



LHAM6

AUTHOR(S)	DATE	Document Change Notice, Release or Approval
E.Sanchez, Calum Torrie	04 Nov 2014	see LIGO DCC record Status

Instructions on the use of this document:

- 1) *Keep this document, and its linked documents, available on a cleanroom compatible computer or Lenovo at all times during installation.*
- 2) *Use this document as a checklist. Check off each step as it is completed. There is a green box at the end of each subsection to record the name of the person(s) who completed and/or approved the work, date, and any comments or notes. In particular, note any discrepancies or deviations and augment with any missing information. If additional notes are too cumbersome to include within the body of this document, then electronically attach them to the completed procedure.  
ALL NOTES MUST BE RECORDED IN THE COMPLETED VERSION OF THIS DOCUMENT (NOT IN OTHER NOTEBOOKS OR FILES).*
- 3) *Once completed, file the document in the LIGO Document Control Center (DCC) as a new version of the procedure. Add a note that this is a completed procedure.*
- 4) *File any significant notes or data from the completed procedure in the electronic logbook (such as any deviations). As a minimum, note in the electronic logbook that the installation was completed in accordance with this procedure (cite document number and revision).*

**Contents**

1	APPLICABLE DOCUMENTS .....	2
2	SCOPE .....	4
2.1	Major Subsystem Assemblies .....	5
3	EQUIPMENT LIST .....	9
4	WARNING .....	10
5	PREREQUISITES.....	10
6	CHAMBER PREPARATION.....	11
7	HAM ISI ASSEMBLY .....	11
7.1	ISI Assembly Installation .....	11
7.2	SEI Phase II Testing .....	12
8	PAYLOAD INSTALLATION.....	12
8.1	Prerequisites .....	13
8.2	Weigh Major Payloads .....	13
8.3	Install Fiducials and HAM Arm.....	14
8.4	Install OMC.....	14
8.5	Install ISC components .....	15
8.6	Install Remaining Payload Components.....	16
8.7	ISI Testing and Table Re-balancing (as required).....	16
8.8	Align Optics .....	16
9	CLEANING .....	16
9.1	Optics and Viewports .....	16
9.2	Optical Table and Chamber.....	17
10	FINAL OPERATIONS .....	17



## LHAM6

### 1 APPLICABLE DOCUMENTS

All of the documents required for the installation of LHAM6 are listed below. Background and reference materials have been excluded to streamline the use of this installation procedure. Users may fill in the revision numbers of documents in the table.

Documents have been subdivided into the following categories:

- aLIGO Systems, HAM6-L1 Top Level Chamber Assembly
- HAM Systems Level Supplementary Chamber-Level Build Documents
- aLIGO Installation Procedures (from sub-systems)
- aLIGO Safety Procedures (associated with install)
- aLIGO Test Procedures (associated with install)
- aLIGO Alignment Procedures (associated with install)
- HAM STRUCTURE LIFT ASSEMBLY, aLIGO, SUS

**Table 1 LHAM6 Document List**

DOCUMENT	REV	TITLE
<b><u>D0901811</u></b>		<b>aLIGO Systems, HAM6-L1 Top Level Chamber Assembly</b>
<a href="#"><u>E1101160</u></a>		HAM6-L1 Top Level Chamber Assembly BOM
<a href="#"><u>D0901812</u></a>		AdvLIGO VE HAM6-L1, Vacuum Equipment Assembly
<a href="#"><u>D1100979</u></a>		AdvLIGO SEI HAM6-L1, XYZ Local CS for ISI Table
<a href="#"><u>D1000514</u></a>		HEPI ASSEMBLY, HAM, aLIGO SEI
<a href="#"><u>D1300077</u></a>		AdvLIGO SUS HAM6-L1, XYZ Local CS for Output Mode Cleaner Suspension
<a href="#"><u>D1000342</u></a>		AdvLIGO HAM6 ISC Block Diagram
<a href="#"><u>D1201021</u></a>		aLIGO HAM6-L1 ISI Table, Payload & Suspended Mass Assembly
<a href="#"><u>D1002890</u></a>		Flange Layout - L1 Horizontal Access Module 6 (HAM 6)
<a href="#"><u>D1300122</u></a>		CABLE HARNESS ROUTING CONFIGURATION, HAM 6
<b><u>F1100030</u></b>		<b>HAM Systems Level Supplementary Chamber-Level Build Documents</b>
<a href="#"><u>D1101296</u></a>		aLIGO, AOS, HAM Chamber, Optical Table, Hole Tabulation
<a href="#"><u>E1000403</u></a>		HAM Optics Table Heights for Advanced LIGO
<a href="#"><u>T1000228</u></a>		HAM SUSPENSION SPACER THICKNESSES
<a href="#"><u>E1100411</u></a>		Interface Control Document on HAM table dog clamps including detailed layout and hardware on HAM ISI tables
<a href="#"><u>T1100180</u></a>		HAM Optics Table Dog Clamp Chart H1, H2 & L1
<a href="#"><u>D1101775</u></a>		aLIGO, ELECTRICAL FEEDTHROUGH TYPES, TYPICAL SUBFLANGES, AND PORT CONFIGURATIONS



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY  
**ALIGO INSTALLATION PROCEDURE**

E1200099 -v4-  
Document No Rev.  
Sheet 3 of 18

## LHAM6

<a href="#">D0901811</a>		LHAM6 – Chamber Coordinates Definition
<a href="#">E1100742</a>		aLIGO Detailed Mass Properties-CG Report HAM Tables (LLO)
<a href="#">T070076</a>		Optical Layout for Advanced LIGO
<a href="#">E1200924</a>		<b>aLIGO HAM Install Procedures (associated with install)</b>
<a href="#">M1000362</a>		LLO HAM Access Door Removal Procedure
<a href="#">E040011</a>		Installation Specification - HEPI Assembly and Installation Procedures
<a href="#">E070271</a>		OMC SUS Installation Procedure
<a href="#">E080012</a>		HAM ISI Installation into HAM Chamber: Installation Procedure
<a href="#">E1100484</a>		Assembly & Installation Specification for the aLIGO, High Quality, Viewports
<a href="#">E1200445</a>		LLO Viewport Assembly Status
<a href="#">T1100174</a>		Weighing ALL assemblies that are mounted to a HAM isolation table, BSC isolation table or a BSC stage 0
<a href="#">E1200923</a>		<b>aLIGO HAM Safety Procedures (associated with install)</b>
<a href="#">E0900042</a>		aLIGO OMC Hazard Analysis
<a href="#">E1300537</a>		Addendum to E0900042 aLIGO OMC Hazard Analysis
<a href="#">E1100246</a>		Viewport Installation Hazard Analysis
<a href="#">T080145</a>		Viewport Safety Protocols
<a href="#">G1200070</a>		Ideal Order/Contents of aLIGO Triple SUS Testing/Commissioning
<a href="#">E1100994</a>		aLIGO HAM-ISI Testing Procedure, Phase II: Integration Process
<a href="#">T1400588</a>		HAM6 Alignment Procedure
<a href="#">E1300822</a>		ECR Fast Shutter and Beam Dump Reposition within HAM6
<a href="#">D1101674</a>		<b>aLIGO, SUS, BSC/HAM INSTALLATION TOOLING</b>
<a href="#">E1100520</a>		Key safety information associated with the FMP supplied Genie's, lifts and carts
<a href="#">D1100886</a>		MODIFIED GENIE LIFT FORKS
<a href="#">D1001664</a>		HAM STRUCTURE LIFT ASSEMBLY, aLIGO, SUS
<a href="#">E1100831</a>		HAM Installation Arm User Guide



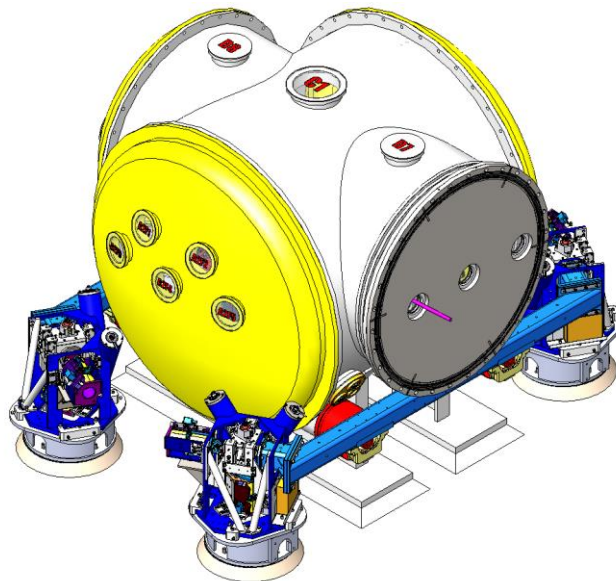
## LHAM6

[D1200482](#)

aLIGO Spreader Bar, HAM / BSC Repair Arm

### 2 SCOPE

This document covers the installation of interferometer components and assemblies into the Livingston HAM6 chamber, shown in Figure 1 and Figure 2.



**Figure 1. LHAM6 with vacuum equipment, HEPI, and ISI support frame**



## LHAM6

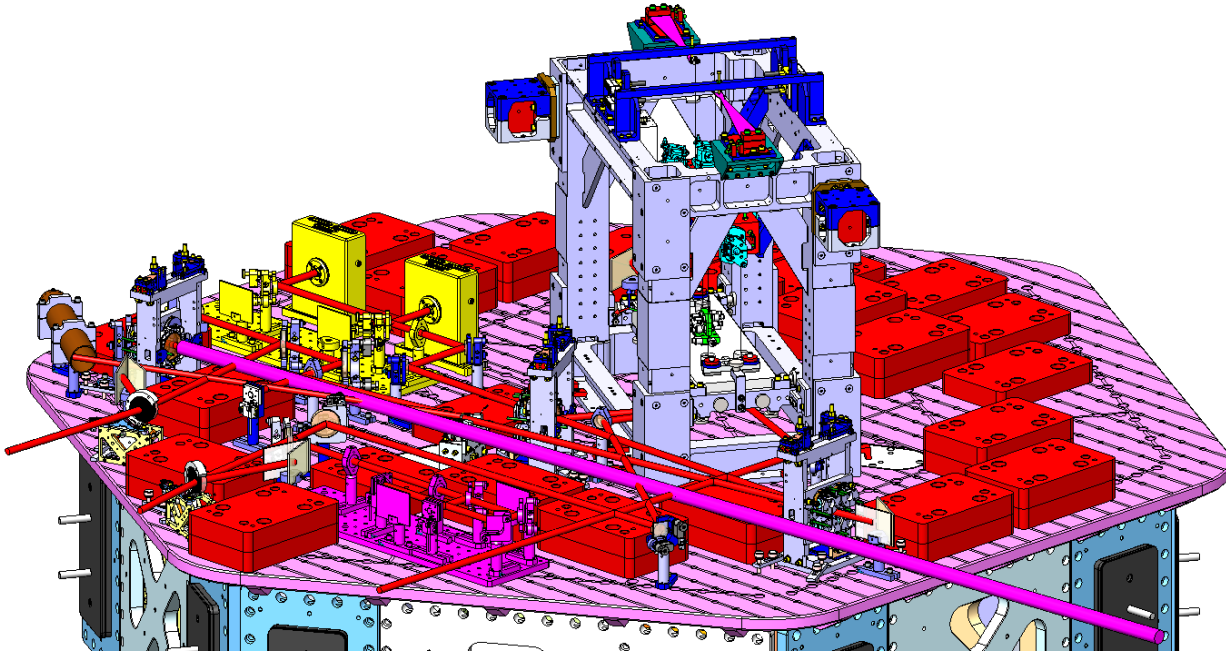


Figure 2. LHAM6 without vacuum equipment, HEPI, and ISI support frame

### 2.1 Major Subsystem Assemblies

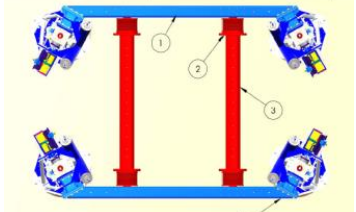
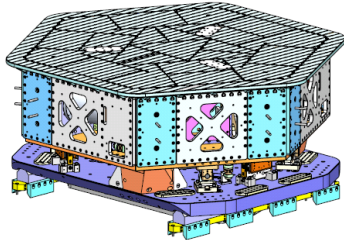
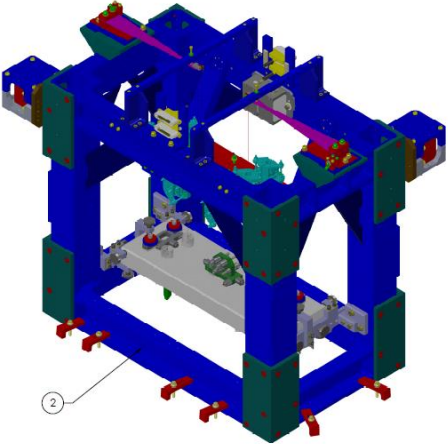
This installation includes the following major assemblies.

*Note: red-lines in subassembly section do not affect install.*



## LHAM6

**Table 2. LHAM6 Subsystem Assemblies**

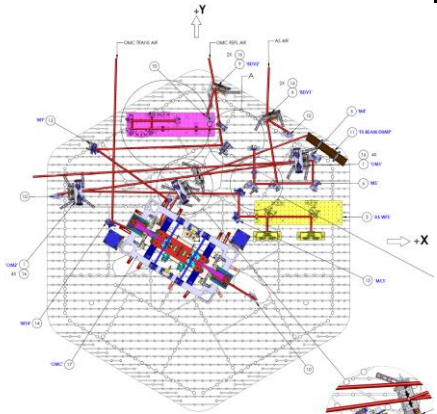
Sub-system	Assy Dwg	Subassembly	Image
INS	<a href="#">D1000514</a>	HEPI HAM Chamber Level Assembly	
SEI	<a href="#">D1100979</a>	LHAM6-ISI assembly including:	
SUS	<a href="#">D1300077</a>	OMC assembly including: OMC SUS, <a href="#">D0900295</a> Vibration Absorbers, <a href="#">D1002424</a> Dog Clamps, <a href="#">D1100640</a>	



**LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY**  
**ALIGO INSTALLATION PROCEDURE**

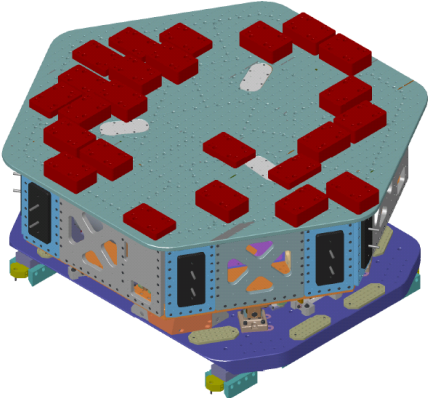
E1200099 -v4-  
 Document No Rev.  
 Sheet 7 of 18

## LHAM6

Sub-system	Assy Dwg	Subassembly	Image
ISC	<a href="#">D1000342</a>	ISC Block Diagram. Please see below for assembly sequence.	

Please Refer to [D1000342](#) for details.

INSTALLATION SEQUENCE	ITEM	PART NUMBER	DESCRIPTION	COMMENTS
1ST	5	D1002042	QPD SLED ASSEMBLY	
2ND	5.1	D1102002	ASC RFPD ENCLOSURE	'AS WFS'
3RD	1	D1001396	aLIGO Tip-Tilt Mirror	
4TH	18	D1003318	ISC Fast Shutter Assembly,	
5TH	9	D1100642	ISC Rotary Beam Div erter	
6TH	14	D1300242	1" Mirror Mnt, LEFT HAND, 4"	
7TH	15	D1300242	1" Mirror Mount,LH,4" Beam	
8TH	6	D1300230	2" Mirror Mount, LEFT HAND	
9TH	7	D1300230	2" Mirror Mount, LEFT HAND	
10TH	3	D1300241	1in Lens Mount for 4in	
11TH	4	D1002106-06	ASC-AS_C QPD for 4"	
12TH	3	D1300241	1in Lens Mount for 4in	BETWEEN OMC AND OM3
13TH	13	D1300242	1" Mirror Mnt, LEFT HAND, 4"	
14TH	2	D1002042	QPD SLED ASSEMBLY	
15TH	10	D1000971	TRANSMON BEAM DUMP -	
16TH	19	D1300231	2" Mirror Mount, RIGHT	
17TH	8	D1300231	2" Mirror Mount, RIGHT	
18TH	11	D1300548	Beam Dump, Fast Shutter,	

<b>SEI</b>	<a href="#">D1201021</a>	AdvLIGO Systems HAM6-L1 ISI Table, Balance Masses Assembly Including viton pads under some masses and screws for "picket fence" protection of some masses.	
------------	--------------------------	--	--





LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY  
**ALIGO INSTALLATION PROCEDURE**

E1200099 -v4-  
 Document No Rev.  
 Sheet 8 of 18

**LHAM6**

Sub-system	Assy Dwg	Subassembly	Image
SEI/SYS	<a href="#">D1101775</a> <a href="#">D1300122</a> <a href="#">D1002890</a>	Electrical Feedthrough Types Cable Routing Configuration Flange Layout	
AOS/SLC	<a href="#">T1100292</a> <a href="#">T1000746</a> <a href="#">E1200445</a>	Viewport Source List <a href="#">(T1000746</a> for pictures) LLO Viewport Assembly Status	
Rack and cable tray layout	<a href="#">D1003141</a>	Rack and Cable Tray Layout, LVEA, L1 <i>Group of these at Rack and Cable Tray Layouts (<a href="#">D1003142</a>)</i>	





## LHAM6

### 3 EQUIPMENT LIST

The referenced documents call out the equipment and parts/assemblies required to complete a given procedure. To assist with setting up for installation, a general list of required equipment is given below.

#### Transportation:

- BSC/HAM Installation Tooling ([D1101674](#)) – info on transporting the HLTS (page 4), HSTS (page 5), and OMC / OFI (page 6).
  - Genie SLA-10 Lift
  - Genie Adapter Plate [D1100515](#). The old iLIGO lift table was used at LLO.

#### Installation:

- HAM Installation Arm User Guide ([E1100831](#)) – main document to refer to for HAM install, including the most up to date information.
  - HAM Installation Arm Assembly ([D1101854](#)):
    - HAM Arm ([D1002052](#)) - Reference only, refer to E1100831.
    - HAM Lift Assembly ([D1001664](#))
      - OMC Lifting Bracket Clamp ([D1001793](#))
      - OMC Lifting Bracket ([D1001792](#))
    - HAM arm being assembled to HAM Lift ([D1101674](#), page 11), also shows surgeon's table option
    - HAM Flange ([D1001994](#))
  - Spreader Bar ([D1200482](#)) – used between arm and forklift to mount arm to flange.

#### Safety:

- HAM Installation Arm Hazard Analysis ([E1000252](#)).
- Key safety info associated with Genies ([E1100520](#)). (In process of migrating to D1101674 load limits for genie and height/load transfer restrictions).

**LHAM6****4 WARNING**

Every chamber entry should be treated as a serious threat to suspended optics. To provide reasonable assurance against the inadvertent introduction of contaminants into chamber:

1. All personnel entering chambers should be familiar with the LIGO Contamination Control Plan [E0900047](#), and LIGO Clean and Bake Methods and Procedures [E960022](#). Vacuum Compatibility and Qualifications was part of E960022, but will be a new document. Should that doc be listed here instead?
2. All components should be vacuumed or wiped down before installation in chamber to mitigate contamination created/accrued during assembly. Ex: Use vacuum to blow off dust generated from turning screws.
3. Wiping and vacuuming (sucking) should be used throughout the integration process.
4. Great care should be taken to preclude touching the optics table, anything on the optics table, and the seismic stacks.
5. When working near the optics, qualified personnel should carefully engage earthquake stops on each optic.
6. Lens caps should remain on the optics whenever possible.
7. Particle count measurements should be taken prior to each incursion into chamber. Record measurements in the green comment boxes in this document.

**5 PREREQUISITES**

- Ensure Support Tubes are in nominal position. See [T1100194](#), [T1100187](#) & [E1200625](#) leveling them to 0.4mrad. In LHAM2 install doc, this is at the end of Section 4.1. Extra notes on IAS group asking for tables to be aligned to 100 micro-radians in angle and 1.0mm in position.
- Install HEPI per [E040011](#) and [E1100094](#). *Leave HEPI actuators disconnected.*
- Vent the vertex vacuum volume and set the purge gas flowing per procedure [M1000360](#).
- Follow the Lockout-Tagout procedure [M990190](#).

Completed, approved, or checked by:

Date:

Comments (optional):



## LHAM6

### 6 CHAMBER PREPARATION

- Install the [output septum plate, D1002462](#).
- Install cable tray around the LHAM6 chamber per [D1003141](#).
- Install HAM Chamber Cleanrooms around the LHAM6 chamber and clean the chamber exterior and the region around the chamber per [E0900047](#) & [E1201035](#)
- Install dial indicators on the HAM support tube ends.
- Take an initial particle count measurement outside chamber door, and record in green comment box at the end of this section. See [T1400024](#)
- Remove chamber doors per procedure [M1000362](#).
- Take particle count in chamber to test purge air.
- Install the electrical feed-throughs listed in [D1002892](#) into LHAM6 per procedure [M990173](#).
- Install the **field cabling** from the electrical feed-through to the electronics racks. **Field-route cables as necessary.**

*Note: The field cabling can be installed later, but must be done after the cable trays are in place, yet before the ISI is installed. For LLO, the field cabling was required for chamber-side testing but it was not necessary to connect it to the chamber prior to ISI installation. LHO installed cable trays after the ISI as it was found that the cable trays could interfere with the SEI dial indicators. Use caution when working around the SEI dial indicators.*

- Install the viewports, [T1100292](#), per [E1100484](#) and Septum Viewport Installation, [E1200995](#), and per Conflat flange assembly procedure [M990173](#). Follow Viewport Safety Protocols, [T080145](#) and Viewport Installation Hazard Analysis, [E1100246](#)

*Note: Viewports can be installed later in the sequence.*

Completed, approved, or checked by:

Date:

Comments (optional):

### 7 HAM ISI ASSEMBLY

#### 7.1 ISI Assembly Installation

- Install ISI assembly into the vacuum chamber per [E080012](#).



## LHAM6

- Install ISI dummy mass per [E1000328](#).
- Float HEPI per [E040011](#).
- Level ISI table to  $\pm 0.1$  mrad and elevate to  $\pm 1$  mm per [E1000403](#) and [E1100784](#) (section 6.1.2).
- Align X, Y, and yaw (about Z) of ISI optical table and adjust with HEPI per [E1100784](#) (section 6.1.3).
- Install HEPI Actuators. If Dial Indicators indicate too much motion, check the table alignment.
- Complete Install all SEI in-vacuum cabling per [D1300122](#).

*Note: During install, check quality of cables and watch out for grounding as discussed in [T1200266](#) (this doc is specific to suspensions, but offers good guidance which can be applied to all cables).*

**WARNING:** Clamping cables too tightly can cause failure.

Completed, approved, or checked by:

Date:

Comments (optional):

### 7.2 SEI Phase II Testing

- Perform the phase II testing associated with HAM-ISI installation prior to attaching payload to the optics table, (i.e. perform Step 6 in [E1100994](#)).
- Lock HEPI per [E040011](#).
- Lock ISI
- Remove Dummy Payload Mass.

Completed, approved, or checked by:

Date:

Comments (optional):

## 8 PAYLOAD INSTALLATION

The LHAM6 assembly is depicted in Figure 3.

## LHAM6

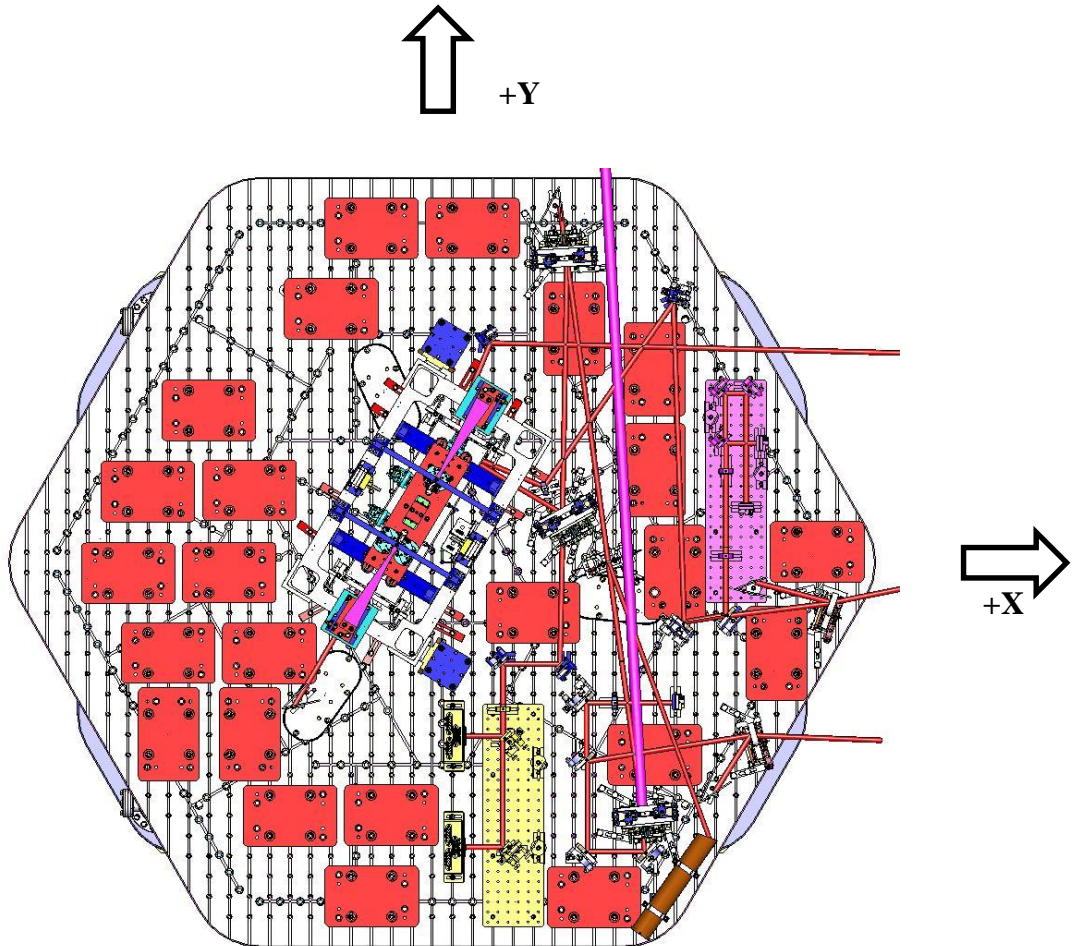


Figure 3. LHAM6 Assembly ([D0901812](#)). Refer to DCC for latest version.

### 8.1 Prerequisites

None.

### 8.2 Weigh Major Payloads

- Using [T1100174](#), weigh the following and record in Table 3.
  - Full OMC
  - ISC Components

*Note: If the measured weight is greater than the mass budget in [E1100742](#) contact Systems immediately.*



## LHAM6

Table 3 Payload Weight

Payload	Mass Budget (kg)	Measured Mass (kg)	Comments/caveats
ISC Components	24.67		
OMC	53.53		

Completed, approved, or checked by:

Date:

Comments (optional):

### 8.3 Install Fiducials and HAM Arm

- Install the Fiducial Kit, [D1300364](#), into the designated holes using [D1101296](#) as a guide.
- Install HAM installation arm on  $-X$ ,  $+Y$  chamber corner.

*Note: Refer to section 3 of this document for tooling documentation including user guide. HAM arm can and should also be used as support for smaller items. "Surgeon's table" is available with HAM Arm Vertical Lift, [D1001664](#) and [D1101674](#) (page 11).*

Completed, approved, or checked by:

Date:

Comments (optional):

### 8.4 Install OMC

- Install the pre-installation plate for OMC ([D1300120](#)) per [D1300077](#).
- Move OMC into position using the HAM installation arm.
- Clamp OMC to the table per [D1300077](#).
- Remove pre-installation plate for OMC.
- Install any outstanding Vibration Absorbers that have not already been installed on OMC as per [D1300077](#), and remove locker pins.
- Remove temporary cable ties, and install cable brackets onto the table per [D1300122](#). Coil excess quadrapuss cables and secure to table near base of suspension with Aluminum strips. Route SRS cables across table and down ISI to flange.

*Note: This step can be performed at a later time.*

- Check grounding and fix any if found.



## LHAM6

*Note: First check cabling on suspension structure. If none is found, next check across table (quadrupuss and SRS cables). Use Rich Abbot's testing setup per [T1200203](#) and [T1200131](#).*

- Remove optic shielding and suspend OMC (as required).
- Perform SUS Phase 3a Testing of OMC as per [G1200070](#) (as required).
- Perform B&K Hammer Testing of OMC per [T1000606](#) (as required).
- Lockdown OMC (as required).
- Install
- Optional (based on time constraints) – For the first instance of the addition of a major assembly to the optics table, the table will be re-balanced, floated, and SEI will take transfer function measurements in order to help identify (at a later time after post-processing) any troublesome modes.**

Completed, approved, or checked by:

Date:

Comments (optional):

### 8.5 Install ISC Components

- Install ISC components as per [D1000342](#).
  - Tip-Tilt Mirrors
  - QPD Sleds
  - Fast shutter
  - Fast shutter beam dump
  - ISC Rotary Beam Diverters
  - Fixed Optics
  - Transmon Beam Dump
  - Pico Motor

Completed, approved, or checked by:

Date:

Comments (optional):





## LHAM6

### 8.6 Install Remaining Payload Components

- Install balance masses per [D1201021](#). Add viton pads, per bug 577, including picket fence screws to protect balance masses.
- Re-balance optical table, [D1101781](#)

Completed, approved, or checked by:

Date:

Comments (optional):

### 8.7 ISI Testing and Table Re-balancing (as required)

- Unlock OMC.
- Perform HAM-ISI Phase II Testing as per [E1100994](#) if required.
- Re-do ISI balance masses (if required) as per [D1101781](#), and balance table.

Completed, approved, or checked by:

Date:

Comments (optional):

### 8.8 Align Optics

- If large errors require significant adjustment in the suspension, re-check TFs as per Phase 2b testing [G1200070](#).
- Remove any IAS fixturing.

Completed, approved, or checked by:

Date:

Comments (optional):

## 9 CLEANING

### 9.1 Optics and Viewports

- Lock suspended optic.
- Inspect suspended optic surfaces and re-clean as needed per [T1200321](#). First Contact procedure, if required is [E1300017](#)



## LHAM6

*Special Note: Per [T1200321](#) (pages 4, and 6-8). After the final clean and pull of the First Contact, if there is more work to be done before closing the chamber, then re-apply First Contact after:*

- Level 2 = 1 week in air
- Level 4 = 2-3 weeks in air

*These timeframes are flexible depending on the work that needs to be done. If heavy install work has to be carried out or planned work is expected to take more than 3 weeks, please contact COC (GariLynn Billingsley).*

*Optics might be harder (or impossible) to access for cleaning after installation in chamber. Talk to COC/SYS group.*

- Inspect viewports, and clean if necessary per [E1201035](#) (page 6).

Completed, approved, or checked by:

Date:

Comments (optional):

### 9.2 Optical Table and Chamber

- Inspect optical table and components for particulate contamination, and clean if required as per [E1201035](#).
- Inspect and clean below the ISI table top and beyond as per [E1201035](#).

Completed, approved, or checked by:

Date:

Comments (optional):

## 10 FINAL OPERATIONS

- Remove all optic covers.
- Remove any TFE SUS Earthquake stop fixturing.
- Remove locker pins from vibration absorbers if not already done.



## LHAM6

- Remove First Contact from suspended optic as per [T1200321](#) and [E1000079](#), if not already done.
  - Set all SUS Earthquake Stop gaps to 0.75mm gap (0.6 turns of screw).
  - Lock all SUS Earthquake Stop nuts.
  - Confirm the suspension controller is working properly, and examine OSEM alignment and adjust if necessary.
  - Check optic table balance.
  - Add (2) 2” Silicon witness wafers and (2) 1” witness optic to the table in the following configuration:
    - (2) 2” Silicon witness wafers lying flat
    - (1) 1” optic placed with HR side pointing up
    - (1) 1” optic placed on its side, as close to an optic as possible.
- Note: Refer to [T1300014](#) for more information.*
- Perform a final wipe down using isopropanol-wetted Alpha 10 wipes for areas recently used/accessed.
  - If mobility experiment are in progress then fix/adjust/align camera and illumination at viewports and ensure silicon wafers can be seen by camera per [E1201035](#).
  - Confirm all cabling is properly secured and free of the beam path.
  - Perform chamber inspection for tools, loose items, etc.
  - Take final configuration pictures and data (count PEEK components).
  - Close doors.
  - Perform SEI Phase III Testing and SUS Phase 3b Testing as per [G1200070](#).

Completed, approved, or checked by:

Date:

Comments (optional):