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1 Announcements & Revision History

1.1 Announcements

A determination of what key optical surfaces are present in particular chamber(s) associated with an upcoming vent should be carried out as part of the pre-vent planning by the detector lead engineer (or delegate) with reference to the “levels” in LIGO-T1200321: Guidelines on protecting the Cavity Optics in chamber. The prepared list of proposed optical surfaces to be First Contact (FC) cleaned along with a brief summary of the work being done (including estimated duration of work in each chamber) should be shared with GariLynn and Dennis or Calum for approval (changes). A counter plan / proposal will then become the working plan.

In addition, Detector Engineering lead or delegate should discuss with commissioners re: discharging the ETM / ERM gap, which will come up as part of the FC removal procedure.

All key optical surfaces should be inspected during chamber vents. An estimate of particles per square inch on these surfaces should be carried out with the Green LED flashlight (of the order 300 lumen) or the Green Lantern, LIGO-D1400060.

1.2 For each vent

PLEASE NOTE THE USED / MARKED UP VERSION OF THIS DOCUMENT SHOULD BE POSTED TO THE DCC.

1.3 Revision History

Refer to DCC field-card for revision history.

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. This key document includes: -

- The step to shut down or restrict power before vent!
- The step to restore power after pump down.

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

Remember to refer to list of open work items (gathered from log and bugzilla) while preparing for vent. Refer to Detector Engineering leads at both sites for reference.

Refer to local vacuum team for vacuum vent procedures (and subsequent pumpdown).

4 Applicable Documents

- LIGO-T1500101: ETM / ERM Gap discharge procedure
- 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: 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 & Removal 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 for Pumpdown or Vent, and Input Power Limits
- LIGO-T1400024: Airborne Particle Counter (Handheld)-General Instructions and LIGO Use

5 Checklist

Pre-Steps

1) ☐ Collect necessary work permits
2) ☐ For End Station volume vents: Lock and Tag out PCAL and ALS lasers, and any others post this writing – Transition to Laser Safe (see Ops for procedure)
3) ☐ For Corner Station volume vents: Lock and Tag out PSL Rotation Stage to <100mW, lock and tag out SQZ and TCS lasers, any others post this writing – Transition to Laser Safe (close light pipe, etc, see Ops procedure
4) ☐ Have steps in M1300464 (Procedure for Preparing for Pumpdown / Vent) been completed and logged on alog?
5) ☐ Refer to local vacuum team for vacuum vent procedures (and subsequent pumpdown).
6) ☐ Lock HEPI where vent tasks require
7) ☐ Opening door. Refer to local vacuum team document. – Install flange protectors.
8) ☐ Stage headsets, phones, CDS computers, WIFI turned on – Make sure up and working. Contact site lead if not available or obvious.

Entrance Steps

9) ☐ Ensure area is clean prior to entering the chamber
10) ☐ Take Particle Counts using handheld particle counter before removing doors & check against table in section 2 of T1400024
11) ☐ Repeat once doors are off in-chamber (section 8.2 and 8.3 of main doc)
12) ☐ Ensure Purge Air is present
13) ☐ Ground all four plates on Electric Field Meter if present, and if personnel are to work in chamber
14) ☐ Lock ISI if working in a HAM chamber. If required, lock ISI if working in a BSC chamber.
15) ☐ Remove Silicon Witness Wafers
16) ☐ Remove the 1" witness optics
17) ☐ Take Surface Particle Count Measurement using the swipe tool
18) ☐ Use the Tiger vacuum and vacuum your way into the chamber.
19) ☐ Apply the lens caps or metal optic cover prior to any work being performed near an optic. Wear ESD gloves.
20) ☐ Inspect the EFM Viton cord for splits and damage – call SYS if damage found
21) ☐ Take in-chamber Particle Count measurements often, using handheld particle counter (section 8.10)
22) ☐ During any in-chamber steps, ensure team members are “Cleaning as you Go“

Exit steps

23) ☐ Perform and correct any ground loop checks on in-chamber components (SUS, SEI, ISC).
    - Specifically, see LIGO-T2200048 for a write up of the ISC checks for HAM5, HAM6, and HAM7.
24) ☐ Check functionality of any shutters, beam diverters, pico motors, piezos, etc. HV may need to be turned on temporarily with a filed WP.
25) ☐ Lock suspended optics
26) ☐ Remove any items required to allow access to the optics. Install new 1" optic and 4" wafer to quad mounts.
27) ☐ Apply First Contact to Suspended Optics, as required refer to section 1 above and to LIGO-E1300142.
28) ☐ Perform small Optic Inspection and preparation for Cleaning
29) ☐ Inspect View-ports. (Pull First Contact from view-ports if not already done.)
30) ☐ Clean as required via Lighting, Wiping and Vacuuming
31) ☐ Clean below the HAM-ISI table top and beyond or BSC flooring.
32) ☐ Clean small optics
33) ☐ Remove First Contact from suspended optics (as required)
34) ☐ Make a measurement of charge on the key optical surfaces with the USSVM2 electrometer
35) ☐ Follow discharge steps as per LIGO-T1500101.

Exit Chamber

36) ☐ Check wiring with respect to beam path
37) ☐ Un-Lock Suspension Optic and Suspension check-list,
38) ☐ Perform one DOF TF to make sure no rubbing.
39) ☐ Check ISI payload
40) ☐ Add (place) Silicon Witness Wafers (priority and minimum should be to vertical)
41) ☐ Add (place) the 1" witness optics (priority and minimum should be to vertical)
42) ☐ Final look round (once a round) - using a flashlight.
43) ☐ Take Surface Particle Count Measurement using the swipe tool
44) ☐ Note on Particle Counter in chamber, refer to section 11.7
45) ☐ If required, check final location of wafer for Mobility experiment

46) ☐ Remove tools and Take and final Pictures
47) ☐ Un-lock ISI
48) ☐ Preform a final wipe down and wipe your way out of the chamber.
49) ☐ Unground all four sensing plates on Electric Field Meter if they were grounded upon entrance to chamber
50) ☐ Get approval to close a vacuum chamber or volume, refer to section 12 (of main doc)
51) ☐ Refer to M1300464 for further steps on preparation for pumpdown.
52) ☐ Refer to local vacuum team for vacuum pumpdown procedures

Post pumdown steps (prior to opening to the arms)

53) ☐ Deploy TMDS as required following measurements to measure charge (under vacuum)
54) ☐ Refer again to M1300464 for further steps on preparation for pumpdown e.g for steps to restore power.

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.
Apply the lens caps or metal optic covers 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) This document
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 are working around suspended optics, you should be wearing ESD scrubs and ESD gloves. 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 - i.e. -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].

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 Airborne Particle Count measurement using handheld particle counters (e.g. Metone 227B or similar) 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. Use the table in Section 2 of T1400024, Airborne Particle Counters (Handheld)-General Instructions and LIGO Use, for guidance on acceptable particle count limits. 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 airborne particle count in-chamber as a test of purge air, using handheld particle counters. Refer to applicable documents in Section 4 for door removal procedures. Refer to LIGO-T1400024: Particle Counters - Technical Note on How to use in the field for full details on using, documenting and values for particle counts and actions to take. If the chamber contains and Electric Field Meter (EFM), it is essential that the first person to enter the chamber ties the EMF sensing plates to ground per the following section.

8.4 Electric Field Meter Grounding

The Electric Field Meter (EFM) contains electronics that are particularly sensitive to static electricity. For this reason, the EFM sensing plates must be tied to ground during chamber access. The person performing this operation must wear ESD conductive gloves with physical contact to the skin of their hands. Upon approaching the EFM, first touch the body of the EFM

[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.*

to establish yourself at ground potential. While remaining in contact with the EFM, free the grounding wires provided on the bottom of the EFM, and attach one wire to each sensing plate using the screw at the 6-o'clock position of each sensing plate. Once all four grounding wires are in place, the EFM is far less likely to be damaged by inadvertent contact with workers in the chamber. Further details relating to the EFM are available at: E1800176, Electric Field Meter Install Procedure, and D1800175, Collection of Drawings Electric Field Meter

8.5 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 a Vacuum Lead person on site or Detector Engineering Lead person.

8.6 ISI

Ensure status of ISI is known prior to starting work. In general, the ISI should be locked prior to starting work on the table, especially if working on a HAM table. This is not exclusive and is left to on site teams to discuss e.g. if only working on floor of BSC chamber.

8.7 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.

8.8 Vacuum your way in (and Wipe your way out)

Using the custom handheld Tiger vacuum cleaner (see Section 9.1), iteratively vacuum your way into the chamber. Be sure to vacuum where you have stepped. If working with a partner in chamber, vacuum where he/she has stepped as well. This "vacuum your way in and wipe your way out" process has shown to be extremely effective in controlling contamination. Tools for this work are detailed in Section 9 of this document.

8.9 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 the full details of the guidelines on removing and storing.

8.10 Remove the 1" witness optics

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

8.11 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.

8.12 Periodically take in-chamber Particle Count measurements

In addition, one should always be periodically taking an in-chamber Airborne Particle Count measurement to track for various in-chamber activities, using the handheld particle counters. Refer to LIGO-T1400024: Particle Counters - Technical Note on How to use in the field for full details on using, documenting and particle count value and actions to take.

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 or pre-wetted Vectra alpha 10 wipes (not on optics, see section 9.2 below and in addition see sections 10.4 and 10.5 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, i.e. the 50:50 ValuTek pre-soaked wipes, CANNOT BE USED IN CHAMBER or on any class A or class B
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 assigned Contamination Lead at each site
   - for use around optics refer to SOP at above link

At both sites all of the items listed above are stored in the cleaning area (adjacent to corner station VEA). For questions contact the local Contamination Lead at each site. Note the UV-A lights are stored separately. Ask Detector Engineering Lead person if not sure or your assigned liaison if unsure who any of the people are.

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 10.4 and 10.5 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 Lock Suspension Optics

Lock the suspension optics. For quads follow LIGO-T1100406. For the beamsplitter follow E1000686, section 11. 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. These procedures should be carried out by or under the supervision of SUS personnel.

10.3 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.

10.4 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. Brushing can again be considered an optional procedure (as of 2018) for applying First Contact (FC) but should only be utilized following an inspection of the optical surface for debris, if unsure call GariLynn prior to proceeding. For details on First Contact Brush and Pour Application and Removal Procedure refer to, LIGO-E1000079.
2. In chamber FC spray cleaning procedure as detailed in E1300017 is still applicable (if preferred) and also in special cases e.g. cleaning up large debris on optic following fiber break.
3. For the General Optics Cleaning Procedure, the one with the flow-chart, refer to LIGO-E1100439.
4. For Guidelines on protecting the Cavity Optics in chamber e.g. hierarchy of which optical surfaces matter, refer to LIGO-T1200321.
5. For the information on when one should brush, spray, blow or wipe all key optic surfaces, refer to LIGO-T1200198: First Contact Application Layer Scenarios. (Only relevant when spraying with FC is preferred choice / being utilized in e.g. large debris scenarios).

With regard to pre-inspection refer to section 1.1 of this document i.e. the note on using the green lantern.

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 10.5, 10.6, 10.7, 10.8 and 10.9, are performed. Details of how to remove the first contact are in section 10.10. 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.

10.5 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 10.7 and 10.8 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 10.10.

10.6 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.

10.7 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.

10.8 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 vacuum 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.

10.9 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.

10.10 Remove First Contact from suspended optics

This section applies to all suspended optics i.e. HSTS, HLTS, ETM, ITM and BS. The main reference for this work is LIGO-E1300017: First Contact Spray Application & Removal Procedure

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 top gun system MUST BE used during removal to mitigate charging, refer to LIGO-T1300687: Guidance on Top Gun Ionizing Air Gun System – from Gas to Gun.

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 both LIGO-E1300017: First Contact Spray Application & Removal Procedure AND LIGO-T1200198: First Contact Application Layer Scenarios prior to attempting any contact with anything of the optical surface.

With regard to pre-inspection refer to section 1.1 of this document i.e. the note on using the green lantern.

As per LIGO-E1300017: First Contact Spray Application & Removal Procedure pay close attention to continuing with the top gun after the first contact is removed AND also remember to perform item #8 in the LIGO-T1500101: ETM / ERM Gap discharge procedure as per notes in E1300017.
As a general rule place witnesses just after removal of the nearest first contact or in the case of no first contact present place witness samples as close to closing doors as possible. Then remove as close to next opening as possible. Refer to sections 11.3 and 11.4.

10.11 Measuring Charge and Discharge Procedure

During chamber work e.g. ring heater, BRD's etc … and even if one has not first contact cleaned the key optical surfaces one should make a measurement of charge on the key optical surfaces with the USSVM2 electrometer, refer to LIGO-E1500457. For the ETM / ITM optics the Electrometer monitoring should be performed from the ERM / CP side. Following First Contact (FC) cleaning Electrometer monitoring should continue. 5 minutes after FC is complete (and checking electrometer is stable +/-0.2) one should then continue with additional discharge steps. Additional discharge steps should be the standard. Only if charge is between - 3V and +3V one should consider not deploying addition discharge steps, with approval from systems (Dennis or GariLynn). If charge is larger than these readings (and larger than any initial readings) move to deploying relevant discharge procedure based on optic. Note: - If similar to initial readings but (slightly) larger than +/-3V (and you are still unsure what to do) call systems (Dennis or GariLynn) for guidance.

- For ETM's in addition to the top gun we need to deploy the Flappy Panel Procedure, refer to LIGO-T1500101.
- For ITM's utilize top gun only on all optical surfaces, refer to relevant sections of LIGO-T1500101. *(Remember Flappy panel only for ETM's as ITM AR is an optical surface and ETM AR is not.)*

As per section 1.1 of this document the Detector Engineering lead or delegate should discuss with SYS/COC ahead of the vent what is meant by key optical surfaces i.e. make a list of what surface will be checked as part of the vent. In addition Detector Engineering lead or delegate should discuss with commissioners re: discharging the ETM / ERM gap.

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. For quads follow LIGO-T1100406, reversing the locking procedure. For the beamsplitter follow E1000686, section 11, reversing the locking procedure. For the HAM suspensions, unlock the 4 or 8 stops which were locked on the intermediate mass and all 8 stops on the optic face. These procedures should be carried out by or under the supervision of SUS personnel.
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 off EQ stops until minimal air gap**, then verify that nothing is rubbing with a 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. Default and minimum should be vertical placement.

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. Default and minimum should be vertical placement.

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 look round (once a round) - using flashlight and do a final wipe down where required

Apply final look round (once a round) - using flashlight and do a final wipe down where required 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 are large visible items present on the face (and in the beam path) then one should blow off the optic with the ion gun. The restrictions of the top gun are laid out in section 4.2 of LIGO-T1300687: Guidance on Top Gun Ionizing Air Gun System – from Gas to Gun

11.6 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.

11.7 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. Refer to LIGO-T1400024: Particle Counters - Technical Note on How to use in the field for full details on using, documenting etc …

11.8 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.

11.9 Wiring with respect to beam path

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

11.10 Ground and Shielding at LIGO

In LIGO-T1200131 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.

11.11 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.)

11.12 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.)

11.13 Wipe your way out of the chamber

Using the steps for how to wipe, Section 9.3, wipe from top to bottom and in linear, overlapping strokes with Vectra Alpha 10 wipes as you back out of the chamber. Be sure to specifically wipe the areas were you have walked. This “vacuum your way in and wipe your way out” process has shown to be extremely effective in controlling contamination.

11.14 Unground the Electric Field Meter

For those chambers containing and Electric Field Meter (EFM) the last step prior to exiting the chamber is to unground each of the four plates that form the sensing elements. Wearing ESD gloves (These gloves must make physical contact with the skin of the hands of the person performing this step. Multiple layers of ESD gloves are fine) first make physical contact with the EFM by touching the body of the cube. After touching the body of the cube, continue to maintain yourself at ground potential while removing the grounding straps from the sensing plates

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. Also refer to LLO HAM Access Door Removal Procedure, LIGO-M1000362.

13 Preparing for Pumpdown

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

14 PUMDOWN

Refer to local vacuum team for vacuum pumpdown procedures (and subsequent vents).

15 TMDS

The following are the Test Mass Discharge steps (TMDS) that must be followed after corner or end station pump-down and prior to opening to the arms. These steps should be discussed with vacuum and commissioning leads.

1) Pumpdown, refer to section directly above. (Included for reference.)
2) For ETM's measure Charge with Op Lev (under vacuum only) prior to opening to arms.
3) For ITM's (even with TMDS) continue to step 6. *(Not currently clear * how to measure charge as we are also blind i.e. we are unable to excite ITMs in pitch or yaw due to ITM ESD quadrants being all ganged together, so it's not viable to use the OpLev, so unfortunately you ideally need the full length sensing IFO. Therefore, for the ITMs we can only go on what we see on the USSVM2 Electrometer prior to close-out.)*
4) If TMDS is required move to step 5. If it is not required go to step 6. As above the discussion on whether or not TMDS is deployed should be held with vacuum and commissioning leads.
5) Deploy TMDS following steps in LIGO-T1500057: Test Mass Discharge System (TMDS) Operation Procedure. After deploying TMDS return to step 1.
6) Open to arm(s). Follow local separate procedures.
7) For ITM's / ETM's measure charge (again in the case of the ETM's) once open to the arms. If charge continues to be an issue one would need to close the gate valves again prior to deploying the TMDS. However, prior to doing so again make decision following discussions with vacuum and commissioning leads.

**To measure length, ideally you need the full IFO, but as Sheila mentioned at Systems call 2/28/2018 maybe DRMI would be sufficient. None of the sites have developed such techniques to measure charge on the ITMs, that I'm aware of but will look at this. This is the remaining missing item for a "complete" process i.e. a diagnostic to measure charge at corner station while corner is closed to the arms.*

PLEASE NOTE THE USED / MARKED UP VERSION OF THIS DOCUMENT SHOULD BE POSTED TO THE DCC.