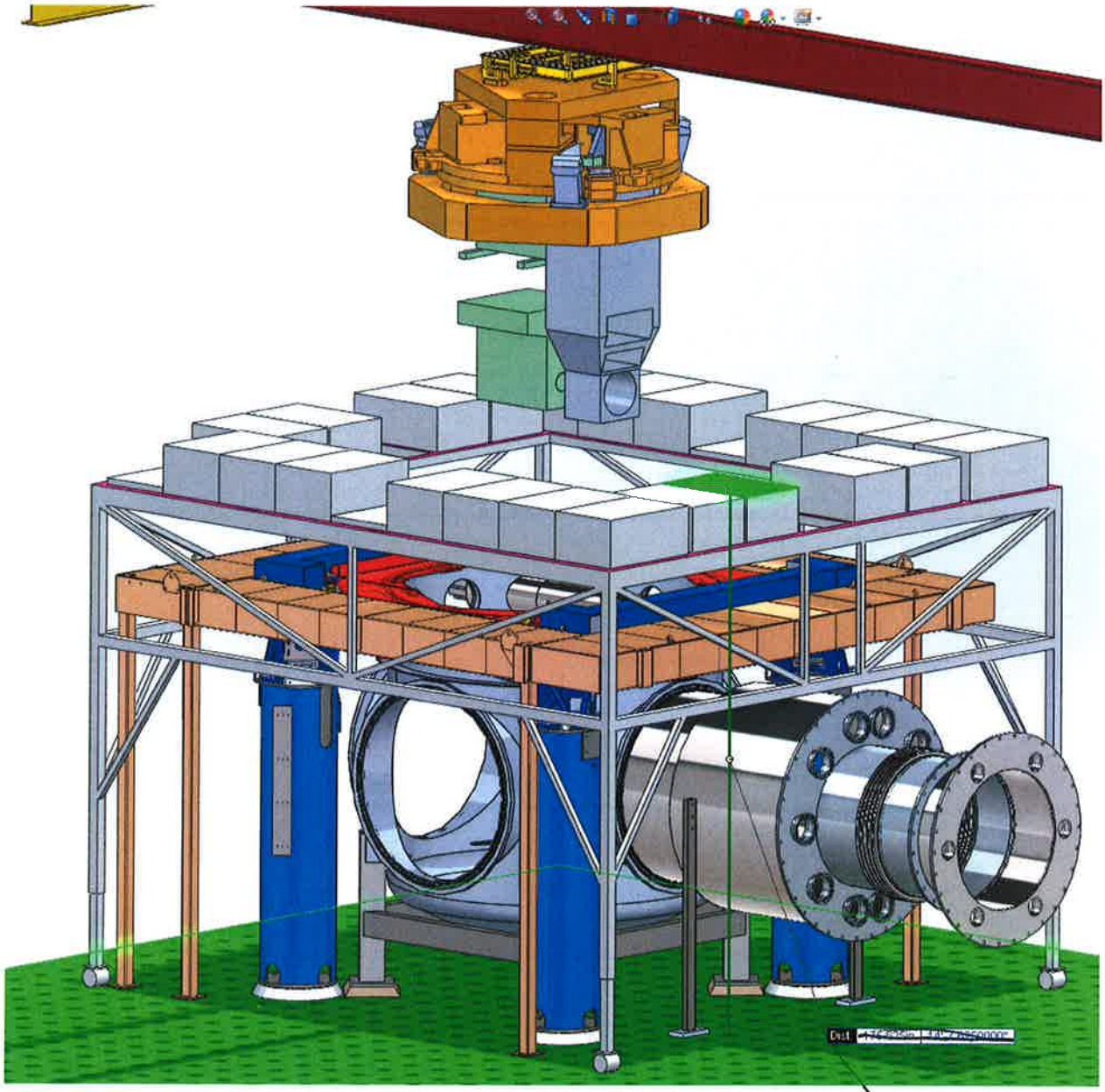



Dist: 130.800in | 10'-10.8002807"

1) Minimum Lowered height

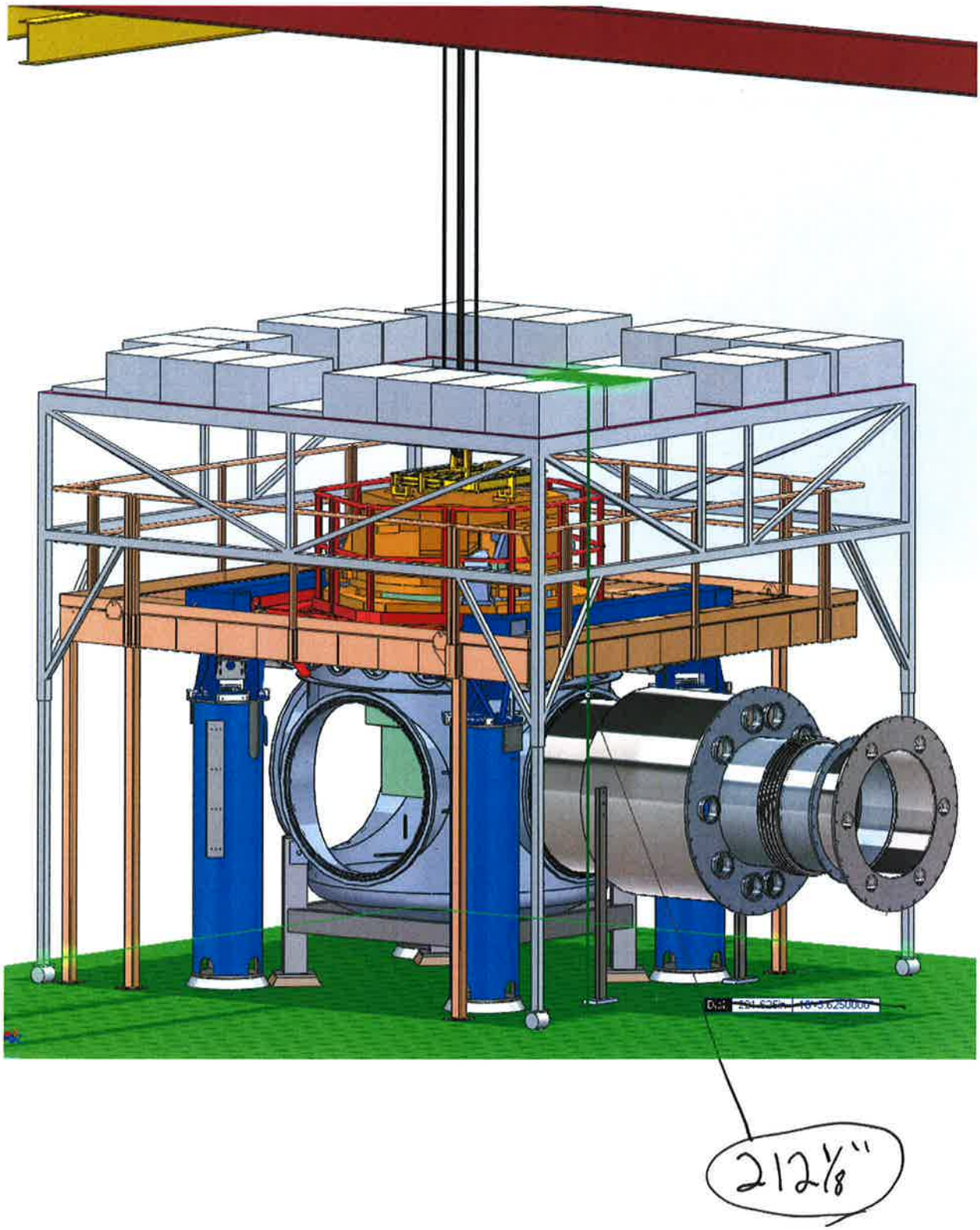


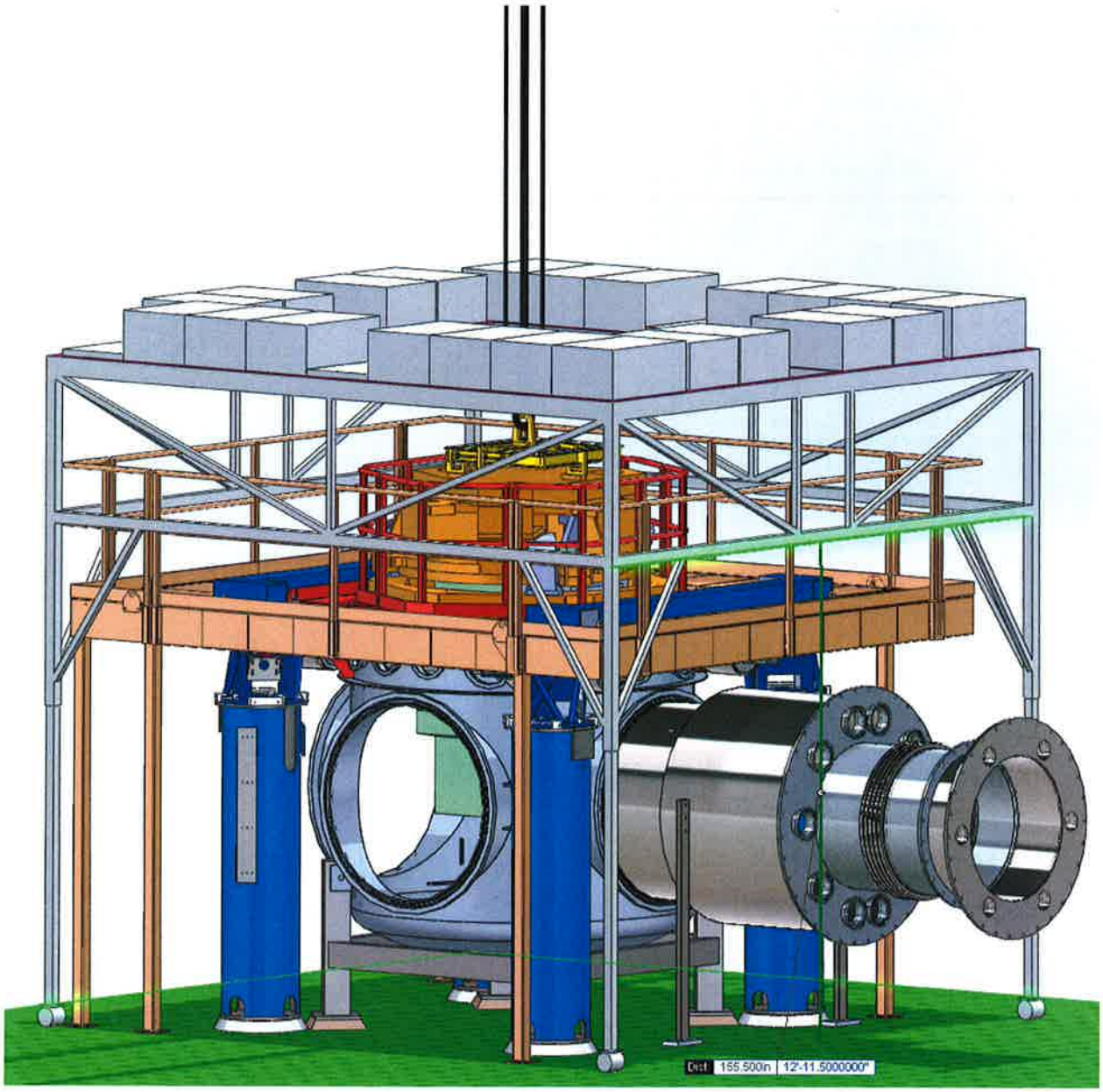
Enhanced minimum height bellow original design, V049-4-133, V049-4-135



Enhanced minimum height bellow original design, V049-4-133, V049-4-135

2) Maximum Raised height, V049-4-133, V049-4-135

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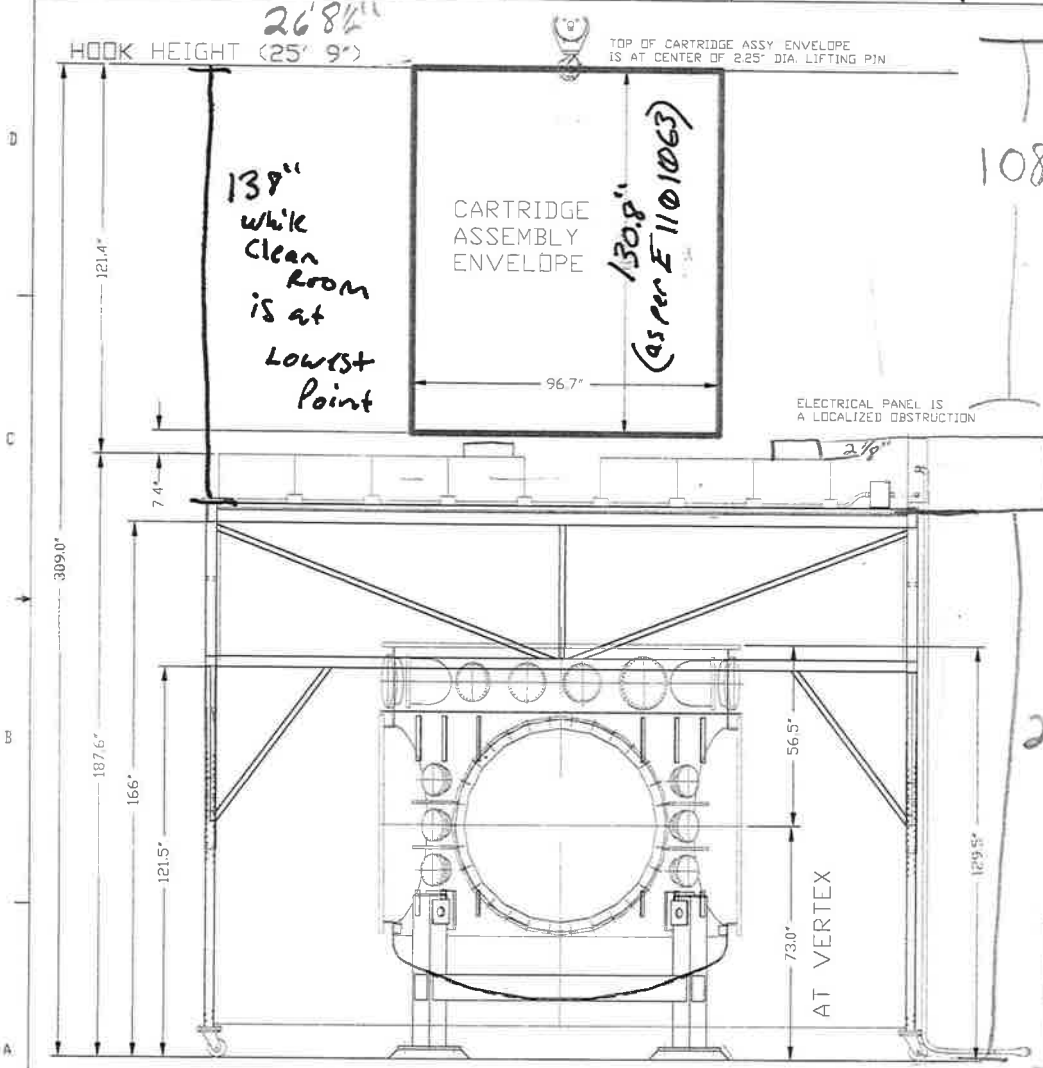


CLEAN ROOM AT CURRENT MINIMUM HEIGHT

REV	DATE	DCN #	DRAWING TREE #
v1	25.JUN2010	NA	NA

NOTES:
1) ALL DIMENSIONS ARE INCHES [MM]
2) THE HOOK HEIGHT IS AS-BUILT FOR LHO
3) HOOK HEIGHT FOR LLO IS TBD
4) CLEAN ROOM IS SHOWN IN LOWEST HEIGHT ACCORDING TO PSI DRAWING V049-4-133, REV. 5

ITEM NO.	REQ.	SPARE	TOT. QUANTITY	PART NUMBER	DESCRIPTION	SUPPLIER

PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
XX±:
XXX±:
ANGULAR:±
MATERIAL: NA
FINISH: NA

	DATE	NAME
DRAWN	25.JUN2005	D. COYNE
CHECKED		

COMMENTS:

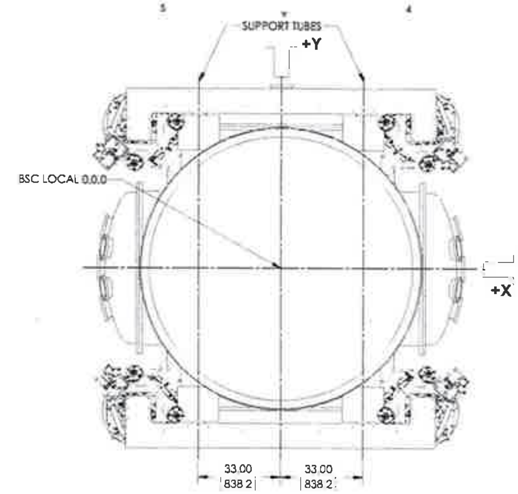
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SYSTEM	ADVANCED LIGO SYSTEM
SUB-SYSTEM	INSTALLATION
NEXT ASSY	ADV. LIGO SYSTEM
DWG NAME	BSC CARTRIDGE INSTALLATION, ELEVATION CLEARANCE
SIZE	B
DWG. NO.	D1001645
REV	v1
SCALE: NTS	
SHEET 1 OF 1	

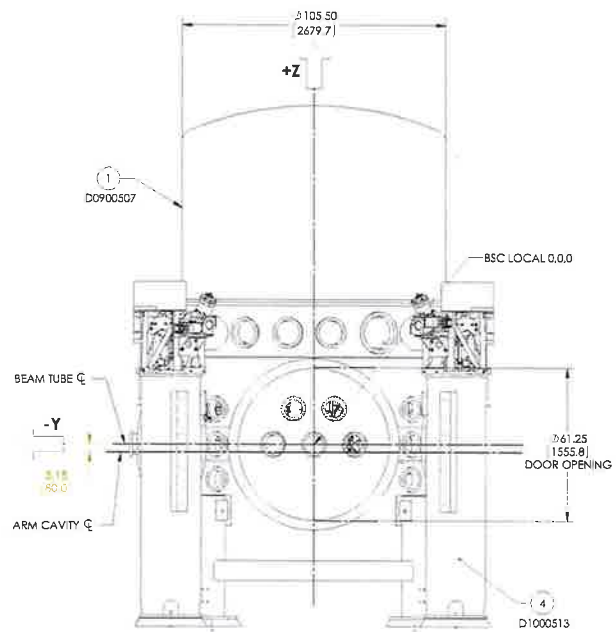
FILE NAME/LOCATION

5. REFER TO DOCUMENT D1101271 FOR OPTICAL TABLE HOLE TABULATION CONVENTION
6. REFER TO G1000125 FOR ISI NAMING AND ORIENTATION CONVENTION
7. REFER TO T1100292 FOR VIEW PORT DEFINITION
8. REFER TO E1200625 FOR LOCAL COORDINATES OF SUPPORT TUBES END.

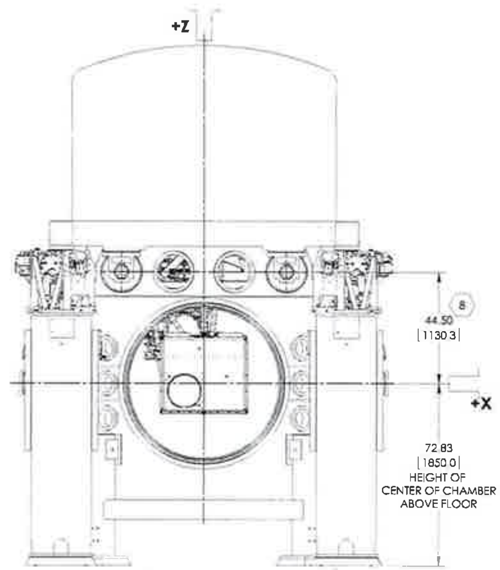
REV	DATE		
v5	18 APR 2013		



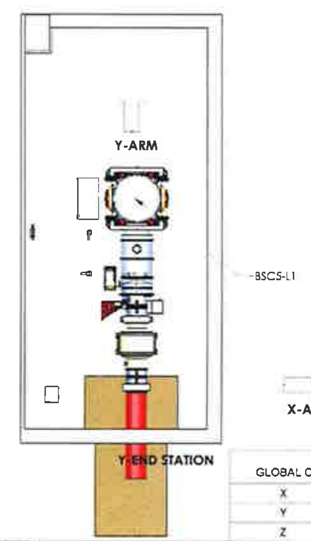
TOP VIEW



LEFT VIEW



FRONT VIEW



GLOBAL COORDINATES (mm)	
X	0.0
Y	4000000.0
Z	0.0

DIMENSIONS ARE IN INCHES [MM]
TOLERANCES:
XX : .01
XXX : .005
ANGULAR : 0.5°

NOTES AND TOLERANCES (UNLESS OTHERWISE SPECIFIED)
1. INTERPRET DRAWING PER ASME Y14.5-1994
2. REMOVE ALL SHARP EDGES .005-.015 FOR MACHINED PARTS, ROUND ALL EDGES APPROXIMATELY R.02 FOR SHEET METAL PARTS.
3. DO NOT SCALE FROM DRAWING.
4. ALL MACHINING FLUIDS MUST BE FULLY SYNTHETIC, FULLY WATER SOLUBLE AND FREE OF SULFUR, SILICONE, AND CHLORINE

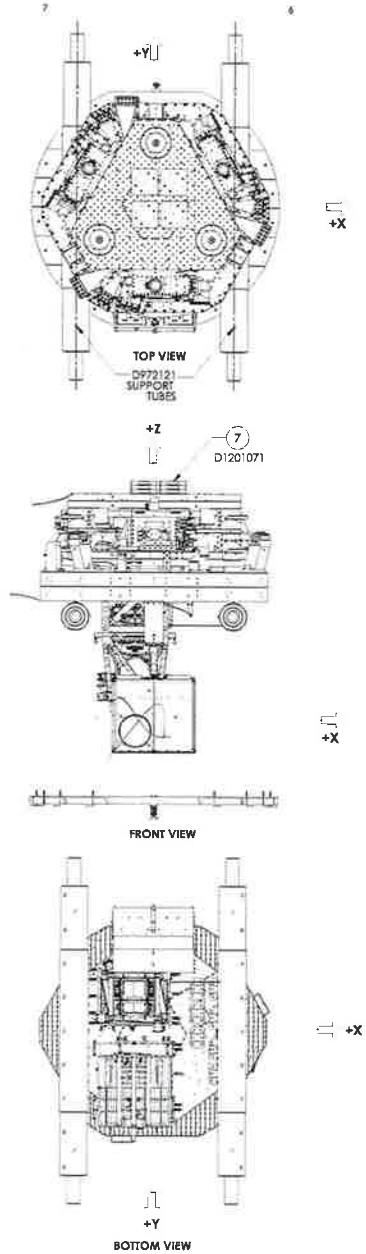
MATERIAL: —
FINISH: — µinch

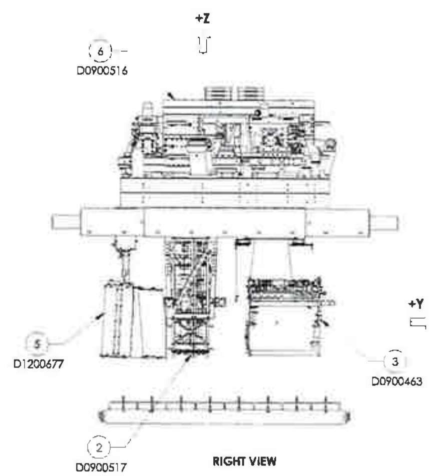
LIGO CALIFORNIA INSTITUTE OF TECHNOLOGY / MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SYSTEM: ADVANCED LIGO
SUB-SYSTEM: SUS

PART NAME: AdvLIGO Systems BSC5-L1, Top Level Chamber Assembly

SIZE: D
DWG. NO: D0900506
REV: v5
SCALE: 1:24
SHEET 1 OF 3





ITEM NO.	PART NUMBER	DESCRIPTION	Full Complete/QTY
7	D1201071	AdvLIGO BSC5-L1 ISI Table, Balance, Ballast & Trim Mass Assy	1
6	D0900516	AdvLIGO SEI BSC5-L1, XYZ Local CS for ISI Table	1
5	D1200677	AdvLIGO SUS BSC5-L1, XYZ Local CS for SLC Arm Cavity Baffle	1
4	D1000513	HEPI ASSEMBLY, BSC aLIGO	1
3	D0900463	AdvLIGO SUS BSC5-L1, XYZ Local CS for ETM Tel Assy	1
2	D0900517	AdvLIGO SUS BSC5-L1, XYZ Local CS for ETMY	1
1	D0900507	AdvLIGO Systems BSC5-L1, Vacuum Equipment Assembly	1

PARTS LIST

LIGO CALIFORNIA INSTITUTE OF TECHNOLOGY
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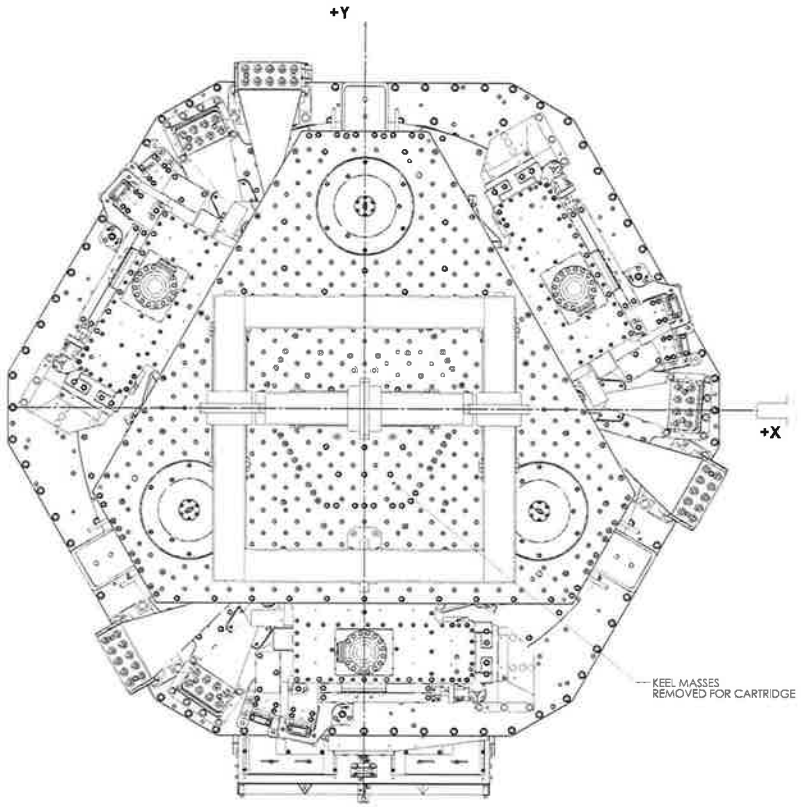
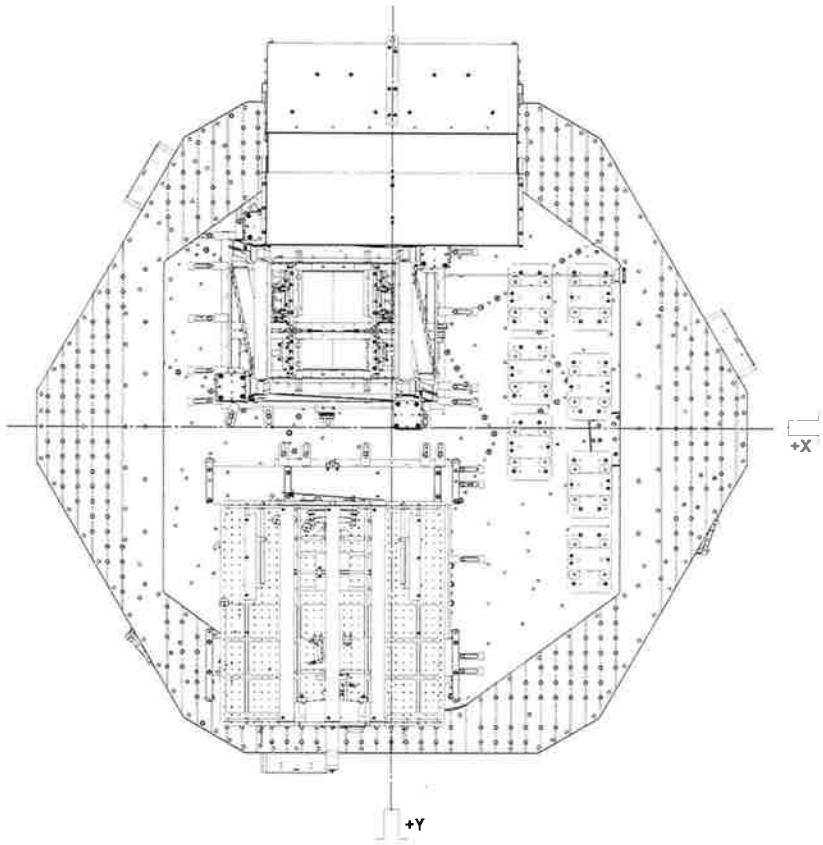
SIZE D DWG. NO. D0900506 REV. v5

SCALE: 1:25 PROJECTION: SHEET 2 OF 3



TOP VIEW
(LOOKING DOWN)
CARTRIDGE ASSEMBLY CONFIGURATION
(KEEL MASS REMOVED)



BOTTOM VIEW
(LOOKING UP)

LIGO CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SIZE	DWG. NO.	REV
D	D0900506	v5

SCALE: 1:10 PROJECTION: SHEET 3 OF 3

AUTHOR(S)	DATE	DCN,Approval
Calum Torrie and Dennis Coyne along with Matthew Heintze, Stuart Aston, Celine Ramet, Brian O'Reilly, Danny Sellars, Gary Traylor, Michael Landry, Jodi Fauver, Betsy Weaver, Kate Gushwa and Margot Phelps	12/19/13	see LIGO DCC record Status

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1 Announcements & Revision History

Please note as per approved DCN, LIGO-E1300142-x0, the requirement for in-chamber application of first contact is suspended until we prepare for Science Runs, with the following exceptions, which should have First Contact Spray (LIGO-E1300017):
Input Mode Cleaner: MC1 HR only, MC2 HR only, MC3 HR only
Power Recycling Cavity: PRM HR only
Any questions on this or substitutes for this please contact GariLynn Billingsley.

V4 – includes HAM2/3 specific notes
V5 – this revision is now generic for post install chamber access (for HAM2/3 specific notes refer to v4)
V6 – Eddie's doc now in,.
V7- Includes updated first contact requirements as of 2/22/13
V8- Now references M1300172, Approval Signatures for LIGO Chamber/Volume Closure, as final exit guideline.
V9 – Updated guidance on Cleaning as you go
V11 – Equivalent to V10 except note to team to refer to the included addendum. Refer to DCC link for addendum to this document.
V12 includes addendum form v12 in body of text as well as an appendix covering the LLO Fall 2103 vent.
V13 – includes addition of 1" optic and 4" wafer removal and re-arrangements of particle count sections
V14 – now has several important sections on contamination, an overall summary checklist as well as updated information on first contact wrt optics, not to mention a new section on grounding and shielding and reference to the new Particle Cleanliness Validation System aka PET system.

2 Scope

The scope of this document is to summarize the general steps associated with entering HAM and BSC chambers, cleaning in-chamber items (as required) and then exiting the chambers. In general, these steps should be followed for all incursions subsequent to initial installation e.g. commissioning, final alignment or venting for scheduled maintenance.

3 Preparing for vent

For Procedure for Preparing the aLIGO Interferometer for Pumpdown or Vent, and Input Power Limits, refer to LIGO-M1300464-v1.

For procedures and steps associated with initial installation refer to aLIGO Chamber (top level) installation procedures which are grouped at LIGO-E1200023-x0.

4 Applicable Documents

- LIGO-E1201035: aLIGO Chamber Entry & Exit Guidelines (this document)
- LIGO-G1301249: Hanford and Livingston Contamination Control Update
- LIGO-T1300665: The LIGO Particle Cleanliness Validation System (PET)
- LIGO-E0900047: LIGO Contamination Control Plan
- LIGO-E960022: LIGO Clean and Bake Methods and Procedures
- LIGO-T1200508: Aligo, WITNESS SAMPLES ILLUMINATION & VIDEO VPORT SELECTION, HAM3
- LIGO-G1201149: LHAM2 and LHAM3 HXTS Prism Inspection
- LIGO-E1000079: Pour and Brush First Contact Procedure
- LIGO-E1300017: First Contact Spray Application Procedure
- LIGO-E1100439: General Optics Cleaning Procedure
- LIGO-T1200321: Guidelines on protecting the Cavity Optics in chamber wrt First Contact
- LIGO-T1200198: First Contact Application Layer Scenarios
- LIGO-M1000362: LLO HAM Access Door Removal Procedure
- LIGO-M1200375: LLO BSC Door Removal and Installation Procedure
- LIGO-M1100039: LHO HAM Door Removal and Installation Procedure
- LIGO-M1100068: LHO BSC Door Removal and Installation Procedure
- LIGO-E000065: initial LIGO Chamber Entry/Exit Checklist
- LIGO-E960022: LIGO Clean and Bake Methods and Procedures, LIGO-E960022.
- LIGO-M1300172: Approval Signatures for LIGO Chamber/Volume Closure
- LIGO-M1300464: Procedure for Preparing the aLIGO Interferometer for Pumpdown or Vent, and Input Power Limits

In addition to the documents listed above we also have a contamination control wiki, https://dcc.ligo.org/wiki/index.php/Engineering_for_LIGO/ContaminationControlWorkingGroup

GENERAL NOTE – FOR ALL LINKED DOCUMENTS, ALWAYS REFER TO LATEST VERSION ON THE DCC.

5 Checklist

Entrance Steps

1) ☒ Ensure area is clean prior to entering the chamber
2) ☒ Take Particle Counts before removing doors
3) ☒ Ensure Purge Air is present
4) ☐ Lock ISI
5) ☐ Remove Silicon Witness Wafers
6) ☐ Remove the 1" witness optics
7) ☒ Take Surface Particle Count Measurement using the swipe tool
8) ☒ Periodically take a Particle Count measurement
9) ☒ During any in chamber steps ensure team members are "Cleaning as you Go"

Exit steps

10) ☐ Check log
11) ☒ Lock Suspension Optics
12) ☒ Remove any items required to allow access to the optics
13) ☒ Apply First Contact to Suspended Optics, as required refer to section 1 above
14) ☒ Perform small Optic Inspection and preparation for Cleaning
15) ☒ Inspect View-ports
16) ☒ Clean as required via Lighting, Wiping and Vacuuming
17) ☒ Clean below the HAM-ISI table top and beyond
18) ☒ Clean small optics
19) ☒ Remove First Contact from suspended optics

Exit Chamber

20) ☒ Un-Lock Suspension Optic and Suspension check-list
21) ☒ Check ISI payload
22) ☒ Add (place) Silicon Witness Wafers
23) ☒ Add (place) the 1" witness optics
24) ☒ Final wipe down
25) ☒ Take Surface Particle Count Measurement using the swipe tool
26) ☒ Note on Particle Counter in chamber
27) ☒ If required check final location of wafer for Mobility experiment
28) ☒ Check wiring wrt beam path
29) ☒ Check ground and shielding of all cables
30) ☒ Remove tools and Take and final Pictures
31) ☒ Un-lock ISI
32) ☒ Get approval to close a vacuum chamber or volume

6 Warning

Any chamber entry is a serious threat to suspended optics and great care should be taken to preclude touching the optics table, anything on the optics table, and the seismic stacks. Qualified personnel should carefully engage earthquake stops on each optic and apply the lens caps prior to work being performed in the vicinity of the optics.
To provide reasonable assurance against the inadvertent introduction of contaminants, all personnel entering chambers should be familiar with

1) LIGO-E1201035-v13: aLIGO Chamber Entry & Exit Guidelines
2) LIGO-G1301249: Hanford and Livingston Contamination Control Update
3) The LIGO Observatory Contamination Control Plan, LIGO-E0900047,

It is important that proper support cleanrooms be in place adjacent to the chamber cleanroom, as described in LIGO-E0900047. It is also critical that proper cleanroom attire is worn in the chambers and in the surrounding cleanrooms. Proper cleanroom attire is "full bunny": gloves, mask, bouffant cap, hood, coveralls, assembly boots, and in-chamber boots. If you have questions about how to don garb, wear garb, perform with garb on or anything else contamination control related, please ask and you will be helped. Silence and prior assumptions only lead to trouble!

7 View-ports

In all of the following sections of this document reference is made to chamber entry/exit with respect to entry via doors. However, it is also extremely important to consider that for the addition / removal of a view-port that the same rules listed below for door access applies except for the need for a clean-room around the area in use. I.e. the steps that do apply are pre-install wipe down of area, smock, head covering and mask, check for purge air, no areas left exposed for long periods of time (greater than a couple of minutes). Refer to the following sections for a full list of steps and also to this note from John Worden.
If the chamber is closed up then a smock, head covering and a mask are sufficient. Under some conditions the purge air which exhausts through the uncovered conflat is boosted by the reservoir of air in the chamber - ie -a large volume of air at a slightly elevated pressure. This will supply a good airflow through the 10 inch hole for a minute or less and normally it is easy to lift a blank off of the port and place the viewport and gasket with 2 bolts in this time. [1]

[1] *I recommend that two people should perform this task to avoid long periods of exposure of the open port. John Worden 27th Nov 2012.*

8 Entrance Steps

8.1 Pre-Entry chamber

Prior to locating chamber and support cleanrooms, ensure that the entire area has been wiped down and that the chamber has been wiped down from dome to floor as outlined in LIGO-E0900047: LIGO Contamination Control Plan. In addition one should un-cable and move external tables prior to final placement of cleanrooms. Also refer to specific top level chamber procedure via LIGO-E1200023: aLIGO Chamber (Top Level) Installation Procedures as needed.

8.2 Particle Counts and Particle Counters (before removing doors)

Take an Initial Particle Count measurement outside chamber prior to removing door to confirm that adequate time has passed since pre-entry chamber cleaning and that chamber cleanroom fans are on and working. For specific door removal documents refer to section 1 of this document.

On each incursion back into the chamber (e.g. if you have paused for lunch and are returning then prior to removing the soft covers from the door (which you put back on when you broke for lunch), re-take a Particle Count measurement in the chamber cleanroom to confirm that cleanroom fans are still on and working.

Tests should be done on particle counters from time to time to see if they respond to dust generation e.g. tearing a piece of foil near particle counter, rubbing your hands together near particle counter. (i.e. don't always assume particle counter is working).

8.3 In-chamber particle counts

Once the chamber door is off and after purge air is on, take particle count in-chamber as a test of purge air. Refer to applicable documents in Section 4 for door removal procedures.

8.4 Purge Air

Prior to accessing a chamber (e.g. prior to removing a soft cover from a door), ensure that purge air is present. One way to check this is to observe whether or not the door cover is billowing out. It is helpful to be aware of other in-chamber work going on (i.e. are there other doors or domes off at the same time as you are working) since this impacts purge airflow. If you note the soft cover billowing is slight, possibly due to other in-chamber activity, then the time spent in-chamber should be limited. No entry if no positive pressure (from purged air) is present at soft cover. If there is no evidence of positive air pressure, then contact Brian O'Reilly (LLO) or Michael Landry (LHO) immediately.

8.5 ISI

Ensure status of ISI is known prior to starting work. In general ISI should be locked prior to starting work on the table. This is not exclusive and is left to on site teams to discuss.

8.6 UHV Foil

Wiping surfaces with acetone then isopropanol wins over covering in aluminum foil every-time due to concerns with particulates from foil. That does not mean foil cannot be used, but its use should be minimized as outlined in LIGO-E0900047.

8.7 Remove Silicon Witness Wafers

Silicon wafers should be removed from the chambers as soon as it is safe and convenient. Refer to section 11.3. for full details of guidelines on removing and storing.

8.8 Remove the 1" witness optics

The 1" should be removed from the chambers as soon as it is safe and convenient. Refer to section 11.4. for full details of guidelines on removing and storing.

8.9 PET System aka The Swipe Tool

At this point one should take Surface Particle Count Measurement using the swipe tool to track for various in-chamber activities. For full details of when to use, how to use etc ... refer to The LIGO Particle Cleanliness Validation System (PET),LIGO-T1300665.

8.10 Periodically take a Particle Count measurement

In addition one should always be periodically taking a Particle Count measurement to track for various in-chamber activities.

9 Cleaning as you Go

9.1 Tools for cleaning as you go

In addition to cleaning just before exiting a chamber, one should clean frequently during activities in the chamber i.e. as you assemble, install, align, commission, de-install for re-work / upgrade.

It is clear from tests that a large portion of the contamination comes from the assembly and installation processes performed by us the humans. Therefore to combat this "Cleaning as you go" has to become part of our in cleanroom and in chamber processes. "Cleaning as you go" should be encouraged and performed using the tools described below. When performing localized cleaning (e.g. a stage of a suspension structure), one should check the status of the optic and at least ensure that the optic is on its stops and the lens cap is in place prior to starting.

1) Custom Handheld Tiger vacuum cleaners, LIGO-D1201075 (vacuuming and air blow-off)
   - Refer to the instructions for handheld vacuum cleaner at LIGO-D1201075, and also to the detail of the custom attachments in the (main pdf, sheet 2 at the same link

2) Wet Wipes or Swabs (wetted with Isoproponal)
   - Vectra Alpha 10 wipes (not on optics, see section 9.2 below and in addition see sections 10.5 and 10.6 below)
   - Absorbond Series Swabs (Example: TX762)
   - Isoproponal 99.5% i.e. ACS Grade BDH1133-1LP from VWR
   - PLEASE NOTE - PRE-SATURATED WIPES INTENDED FOR GROSS CLEANING CANNOT BE USED IN CHAMBER or on any class A or class B i.e. the 50:50 ValuTek pre-soaked wipes.

3) Flashlight arrays, LIGO-D1300223
   - high intensity lights used at grazing incident on optical table and components on optics table (e.g. suspension towers, baffles, HAM AUX's) to assess and locate particulate contamination.

4) UV-A Inspection Blacklight,refer to SOP LIGO-M1300383
   - again used at grazing incident to illuminate dust
   - available on demand through Jodi and Betsy at LHO and Matt and Brian at LLO for use around optics refer to SOP at above link

For all items listed above

- See Jodi Fauver or Betsy Weaver at LHO or obtain from cleaning area (adjacent to corner station VEA)
- See Bryan Smith or Matt Heintze at LLO for sign-out of specific items e.g. vacuum cleaners or flashlight arrays

9.2 Frequency of cleaning-as-you-go

The following should be applied as guidelines to the frequency of cleaning-as-you-go. They should be followed in the order given i.e. vacuum before wiping.

During Assembly, have Vacuum, Wipes, Swabs, IPA and Flashlight array on hand

- At key steps in your assembly process
    - Inspect with visible light (flashlight array)
    - Vacuum and then wipe/swab or wipe only depending on access

At the end of assembly (ahead of storage / transport) have Vacuum, Wipes, Swabs, IPA, Flashlight array and UV-A light on hand

- At the end of your session
    - Inspect with UV light and visible light (flashlight array)
    - Vacuum and then wipe/swab or wipe only depending on access

Pre-Install (after removing from storage / transport) have Vacuum, Wipes, Swabs, IPA and Flashlight array on hand

- At the end of your session
    - Inspect with visible light (flashlight array)
    - Vacuum and then wipe/swab or wipe only depending on access – as required

Post Install again have Vacuum, Wipes, Swabs, IPA, Flashlight array and UV-A light on hand

- At the end of your session
    - Inspect with visible light (flashlight array) and if appropriate with UV-A light
    - REMEMBER CURRENT RESTRICTION ON USING UV-A LIGHT IN PROXIMITY OF OPTIC!
    - Vacuum and then wipe/swab or wipe only depending on access

For Pre-Chamber close-out i.e. exit steps, refer to section 10 of this document.

9.3 Steps for how to wipe

1. An excellent method for removing dust from surfaces is using a Vectra Alpha 10 wipe, (Contec PNHS99 wipe can be used if already on site but one should move to Vectra Alpha 10 as soon as currently stocks run out) or Absorbond Series Swabs (Example: TX762).
2. Wet the wipe or swab with Isoproponal and then apply to section that needs to be cleaned. This can be done on all surfaces except for optical surfaces, refer to item 6 below and also to sections 10.5 and 10.6 below.
3. Wipe from top to bottom and in linear, overlapping strokes. (Circular wiping re-contaminates the area just cleaned and is unacceptable.)
4. Refold wiper to expose fresh wipe surface for each run (Otherwise, the wipe re-contaminates the area just cleaned and is unacceptable.) or replace wipe as needed.
5. The wipes, swabs and Isoproponal are all already on site and in use by you all, refer to LIGO-E1300399 and LIGO-E0900047.
6. For full details on how to clean optical faces refer to section below. Wiping the optic barrels with isopropanol/cleanroom wipes [Berkshire LensX 90 or Vectra Alpha 10] to remove dust is acceptable (wet only)
7. **It should be noted that it is important to first check that there is no First Contact from overspray or other on the barrel before wiping it with wipe and isopropanol. If there is any First Contact residue on the barrel, first wipe with acetone and a (pre-folded) Berkshire (LensX 90) wipe to remove.**
8. PLEASE NOTE - PRE-SATURATED WIPES INTENDED FOR GROSS CLEANING CANNOT BE USED TO CLEAN YOUR GLOVES i.e. the 50:50 ValuTek pre-soaked wipes.

10 Exit steps associated with the optics

The following steps are listed in the order that they should be carried out.

10.1 Planning before or after cleaning

If possible, ALL in-chamber work should be completed prior to applying the cleaning steps outlined below. However, it is understood that there are steps that have to be done once First Contact is removed. Installers / commissioners should consider whether or not all work performed post-cleaning is essential and whether the work could be done pre-cleaning.

10.2 Check log

Check log of corrective tasks to confirm that all tasks appropriate for this chamber entry have been completed. Multiple incursions for individual items will not be permitted.

- Where can one find the log of corrective tasks? Add link??

10.3 Lock Suspension Optics

Lock the suspension optics as per LIGO-T1100406. For the HAM suspensions, specifically lock 4 or 8 stops on the intermediate mass to protect the magnets and all 8 stops on the optic face, to protect the optic.

10.4 Accessing the optics

Please note that it might be necessary to remove items from the optics table in order to gain access to clean the optics on the table, e.g. with First Contact. This should be discussed, and not just rejected early on as "impossible".
One should mark positions then move balance masses, baffles, dog clamps and cables as required (roughly one set per optic). Using some of the spare SUS/IO dog clamps, flipped them upside down, you can then push them up against the thing you want to mark the position of using an edge or a point and then tighten the dog clamp in place and remove the item in question.

10.5 Applying First Contact to Suspended Optics

The following section summarizes all of the first key contact documents associated with applying and removing first contact.

1. Existing optics on site will be delivered to the sites with first contact on their faces. Instead of peeling and re-sticking the same fc layer, one should wait as long as possible before peeling a layer off, then leave it off until it must be re-applied. This applies to both HR and AR surfaces.
2. Removing (and applying) the Alignment layer: See Section 5.3 of E1300017 for how to thicken up the alignment layer prior to removal of first contact. In general alignment layers should not be re-applied when cleaning an optic on site. However, for reference the application process is outlined in Section 5 of E1300017.
3. In general refer to LIGO-T1200321, for guidance on the re-application of first contact prior to the closing of chamber doors. However, as stated above, the first contact should not be applied to suspended optics in chamber until right before the start of the Science run, with the exception of the HR surfaces of MC1, MC2, MC3, and PRM. These surfaces cannot have any dust on them, as they will be subjected to high power alignment/testing before the science run. (The reference for this exception is LIGO-E1300142-x0.)
4. The in chamber spray cleaning procedure is detailed in E1300017.
5. For details on First Contact Brush and Pour Application and Removal Procedure refer to, LIGO-E1000079.
6. For the General Optics Cleaning Procedure, the one with the flow-chart, refer to LIGO-E1100439.
7. For the key information on when one should brush, spray, blow or wipe all key optic surfaces, refer to LIGO-T1200198: First Contact Application Layer Scenarios

Prior to applying First Contact, it is preferable to visually inspect and photograph the optical surface, especially if there are unfamiliar contaminants. The inspection should be

performed using grazing incident high intensity light via the LED flashlight arrays, LIGO-D1300223.

Please note, while examining optic surface please also examine the prism / standoff bonds to see that no cracks have formed, refer to LIGO-G1201149: LHAM2 and LHAM3 HXTS Prism Inspection.

Once First Contact is applied, it should be left on as long as possible. First Contact will be removed once the next cleaning steps, described below in sections 10.6, 10.7, 10.8, 10.9 and 10.10, are performed. Details of how to remove the first contact are in section 10.11. The lens caps should already be in heavy use, but are particularly important from this stage on, as they are the last line of protection for the optical surfaces.

10.6 Small Optic Inspection and preparation for Cleaning

Small optics are defined as all optics used in chamber except for SUS optics (HSTS, HLTS, BS, ETM, and ITM), for example the HAM AUX's and IO Fixed 2" optics. Prior to applying a cleaning layer of First Contact onto the small optics, one needs to consider whether First Contact is required. This should be done by consulting the General Optics Cleaning Procedure, and if you are still unsure, discuss it with Install, COC, IO or optic's "owner" group.
See section 10.8 and 10.9 below for cleaning steps prior to exiting chamber. If First Contact is used here it should be left on and be removed later. Refer to Section 10.11.

10.7 Inspecting View-ports

Use grazing incident high intensity light on view-ports to inspect the surface. Both sites now have a selection of these flashlight arrays, LIGO-D1300223. If required, apply a brushed on cleaning layer of First Contact. Add a PEEK tab and then remove film while blowing with an ion gun. Specific ion gun reference documents are below:

1) LIGO-T1300687: Guidance on Top Gun Ionizing Air Gun System – from Gas to Gun
2) LIGO-D1300948: aLIGO, TOP GUN IONIZING AIR GUN SYSTEM LAYOUT

For information on specific view-ports per chamber, refer to the chamber installation procedures, which are grouped LIGO-E1200023: aLIGO Chamber (Top Level) Installation Procedures.

10.8 Lighting, Wiping and Vacuuming

Use a combination of the resources outlined in section 9.1 and 9.2 above to clean all of the items in the chamber from the top down, e.g. from the highest point on the suspension towers to the lowest (the top of the HAM ISI-table) and working from the middle of the table toward the perimeter.

In parallel to inspection with: -

1) Flashlight arrays, LIGO-D1300223
2) UV-A Inspection Blacklight, LIGO-M1300383 (and associated safety)

One should clean in the following order: -

1) Custom Handheld Tiger vacuum cleaners, LIGO-D1201075 (vacuuming and air blow-off)
2) Wet Wipes or Swabs (wetted with Isoproponal)
3) Ion gun blow or Tiger vacuum blow. This steps needs to be done in consideration of the other parts around at the time. It should only be performed if required and if safe to do so.
4) Specific ion gun reference documents are LIGO-T1300687: Guidance on Top Gun Ionizing Air Gun System – from Gas to Gun and LIGO-D1300948: aLIGO, TOP GUN IONIZING AIR GUN SYSTEM LAYOUT
5) In general both of these steps should be performed on all class A parts (except optics) prior to the inspection and cleaning of the optics and removal of first contact. These steps are covered in the sections below.

10.9 Cleaning below the HAM-ISI table top and beyond

Using a combination of the following resources, clean below the HAM-ISI table top and beyond.

- Class B vacuum cleaner (Chamber Cleaning HEPA vac is fine for this application) and
- Vectra Alpha 10 wipes

Specifically use the Class B vacuum cleaner to remove any particles that may be left on the chamber floor and lower portions of the spools/nozzles. Vacuum the lower portions of the spool expansion joint convolutions. Use isopropanol-wetted Alpha 10 wipes as needed to remove any particulate that the vacuum leaves behind.

10.10 Cleaning small optics

This section refers to e.g. IO fixed and HAM AUX optics: it should be considered for all optics used in chamber except for HSTS, HLTS, BS, ETM and ITM.

If a cleaning layer of First Contact has been applied to small optics, then it is essential to use the ION gun during removal of the First Contact layer. In addition, a PEEK tab should be applied to aid with peeling – ideally the PEEK tab application should be done at the time of applying the first contact cleaning layer but it can also be done now. Inspect optics post-peeling for First Contact streaks around the outer perimeter of where the film was. Remove any FC streaks with acetone and Berkshire (LensX 90) wipe.

If a cleaning layer of First Contact was not applied, blow off the optic with an ion gun. Any large chunks that are not blown off should be removed by lightly touching the surface with one of the Absorbond Series Swabs (Example: TX762) while blasting it with the ion gun.
For either case, the cleaning should be done starting with the highest items on the middle of the table, working down and out toward the perimeter.

10.11 Remove First Contact from suspended optics

This section applies to all suspended optics i.e. HSTS, HLTS, ETM, ITM and BS. Please note that examination of prism / standoff bonds to see that no cracks have formed is the first task with these optics.

Prior to removing the first contact, one should re-position baffles etc ... as much as is possible before going back to remove first contact. If possible the team should also add on one door - to minimize work post first contact removal. This last step should only be done if it is feasible e.g. it may not be possible for HAM2.

At this point the optics lens caps should also be removed. The next step is to remove any existing layers of First Contact from the suspended optics. The ion gun MUST BE used during removal to mitigate charging. Specific ion gun reference documents are

1) LIGO-T1300687: Guidance on Top Gun Ionizing Air Gun System – from Gas to Gun
2) LIGO-D1300948: aLIGO, TOP GUN IONIZING AIR GUN SYSTEM LAYOUT

Inspect optics post-peeling with flashlight array and dark background (if possible) for any remaining First Contact (or other). If any items (first contact or other) are left behind it is essential that one refer first to LIGO-T1200198: First Contact Application Layer Scenarios prior to attempting any contact with anything of the optical surface.

As a general rule place witnesses just after removal of the nearest first contact. Then remove as close to next opening as possible. Refer to sections 11.3 and 11.4.

11 Exiting Chamber

The following steps are generic with respect to exiting chamber. For steps associated with a particular chamber refer to the relevant installation document. The chamber installation procedures are grouped in LIGO-E1200023: aLIGO Chamber (Top Level) Installation Procedures

11.1 Un-Lock Suspension Optic and Suspension check-list

Un-Lock the suspension optics as per LIGO-T1100406. One suspension should be able to be unlocked in 10 to 15 minutes e.g. in HAM2 with 2x people this should all be done in 1 hour.
One should confirm that suspension controller is working properly and examine OSEM alignment and adjust if / as necessary. In particular - apply pitch & yaw alignment offsets at

90% of full range. Visually back of EQ stops until minimal air gap, then verify no rubbing with single degree of freedom transfer function. This procedure requires one person garbed-up in-chamber backing off EQ stops, and one person chamber-side on a workstation. Such an operation would be sequential and cannot easily be parallelized, without more expert manpower and workstations. The overall back on forth on steps should only take e.g. 1 h 30 minutes for HAM2.

11.2 Seismic Check-list

If any payload has been added/removed/shifted, check optics table balance prior to exiting. Full details of ISI work is outlined in section 10.10 below.

11.3 Add (place) Silicon Witness Wafers

Silicon wafers should be added to the chambers. One set of two 4" Silicon witness samples should be placed per table on or adjacent to the beam centerline (looking from above).

- For the HAM chambers these should be placed one horizontally and one vertically on the HAM-ISI table. The vertical wafers should utilize the vertical wafer holders, as per T1300014. If available these wafer holders should also be used for the horizontal wafers. However, if not available it is okay to place the wafer horizontally directly on the table.
- For the BSC chambers these should be placed one horizontally on the BSC flooring and one vertically either (preferably) on a ITM / ETM and BS suspension or on the BSC flooring. This will depend on availability of vertical wafer holders and access to the relevant suspension.

Refer to LIGO-T1300014: Aligo, BSC Flooring + HAM ISI, Witness Sample Placement Guidelines for placement guidelines.

11.4 Add (place) the 1" witness optics

1" optics should also be added to the chambers. One set of two 1" optic witness samples should be placed per chamber as close to the beam centerline (looking from above) as possible. The optics should be place HR side up or HR side facing in the same direction as the HR surface of the closest optic.

- For the HAM chambers these should be placed one horizontally and one vertically. The optics should utilize the optic holders, as per T1300014.
    - The vertical one should be attached to the leg of a suspension structure, as per T1300014 with the optic holder. If the optic holder is not available the optic should instead be placed vertically on the HAM-ISI table with a pair of PEEK cable clamps.
    - The horizontal one should be on the HAM-ISI table. If available the optic holders should also be used for the horizontal optics. However, if not available it is okay to place the optic horizontally directly on the table.

- For the BSC chambers these should be placed one horizontally on the BSC flooring and one vertically either on a ITM / ETM and BS suspension (preferable option is on a suspension) or on the BSC flooring (back-up option. This will depend on availability of optic holders and access to the relevant suspension.

Refer to LIGO-T1300014: Aligo, BSC Flooring + HAM ISI, Witness Sample Placement Guidelines for placement guidelines.

The 1" optics should have an arrow pointing to the HR side, a unique serial number and should arrive clean with First Contact (and PEEK tabs) on both faces. Remove First Contact (no ion gun required) from both faces and lay on table HR side facing up. Note location of particular optic by serial number. These 1" HR optics are for absorption post-analysis only.

11.5 Final wipe down

Apply final wipe down using isopropanol-wetted Alpha 10 wipes to areas recently used / accessed (except of course on the optics.) At this point and one could do a final optic inspection. If there is items present on the face (and in the beam path) then one should blow off the optic with the ion gun.

11.1 PET System aka The Swipe Tool

At this point one should also take Surface Particle Count measurements using the swipe tool to track for various in-chamber activities. For full details of when to use, how to use etc ... refer to The LIGO Particle Cleanliness Validation System (PET), LIGO-T1300665.

11.2 Note on Particle Counter in chamber

As mentioned earlier, on each incursion back into the chamber (e.g. if you have paused for lunch and are returning then prior to removing the soft covers from the door which you put back on when you broke for lunch), re-take a particle count measurement in the cleanroom (outside the chamber) to confirm that cleanroom fans are still on and working. Tests should be done on particle counters from time to time to see if they respond to dust generation e.g. tearing a piece of foil near particle counter, rubbing your hands together near particle counter to demonstrate that particle counter is still working.

11.3 Camera and illuminator

If applicable, prior to closing, fix / adjust and align camera and illumination at viewports and ensure silicon wafers can be seen by camera.

11.4 Wiring wrt beam path

Confirm all wiring appears properly secured and is free of the beam path.

11.5 Ground and Shielding at LIGO

In LIGO-T1200131-v2 users will find a one page cartoon showing the right way and wrong way of grounding and shielding. This document is written to aid installation crews in understanding how to check wiring. This should be done prior to the chamber closing.

11.6 Removing tools and Taking Picture

Confirm all fixtures, tools, foil, C-3, lens caps, temporarily placed beam-blocks etc ... have been removed.

Take pictures of (at least) the suspension towers (both horizontal and vertical) surfaces and pictures of the HR optic surfaces (at least one per chamber.)

11.7 Un-lock ISI

Un-lock ISI. This should only take 5 to 10 minutes. No transfer functions should be taken at this point. The assumption is that the ISI will be good i.e. it will be in the same state it was before the above SUS INS work was carried out. This should be immediately followed by the addition of the doors (30 minutes to 60 minutes.)

12 Approval to close a vacuum chamber or volume

This step must be last in this list of exit guidelines, i.e. any additional edits to this document should occur above and thus prior to the approval process.

In order to restore doors, spools pieces etc. and thus seal the vacuum envelope for pumpdown, a series of subsystem approvals are required. In signing, each subsystem lead is acknowledging that the given team has completed their respective exit checklists and the volume has been scanned and secured for pumpdown.

Print and obtain signatures for the signoff page (lists available for both LLO and LHO): M1300172 - Approval Signatures for LIGO Chamber/Volume Closure. Signed approval lists are typically then retained in a binder in the site control room.

13 Pumpdown Procedure

For Procedure for Preparing the aLIGO Interferometer for Pumpdown or Vent, and Input Power Limits, refer to LIGO-M1300464-v1.

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-E1300597-V1 *Advanced LIGO* 12 JUL. 2013

BSC5-L1 & BSC10-H1, Requirements & Procedure, Cartridge Flight & Insertion into BSC Chambers, aLIGO

Sam Barnum, Calum Torrie, Eduardo Chavez

Distribution of this document:
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http://www.ligo.caltech.edu/

1. Reference Documents

D0900506, D0901154, aLIGO Systems, BSC5-L1 BSC10-H1 Top Level Chamber Assembly

2. Rules about constructing BSC Installation Cartridges:

1. Items hung from the BSC-ISI that break the following rules will need to be removed, Or the cartridge will needed to be maneuvered such that rules are maintained.
   a. Items must fit within support tubes. See Clearance Zone On P2
   b. Items must fit within all 4 Beams on the Test-Stand. Also see P2

2. MAX Cartridge weight without 3PT Lifter is 9,500 lbs. See detailed mass budget *E1000202*.

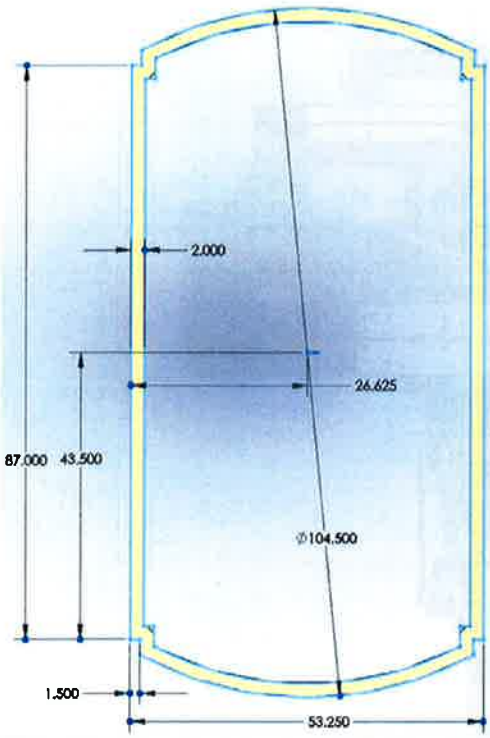
3. CG of the Cartridge in X and Y, must be in the adjustable range of the lifting bar, or masses will need to be added back on, to balance the cartridge (Keel Mass will be removed). Balance may be achieved with temp mass on sidewalls if needed. (In this case, go below 9,500 lbs/4310 kg, then add back on to achieve XY balance).

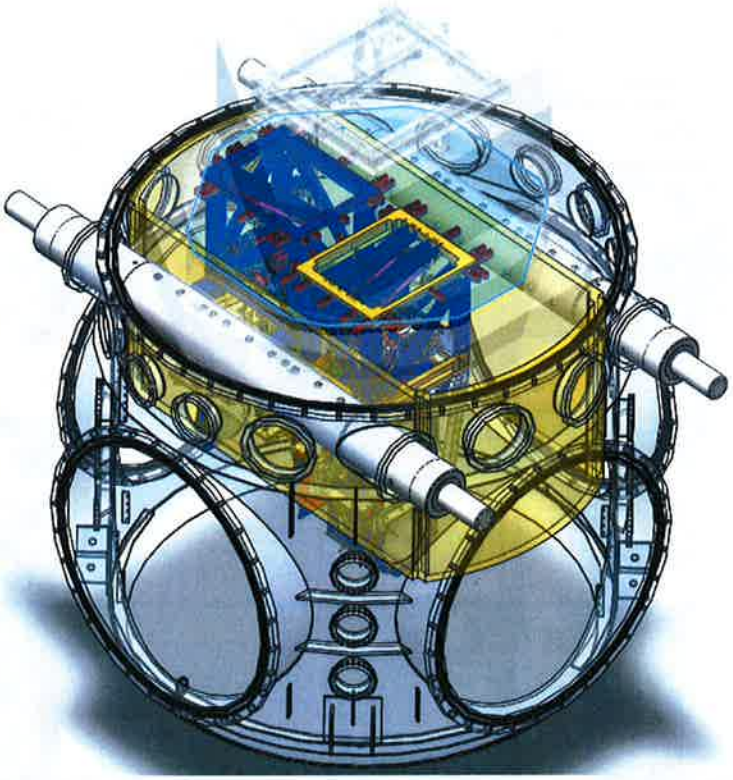
4. Listing of items on ISI, ITM, ETM, BS/FM, TMS, that will need to be locked down when the cartridge is moved. And Cartridge Install procedure.

Conventions:

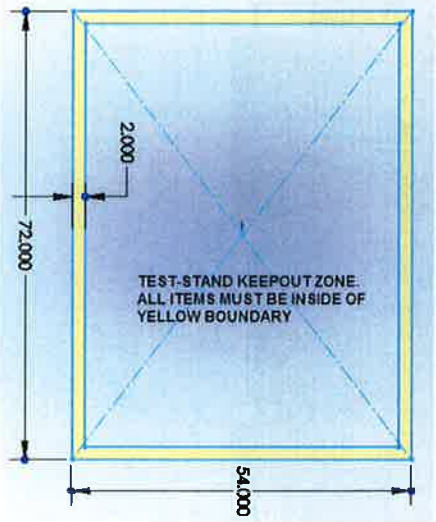
1. Views Labeled TOP are viewed from above looking down
2. Views Labeled Bottom are from bellow looking up.
3. Views Labeled Front are looking forwards from behind, so you see the back of the Cartridge.
4. Views Labeled Left are looking left from right side of the cartridge, so you see the right side.
5. All View Names correspond to the Views used in SolidWorks.
6. X-Y-Z Triad in each figure is relative to *G1000125*.
7. Cranes, and the direction of movement, are referred to by their compass orientation. At LHO: +X=North, +Y=West, LLO: +X=West, +Y=South.

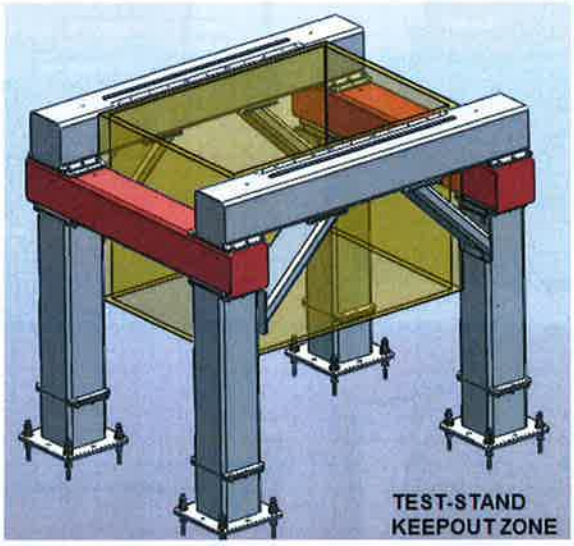
Clearance zone layout for BSC





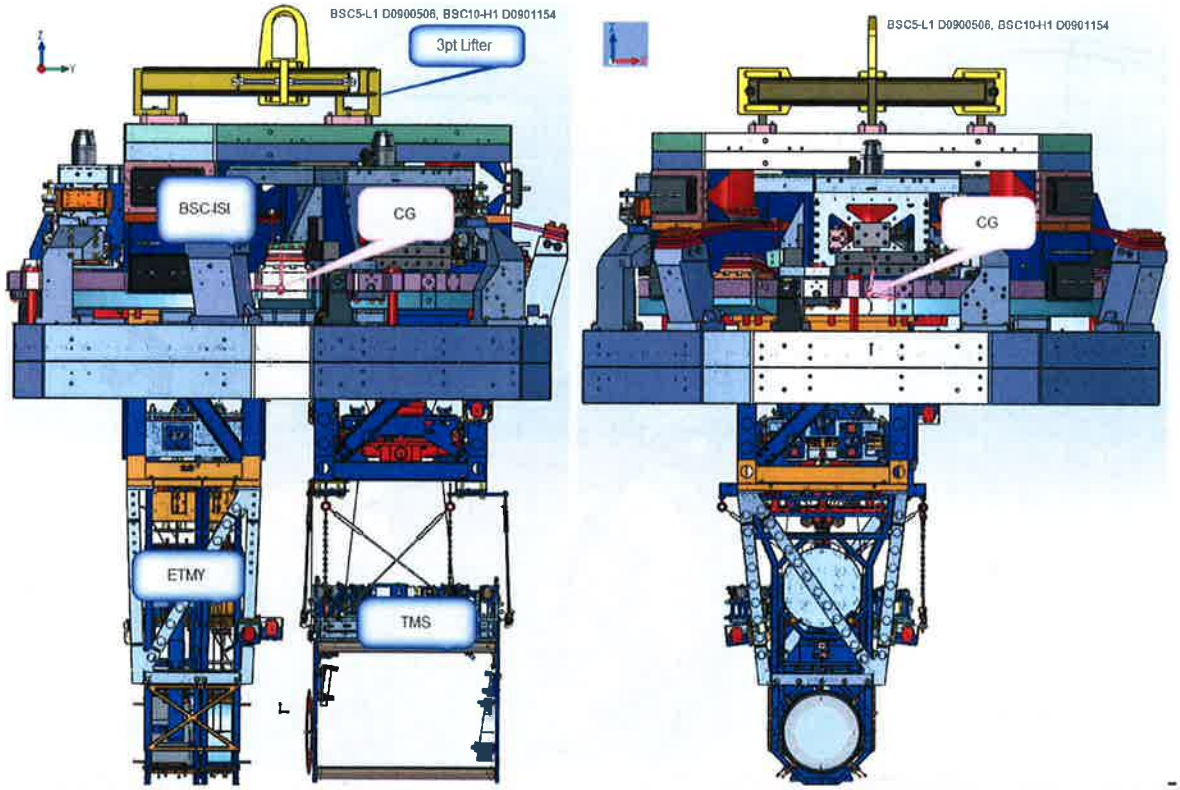
The Clearance Zone is a 2 inch wide area defined between the support tubes, and by the chamber shell. Any items on the cartridge that protrude partly into this zone should be considered for alteration or removal during install. **ANY ITEMS THAT PROTRUDE ALL THE WAY INTO, OR THRU, THE ZONE, MUST EITHER BE REMOVED OR ALTERED SO AS TO STAY CLEAR OF THE ZONE FOR INSTALL.**



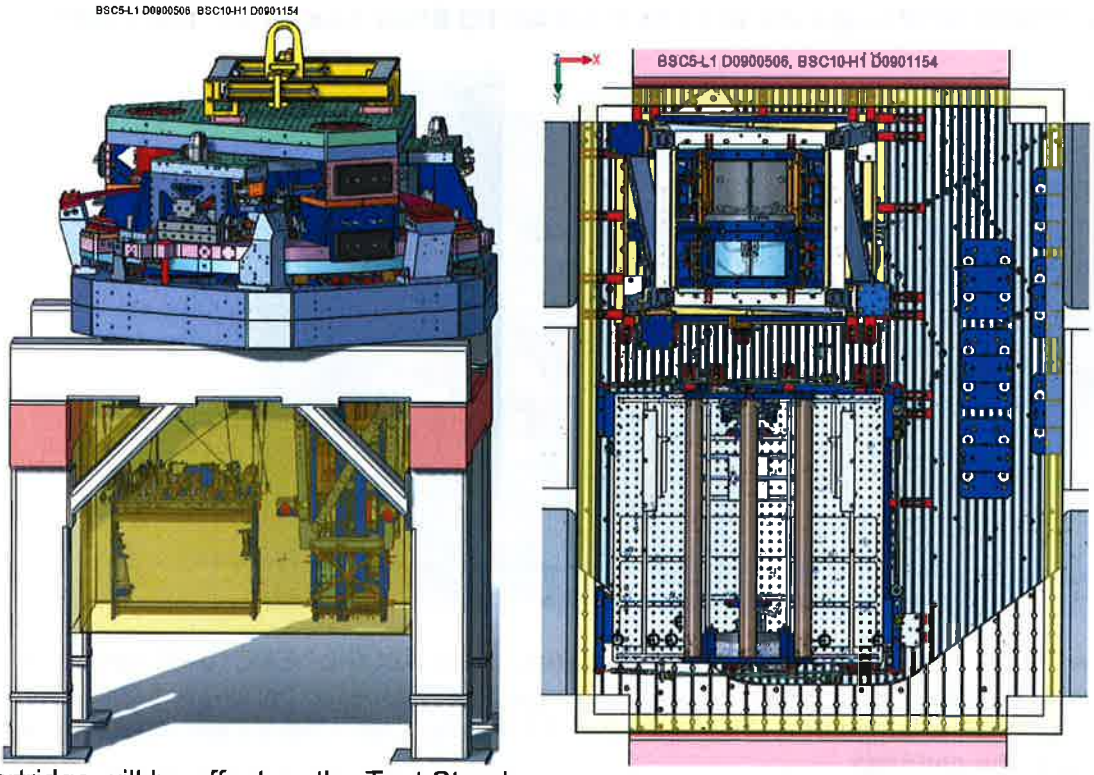


The following pages show the current expected configuration of the BSC5-L1-BSC10-H1 cartridge. Any issues with items violating the Clearance Zone are flagged, and possible cartridge maneuvering with the crane during install is suggested. The locations of the CGs is also shown with reference to the lifting bar on top of the cartridge.

Start BSC5-L1 D0900506, BSC10-H1 D0901154 Considerations

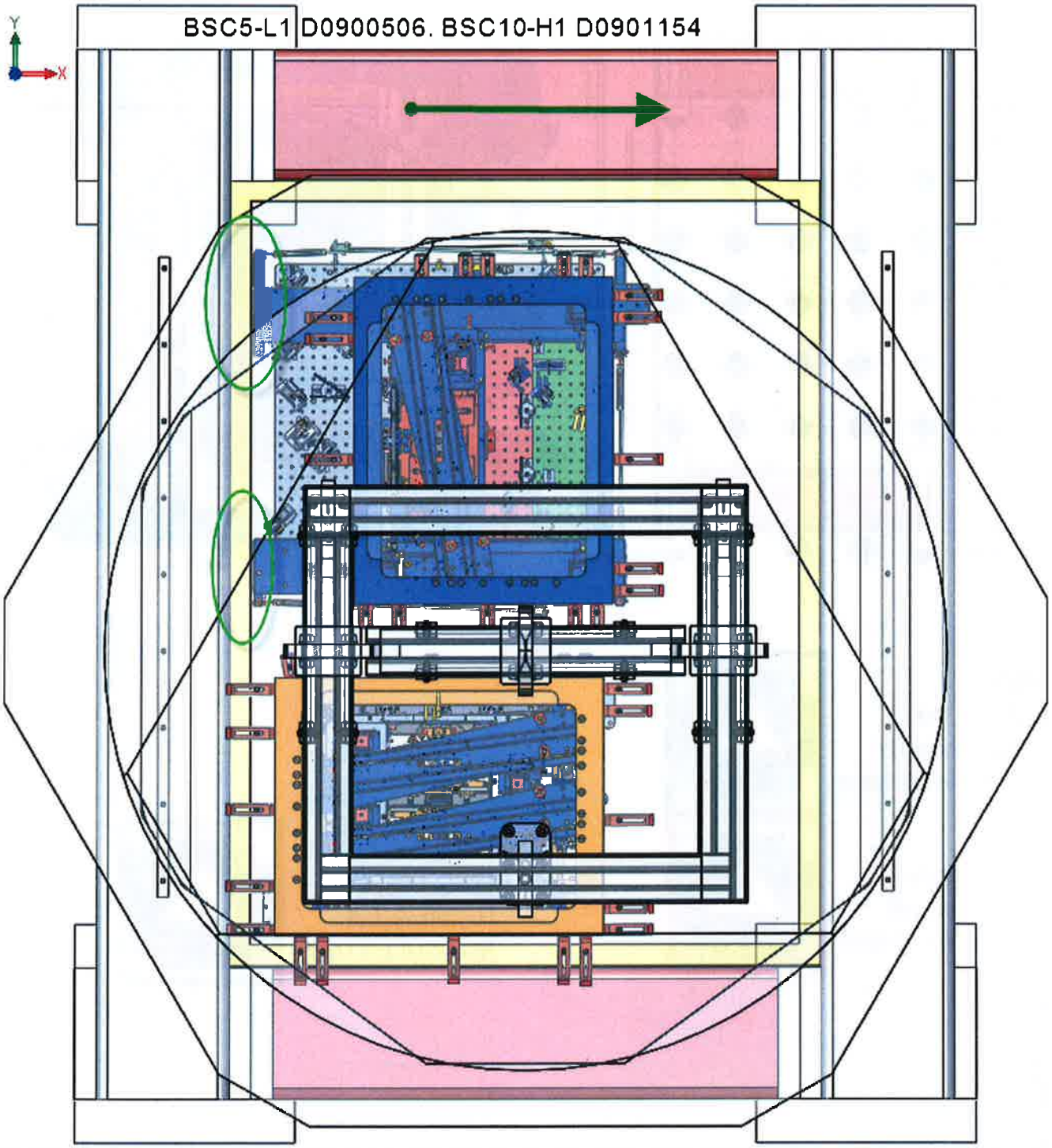


Cartridge installation of BSC. 3pt Lifting bar can cover the range of locations for the XY CG



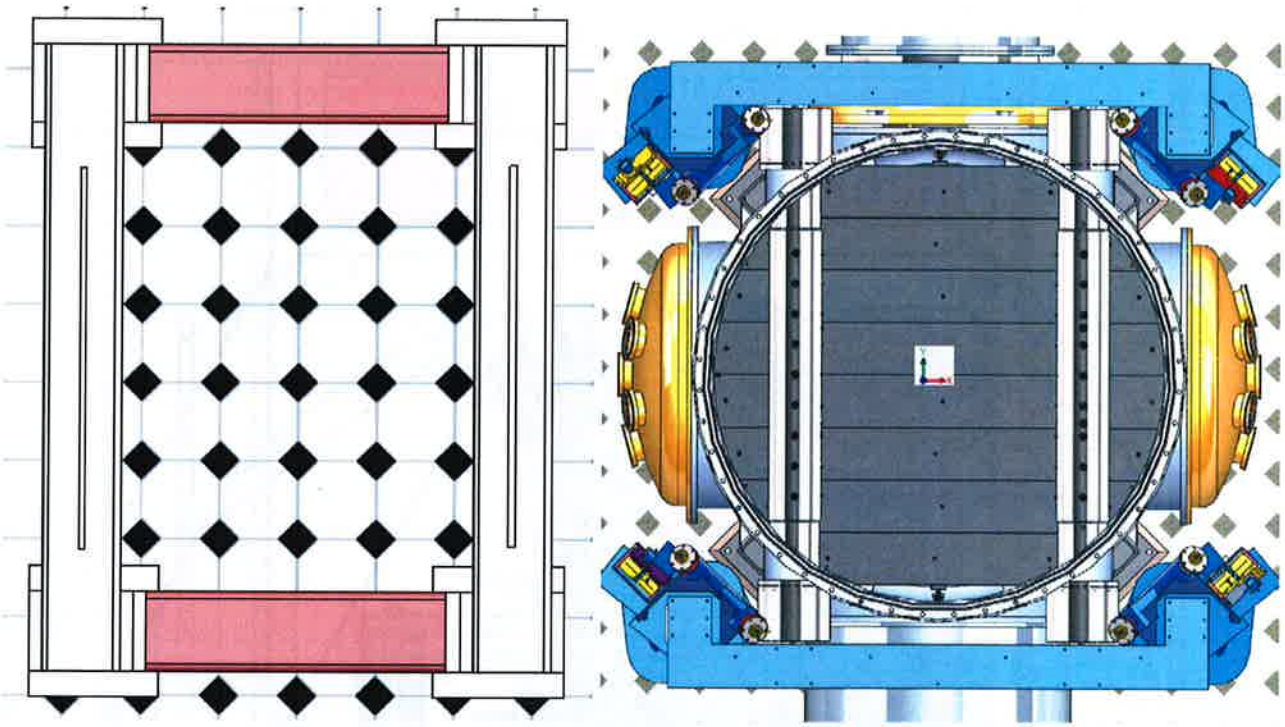
Cartridge will be offset on the Test Stand.

BSC5-L1 D0900506, BSC10-H1 D0901154, Crane moves need to clear the Test Stand Clearance Zone. (NONE)



Circles in green indicate any protrusion into the keep out zone. Any global XY moves relative to the Test-Stand will depend on the orientation of the Test-Stand.

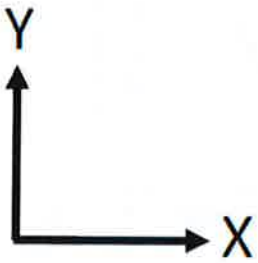
BSC5-L1 D0900506, BSC10-H1 D0901154, will not need to be rotated before insertion into the camber because the test stand is oriented parallel to the support tubes in the BSC chamber.



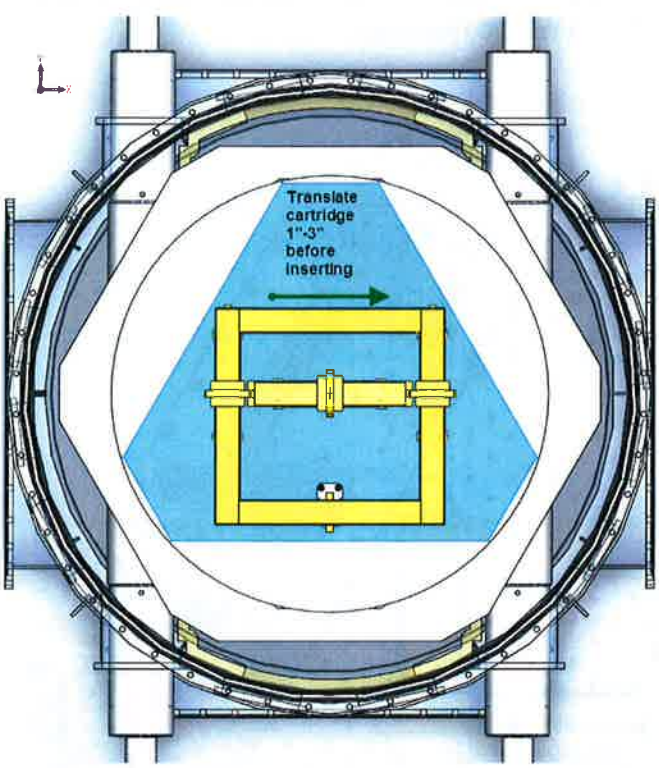
BSC6
H2:ISI-ETMY
h2isietmy.mdl
BSC-ISI/H2/ETMY/

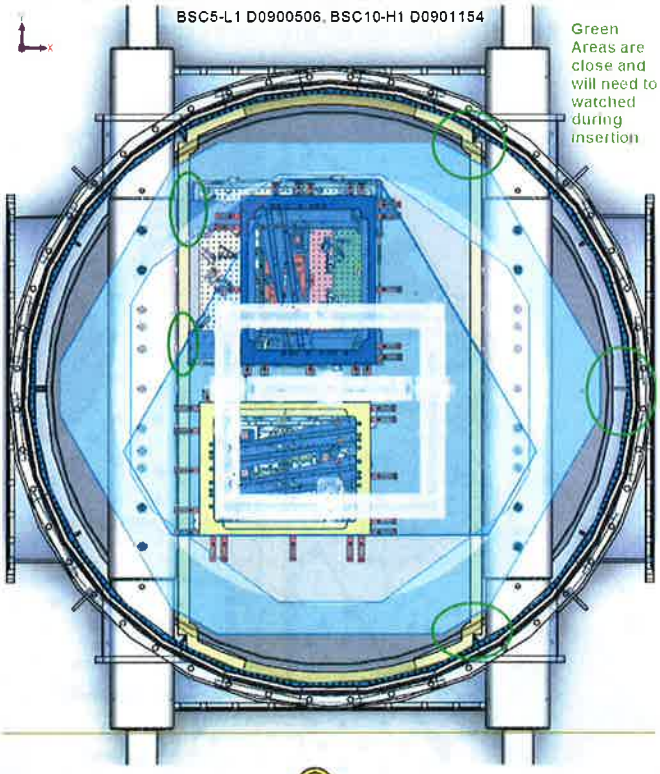
BSC10
H1:ISI-ETMY
h1isietmy.mdl
BSC-ISI/H1/ETMY/

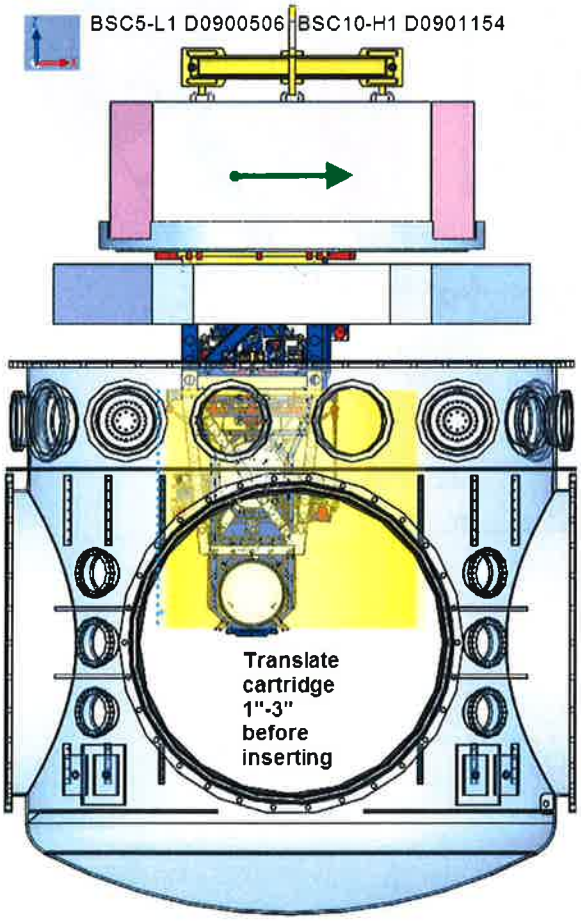
BSC5
L1:ISI-ETMY
l1isietmy.mdl
BSC-ISI/L1/ETMY/

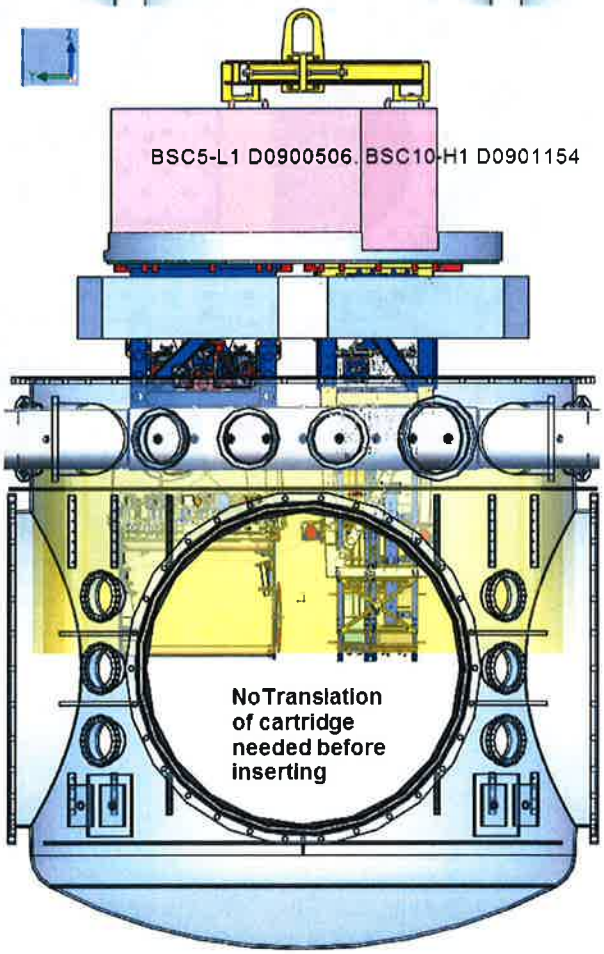


BSC5-L1 D0900506, BSC10-H1 D0901154, Crane moves to clear the Chamber Clearance Zone

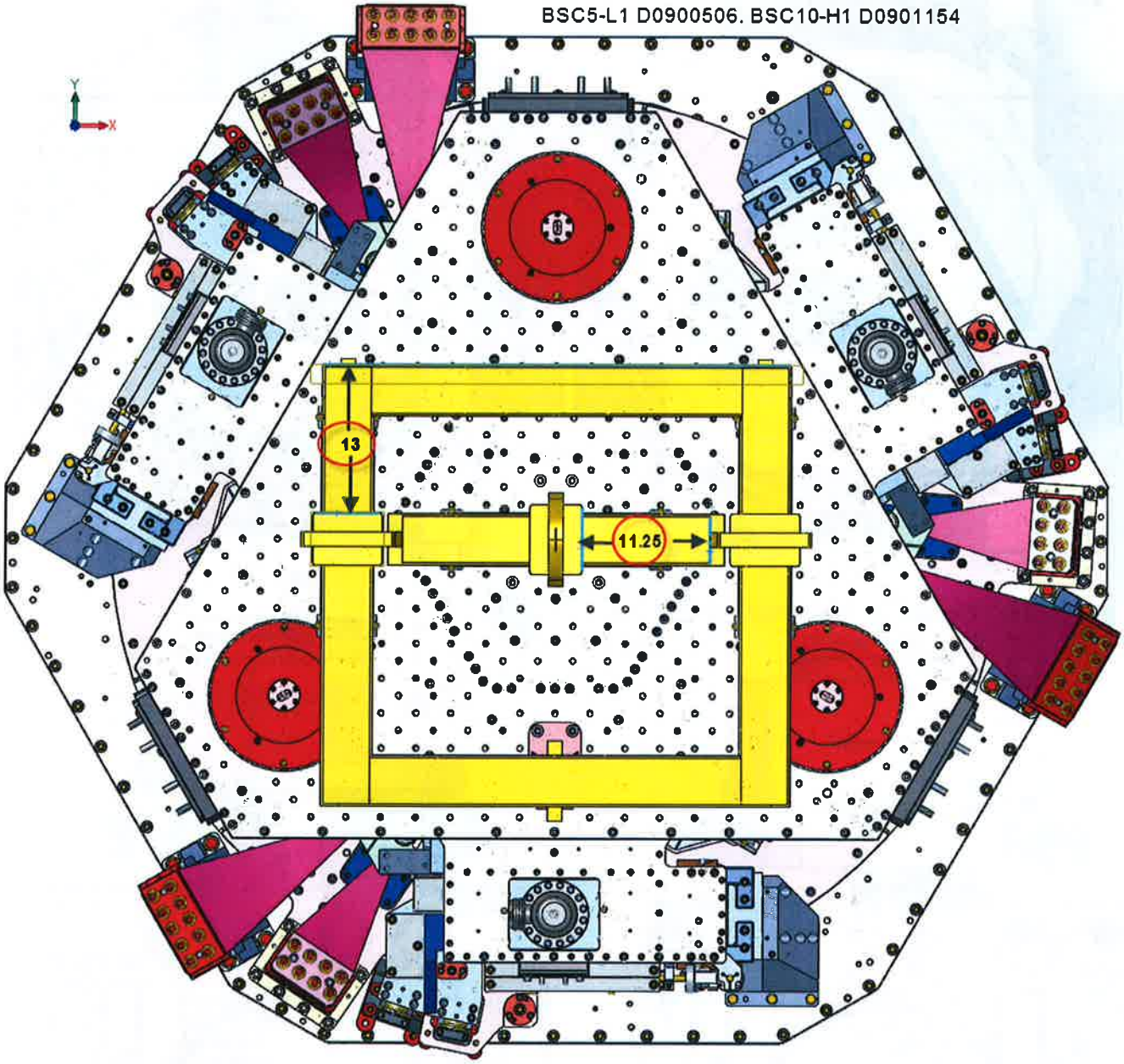


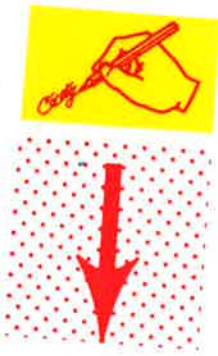






Locating the Bale pre-lift of the cartridge (Some adjustment will be needed)





Items that will need to be locked down when the cartridge is moved:

1. **BSC-ISI:** (see E1200344 sections 4.2)

completed, approved or checked by: Jeremy Birch *date:* 2/20/14 *comments (optional):*

ETMY

2. [redacted]: Final checks before moving (T1100406):

completed, approved or checked by: *date:* 2/20/14 *comments (optional):*

Cartridge: Preparation for, and installation into Chamber:

aLIGO BSC ISI/Quad Install Procedure: (see E1200344)

completed, approved or checked by: Jeremy Birch *date:* 2/20/14 *comments (optional):*