ALIGO SYSTEM ACCEPTANCE DOCUMENT/DATA PACKAGE

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This document covers the technical content for acceptance review of the Advanced LIGO (aLIGO) System. See document M1300468 for an overview of the aLIGO acceptance process. The intent is to provide an acceptance data package by providing an organized list of reference documents with some explanatory text. For abbreviations see M080375.

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List of Tables

1 aLIGO System

This data/document package is the basis for system acceptance by the aLIGO Systems Engineering group. The scope of this aLIGO System Acceptance Data/Document Package is the installed interferometer detector system at both of the LIGO observatories. All of the documentation cited in this acceptance document is filed electronically in the LIGO Document Control Center (DCC) and linked in a document tree accessible from the root node entered below.

Interferometers:	L1 at LIGO Livingston Observatory (LLO) H1 at LIGO Hanford Observatory (LHO)
DCC document tree root node:	E1200123, aLIGO Document Tree

From the root node of the document tree all relevant documentation for the aLIGO system can be reached through the related and referenced document links.

2 System Design

If there are any caveats or explanatory notes regarding the documentation cited in the table below, then add these notes to the table entries.

2.1 Requirements: *[enter a linked list of DCC documents addressing performance and generic requirements]*	The system-level performance requirements are defined in section 2 of T010075. The top-level derived requirements for the subsystems are given in section 3 of T010075. System Performance Requirements: • T010075: Advanced LIGO Systems Design Project Management Requirements: • M050303: Advanced LIGO Project Execution Plan • M050220: Guidelines for Advanced LIGO Detector Construction Activities • M080036: Advanced LIGO Project Procurement Guidelines • M1000051: Tracking Serial Numbers General Technical Requirements: • E010613: Generic Requirements & Standards for Detector Subsystems • M1000211: Subsystem-Level and System-Level Testing Requirements • E030350: Drawing Requirements • M1200366: Guidance and format for writing an “Operation Manual” (aka “User’s Manual” or “Operator’s Manual”) Quality Assurance: • M960076: Advanced LIGO Quality Assurance Plan • M080331: Advanced LIGO Supplier Quality Requirements • M080352: Quality Assurance Boilerplate for RFQ`s

2.2 System Design/ Description: *[enter a linked list of DCC documents which provide a description of the system]*	The principal description of the system is given in T010075., which was also the principal document for the Systems Final Design Review. This document has been updated slightly to reflect the as-built system. (The changes are described in the "notes and changes" metadata field of the DCC entry for this document.) An abbreviated version (for peer reviewed publication) is given in P1400177. A bibliography, partitioned into subsystems, is given in P1400112. • T010075: Advanced LIGO Systems Design • P1400177: Advanced LIGO • P1400112: aLIGO Instrument Science Publication Compilation or Bibliography The aLIGO Final Systems Design Review (FDR) Report, L1000439, cited five areas of concern which were not completely resolved at the time of the FDR. The final status of these five areas of concern are discussed in L1400154 (item #1). The responses to questions formulated by the FDR committee at the time of the FDR are captured in L1000311. • L1000439: aLIGO Systems Final Design Review Report • L1000311: aLIGO Systems Final Design Review Questions & Answers • L1400154: Response to Questions from the L1 Systems Acceptance Review
2.3 Reliability/ Availability: *[enter a linked list of DCC documents which address system reliability/ availability]*	• T1300519: Sparing Analysis • E1400299: aLIGO System FMEA • E1400310: aLIGO Availability Estimate

3 System Layouts/Drawings

Enter hyperlinked DCC document number(s) for each drawing in the table below. If elements of the table are not applicable, enter "not applicable". All chamber-level, assembly drawings can be found linked under D0901491.

3.1 Optical Layout: *[enter a linked list of DCC documents addressing the optical layout]*	The optical layouts are maintained in Zemax™. The optomechanical layouts (top level assemblies) are maintained in SolidWorks™. These layouts are not independent. Zemax uses envelope representations of the payload elements in 3D whereas SolidWorks uses the actual 3D CAD models used to create the drawings. Zemax determines the positions of the optics making rough checks that there are no interferences (physical or lines of sight). These optical positions are used to set the locations of assemblies in SolidWorks where more accurate checks of interference are made. In addition the Zemax optical rays are imported into SolidWorks. The Zemax optical layouts are non-sequential models which are aligned "by hand". The optic positions and orientations are tweaked iteratively by the Zemax user, much as one would align the real interferometer. This results in small positional and angular errors and positional/angular data which change for each new release of the Zemax layout. As a consequence, a separate (invariant) optical layout calculation using vector analysis in Mathematica, with as-built/assigned optic parameters (not just nominal values) was

	created (E1300128) as a definitive source of positional/angular data for the Initial Alignment System (IAS) and calculations of IAS alignment solutions. It also serves as a sanity check on the Zemax optical layouts and IO PRC layouts. Note that the Zemax layouts reported in D0902216 (L1) are the sources for positional information for the primary interferometer optics for SolidWorks (CAD), with the exception of the PRC optics (PRM, PR2 and PR3). The PRC optic positions for SolidWorks are defined in the IO documents E1100492 (LHAM2) and E1100493 (LHAM3). • T010076: Requirements and Constraints for the Optical Layout • T0900043: Optical Layout and Parameters for the Advanced LIGO Cavities • D0902838: Advanced LIGO Optical Layout • E1300128: aLIGO Interferometer Optics Positions and Orientations for Initial Alignment • D0902216: Advanced LIGO L1 Optical Layout, ZEMAX • T1000581: Optical Layout and Parameters for the POP/ALS Beams • E1100492 (LHAM2 component coordinates) • E1100493 (LHAM3 component coordinates)
3.2 Coordinate Systems: *[enter a linked list of DCC documents defining the coordinate systems employed]*	Document T0900340 defines the global and local (building & chamber) coordinate systems used by aLIGO. Document T1100617 defines the coordinate systems used by our two principal servo-actuator systems (SUS & SEI). Document T980044 remains the fundamental source document for the global coordinate system. • T0900340: aLIGO Coordinate Systems • T1100617: Transformation Matrices Between SEI/SUS Coordinates • T980044: Determination of Global and Local Coordinate Axes for the LIGO Sites

3.3 Opto-Mechanical Layouts:

[enter a linked list of DCC top-assembly drawings.
N.B.: Chamber top-assembly drawings are reviewed in the installation acceptance reviews]

D0901491, aLIGO Mechanical Layout

The SolidWorks™ three-dimensional (3D) Computer Aided Design (CAD) models are maintained in a PDMWorks™ vault for shared secure access across the project, with check-in/out and change tracking. All 3D CAD models are assigned drawing (D) numbers using the DCC. Assembly drawings created from these 3D CAD models are version controlled and published in Adobe Acrobat format in the DCC. Subassembly drawings and part drawings are linked to the assembly drawings as “related documents” in the DCC forming a hierarchical drawing tree. The top-level assembly drawings for the L1 drawing trees are given below.

Building	**Next Level** (Chambers, Rooms, Enclosures) – linked in the DCC as “related documents” for each of the buildings
Observatory:	D0901490, aLIGO Livingston System Layout
Corner Station:	D0901466, aLIGO Systems Layout, LLO Corner Station

X-End Station:	D0901465, aLIGO Systems Layout, LLO X-End Station
Y-End Station:	D0901464, aLIGO Systems Layout, LLO Y-End Station

4 Contamination Control

4.1 General Contamination Documents: *[general requirements and procedures]*	The overall contamination control plan and procedures document is E0900047. The document which defines the cleaning and preparation for parts is E960022. All approved materials are listed in E960050. The processes and requirements for qualifying parts for service in the LIGO vacuum system, from an outgassing perspective, are defined in E1000088. The particulate contamination goal for the Test Mass optics are defined in T1300511 on the basis of allowed optical absorption. The processes and procedures for preparing parts for low outgassing and low particulate count are defined in E1400258. Each of these documents have many supporting documents (specifications, procedures, etc.) but these are the top-level, principal documents. In the early period of the project, after de-installation of the Initial LIGO (iLIGO) components, the frangible oxide layer on the interior walls of the vacuum chambers was removed and the walls cleaned (of particulates and hydrocarbons). This effort was called the In-Chamber Cleaning (ICC) process. The documents associated with ICC (protocols, tooling, procedures, FTIR measures of cleanliness, etc.) have been linked to the top-level DCC entry E1500182. E0900047: LIGO Contamination Control Plan E960022: LIGO Clean and Bake Methods and Procedures E960050: LIGO Vacuum Compatible Materials List E1000088: Qualifying Parts for LIGO UHV Service T1300511: Particulate Contamination Requirements E1400258: Contamination Control Mitigation Processes & resulting Cleanliness Levels E1500182: In-Chamber Cleaning Documentation and Test Results
4.2 Hydrocarbon Contamination: *[documents specific to hydrocarbon contamination including qualification tests for UHV compatible materials and an estimate of the residual gas load in*	An estimate of the residual gas based on materials and amounts is given in E0900398. However actual measurements are far more compelling. A measurement of the hydrocarbon partial pressures in the LLO vertex volume on in December 2013 (T1301006), after 163 days of pumping, indicated that the drop in hydrocarbon outgassing is a little faster than 1/t. The total hydrocarbon pressure when projected to the end of 2014, and with the cryo-pumps open to the system is expected to be about 1/100 of the Dec 2013 values[1], and close to the 1 x 10^{-13} torr goal[2].

[1] Similarly a measurement of the hydrocarbon partial pressure in the vertex volume at LHO after 145 days of pumping (T1300840) was 6.2 x 10^{-13} torr with a "good chance" that with both cryo-pumps open and additional time the base pressure will get close to the 1 x 10^{-13} torr goal.

[2] Note that the theoretical model connecting HC partial pressure to an optical absorption rate increase due to a putative molecular film deposition, has not been experimentally confirmed. In fact none of the optical cavity exposure tests to date (E1000193) show an increase in optical absorption even at 10 times the HC partial pressure in our observatory chambers.

the system]	No measurements of the hydrocarbon partial pressures in the LLO end stations have been made to date. However a series of measurements made in the LHO Y-End station are summarized in T1300046. The conclusion, regarding the HC total partial pressure at the ETM, is that the pressure will be below the goal by a factor of 3. Reports on material qualification tests (RGA and optical contamination cavity exposure tests) are collected under the DCC entry E1000193. E0900398: Advanced LIGO residual gas estimate T1301006: Hydrocarbons in the LLO LVEA on Dec 17, 2013 T1300046: Report on Hydrocarbon Measurements at LHO Y-end IV E1000193: LIGO UHV Qualification Test Results
4.3 Particulate Contamination: *[documents specific to particulate contamination including cleaning procedures, sampling/measurement techniques and an assessment of the surface particulate contamination level in the system]*	The project started its particulate mitigation efforts with an In-Chamber Cleaning (ICC) effort to removed exogenous and autogenous particles (G1000985, G1100182) from the chambers and the vacuum spools. In particular methods and tooling were developed to remove the oxide layer from the interior surfaces of the 304L stainless steel chambers. The oxide layer was a result of heat treatment at the time of manufacture (for iLIGO). Although this oxide layer reduced stray light reflection amplitude, it was found in operation to be frangible and the source of many particulates. The documents summarizing the successful ICC effort are collected at E1500182. Reports with reduced and interpreted results are collected under E1400028. The latest results on particulate cleanliness performance is summarized in G1400142, G1400614 and P1400205. In summary, the current Particulate Cleanliness Levels (PCL)[3] for vertical witness samples in the chambers is from ~100 to ~250 versus our absorption-based goal of PCL = 65 for test mass optics (a factor of ~5 to ~100 times higher particulate density than the goal). However in situ optical absorption measurements indicate that all is well. The L1 IMC optical absorption measurements have held steady at ~1.5 ppm/optic over 1 year (Jan 2013 through Apr 2014 compared to a requirement of 1 ppm and compared to 8 ppm in eLIGO[4]. The L1 ITMx and ITMy coating absorption is measured[5] to be 0.14 ppm and 0.20 ppm respectively. The requirement for TM HR absorption was defined as < 1 ppm. Given our lab measurements of absorption on the pristine coating, it seems that our in situ contamination makes a negligible contribution to absorption. There is evidence, from optical microscopy of eLIGO IMC optics, of pin holes in the HR coatings caused by particulate-initiated and laser-induced coating damage. On-going testing (on LIGO Operations funding) on laser induced coating damage seeks to determine initiation fluence levels for typical particulates (geometry, composition) and to characterize the coating damage. It appears that we can tolerate a limited number of vent/purge/pump-down cycles, before we accumulate an unacceptable level of coating damage (pin-holes). In case this number is found to be operationally restrictive, an

[3] PCL is the diametrical size of a single particle per 0.1 square meters.
[4] Pg. 45 of G1400614-v7.
[5] LLO elog entry #14634, 16 Sep 2014.

	ionized gas jet designed to remove particulates on optics, in vacuum (after a vent/purge/pump-down cycle) is being explored (on LIGO Operations funding). G1400614: Contamination Control Update - NSF 2014 G1400142: Summary of 4" Wafer Data P1400205: Progress is Quantifiable - SPIE Laser Damage Conference 2014

5 Configuration Control

5.1 Configuration Control System: *[list of documents describing the configuration control system, policies and guides]*	E010613: section 1.4.2 of Generic Requirements & Stds for Detector Subsystems E030350: Drawing Requirements M1000051: Tracking Serial Numbers M1200274: Engineering Change Request (ECR) Process T0900520: Documenting Electronics using the DCC and the E-traveler
5.2 Interfaces: *[collect a list of all interface definition]*	Interface documents are collected as a flat list of links under the DCC entry E1300955
5.3 Records of Decisions & Agreements (RODAs): *[collect a list of all RODAs]*	The purpose and process for RODA documentation is described in the memo M040004. All aLIGO RODA documents are collected as a flat list of links under the DCC entry E1300956
5.4 Technical Review Board (TRB) Reports: *[collect a list of all TRB reports]*	Technical Review Board (TRB) reports are collected as a flat list of links under the DCC entry E1300957
5.5 Engineering Change Requests (ECRs): *[collect a list of all approved and completed ECRs issued during the project]*	*See M1200274 for a description of the Engineering Change Request (ECR) process.* *See M1300323 for a description of the Integration Issue and ECR Tracker.* The ECR process (M1200274) for aLIGO[6] was implemented 31 July 2012. The purpose is to review and document all proposed changes to the design baseline. This ECR process applies to hardware and software. The only current exceptions are Guardian and ISC software, because they are not mature enough yet; This software is evolving rapidly as part of the commissioning effort. Unless otherwise noted, an ECR applies to both interferometers (i.e. applies to the common design baseline). Lists of ECRs are available as a filtered list of the Integration Issues and ECR Tracker, using these URLs: • All ECRs • Open ECRs As of this report’s date, there are 159 ECRs of which 44 are still open, i.e. not fully

[6] This same ECR process continues for LIGO Operations (post aLIGO project phase).

resolved. An ECR is resolved either by (a) rejecting the proposed change, or by (b) approving and then fully implementing the change, including all documentation updates. The open ECRs are listed in the Appendix (section 12), with a brief summary of the status. Of these 44 open ECRs:

- 7 have been completed for L1, and remain open for H1, or document completion;
- 11 have been completed for H1, and remain open for L1, or document completion;
- 9 are marked "key", or "somewhat significant";
- 6 marked with status "WHENVENT" meaning that when an opportunity arises during a vent, the ECR will be implemented. (3 of these 6 are "key")

The 9 "key", unresolved ECRs relate to primary risk factors as indicated in Table 1.

Table 1: Risk Factors for the Key, Unresolved (incomplete) ECRs

A filtered list from the Integration Issue and ECR Tracker. See M1300323 for a description. WHEN = WHENVENT status, waiting for an opportunity during a vacuum vent; PEND = PENDING status, being actively worked to a resolution. The risk factors are defined as follows:

- Impact: potential for significant cost or schedule impact to operations (e.g. requiring a vacuum vent, lengthening commissioning time)
- Performance: potential to limit performance, or key functionality
- Reliability: potential to limit duty cycle
- Safety: potential for unsafe conditions (personnel or machine)

ID	Status	H1	L1	Summary	Risk Factor Comment	Impact	Performance	Reliability	Safety
505	WHEN		✓	drift of BS pitch during PRMI carrier lock	Installed on H1. Waiting for a vent opportunity on L1. Not currently impeding commissioning; Using control loop to compensate for wire heating induced pitch drift.	✓	✓		
630	PEND	✓	✓	CPS cross talk	Solution fabricated. Installation when convenient for commissioning efforts.		✓		
659	WHEN		✓	options to ameliorate spot size issues with ISS PD arrays in HAM2 chambers	Hardware replacement to (a) correct poor optical mode matching to the photodiode array of the outer loop Intensity Stabilization Servo (ISS) and (b) replace PD array with improved design. Completed on H1. Waiting for vent for L1.	✓	✓		
907	WHEN	✓	✓	universal & long-term solution to the systemic ESD shield-to-center conductor shorting	The re-designed high voltage, electrical feed-through has not been implemented on all test mass	✓		✓	

ID	Status	H1	L1	Summary	Risk Factor Comment	Impact	Performance	Reliability	Safety
				problem	chambers. Requires a vacuum vent.				
944	PEND	✓	✓	ECR for a low-noise, low voltage electrostatic driver	Fabrication to be completed on the aLIGO project. Installation on Operations when convenient for the Operation's commissioning effort.		✓		
948	PEND	✓	✓	Test Mass Charge Prevention and Neutralization	Fabrication to be completed on the aLIGO project. Installation on Operations when convenient for the Operation's commissioning effort.		✓		
950	PEND	✓	✓	Facility Class UPS	LIGO Operations scope. In the exploratory stage.			✓	
1002	PEND	✓	✓	scattering noise in DARM from HAM6	LIGO Operations scope. AR coated, black glass assembly is in the prototyping stage.		✓		
1011	PEND	✓	✓	Hardware Watchdog	Production units delivered by the aLIGO project, but found to be inadequate. Requires technical evaluation to determine if rework, or re-design is needed. In the interim machine safety is relying on software watchdog layers.			✓	✓

6 System Performance Models[7]

The software tool used to generate the (amplitude spectral density) noise curves in the System Design Document (T010075), for fundamental sources (quantum, test mass internal thermal noise, suspension thermal noise) and facility limits (seismic gravity-gradient noise, residual gas noise), is GWINC (Gravitational-Wave Interferometer Noise Calculator). The GWINC wiki page is:

https://awiki.ligo-wa.caltech.edu/aLIGO/GWINC

GWINC also calculates range to astrophysical sources. Since GWINC does not include technical noise sources, it provides lower bounds to the potential performance of the instrument. The aLIGO instrument has been designed with the intent to limit all technical noise sources well below these fundamental noise limits. Nonetheless, during integrated system testing and commissioning, realistic performance assessment requires inclusion of technical noise sources (ground seismic transmission, laser intensity noise, mode mis-matching, contrast defect, etc.)

Most of the various System (or ISC) performance modeling tools are listed on the aLIGO wiki:

https://awiki.ligo-wa.caltech.edu/aLIGO/ISC_Modeling_Software?highlight=%28modeling%29

A summary of several modeling projects that have been carried out in parallel with integration/commissioning at the observatories is given on this aLIGO wiki page:

[7] Not all of the work discussed in this section was performed on aLIGO project funding.

https://awiki.ligo-wa.caltech.edu/aLIGO/ModelingEffort
and in the presentation G1400573, regarding modeling tool use in support of integrated system testing and commissioning. Although there are some specialized variant simulation tools, the primary tools and models are the following:

- Optickle: A frequency domain Matlab package for interferometer simulation. (There are a few variants of this simulation package : Lentickle adds SISO control loops to Optickle; LoopTickle adds MIMO controls; Optickle QND and quantum non-demolition modeling.) Measurements compare well with the models except for some areas of disagreement (3f LSC sensing matrix amplitudes, ASC sensing matrix signs, contrast defect; see G1400573). The Optickle code repository is GitHub: https://github.com/Optickle
- Noise Budget (NB): Our plan is for NB to be the primary tool for noise hunting during commissioning. NB utilizes Optickle for the interferometer response model and "live" parts, i.e. updated data consisting of:
  - Machine state: digital filters, gains, switch settings, matrix values, filter module transfer functions, etc.) from the front end userapp code
  - Current data: read "live" noise spectra.

  NB has been used to model the full IFO noise budget (G1401264) and continues to evolve in support of commissioning. The NB repository is the LIGO SVN: /ligo/svncommon/NbSVN/aligonoisebudget/trunk/Dev/DRFPMI
- Finesse: The Finesse software (http://www.gwoptics.org/finesse/) is a frequency domain optical simulation code. Input model files for the aLIGO interferometer are filed at (or linked as related documents to) L1300231. Finesse has been used to investigate (a) IMC alignment (T1300074), (b) possible causes of observed low PRC gain in the L1 PRMI (T1300954) and (c) possible causes for alignment drifts/changes in the ALS alignment matrix (G1400622).
- E2E: The end-to-end (e2e) code is a time domain simulation which has been used to establish the locking sequence plan for the full interferometer (T1400298). The code can be downloaded from http://www.ligo.caltech.edu/~e2e/
- SIS: The Stationary Interferometer Simulation (SIS, T070039) calculates optical fields of various optical configurations relevant to the aLIGO system using FFT and employing surface map definition of the optics. SIS has been the 'workhorse' in many studies of the as-built core optics and scattered light control geometry to determine if proposed parameters, designs or waivers are acceptable. Many examples are compiled (linked) at T1300873 and include (a) BS baffle design (T1000090), (b) effects of surface perturbations in the FP cavity (T1000154), (c) acceptable ETM coating thickness uniformity (T1100111, T1200503), (d) ETM coating absorption effect on the carrier and sidebands (T1100281), (e) scattered light noise from the ETM "spirograph" coating ripple (T1300354). The code can be downloaded from www.ligo.caltech.edu/~hiro/SIS/
- FOGPrime13: FOGPrime13 (G1301260) is an object oriented, FFT-based, interferometer code and analysis package built on Matlab (and incorporates elements of FOG, SIS, E2E and twiddle). Has been successfully used to explain the L1 PRMI contrast defect measurement (G1400162). The code and manual can be downloaded at T1300942.
- MIST: MIST (G1400322) is a modal based, frequency domain simulation tool of paraxial optical systems, packaged as a Matlab toolbox. MIST simulation input files for aLIGO are posted at T1301002.

MIST can be used to study parametric instabilities in aLIGO (G1400382) and intensity noise coupling on L1 (G1400879). The MIST code repository is https://sourceforge.net/projects/optics-mist/

All of these software tools (and many of the model input files) are archived and most are revision/version controlled. Some model files (e.g. Finesse models, Opticle models) and code is also archived in the LIGO SVN repository (https://emvogil-3.mit.edu/svn/iscmodeling).

7 Supervisory Control, Monitoring & Operation

Some of the tools and resources referenced below were not built by the aLIGO project, but by LSC members. They are called out because they likely are useful tools in support of the overall system. If as time progresses these tools are found to be essential operational tools, then the maintenance, upgrades and debugging may end up being LIGO Operations tasks.

<table>
<tr>
<td>7.1 Interferometer Automation System (Guardian):</td>
<td>The aLIGO automation system is known as Guardian. The purpose of the Guardian system is to control the global state of the interferometer, by managing and automating the interferometer locking sequence and coordinating the states of all of the interferometer subsystems. Guardian is a hierarchical state machine built on directed graph representations of the systems. The requirements for Advanced LIGO automation are defined in T1300884, and an overview description and user manual for the aLIGO Guardian system is described in G1400016.

The initial aLIGO Guardian implementation has been completed:

the core Guardian engine has been developed and deployed,
the supervision infrastructure has been deployed,
suspensions and seismic isolation subsystems are fully automated with Guardian managers,
the Input Mode Cleaner (IMC) auto-locker has been implemented,
an initial automation procedure for full lock acquisition has been demonstrated on L1
a top-level Guardian node has been implemented for the purpose of reporting the overall state vector (lock status)[8] to the frames and the ODC system
Guardian monitoring of the SDF (front-end settings definition file) is a new feature in the latest release (only currently available at LHO) and not fully commissioned
automatic SVN commitment (archival) of Guardian user code system upon Guardian initialization or reload. This new feature (only currently available at LHO) provides a permanent record of all running Guardian code at any given point in time, regardless of SVN commit status of user application code (aka userapps; user models).

Implementation of the latest Guardian release at LLO is awaiting a convenient time to minimize disruption to the ongoing commissioning efforts. There are some differences[9] between the Guardian implementations at the two observatories, beyond the core</td>
</tr>
</table>

[8] The Guardian nodes each report a status bit. ODC collects these bits into a state vector (word).

[9] At the time of this report (Feb 2015) the H1 and L1 IMC auto-locker Guardian code, and suspension Guardian code, are somewhat different. The L1 full-IFO, auto-locker Guardian code employs scripts launched by the Guardian, but not embedded code. As a consequence Guardian can’t recover from (handle) faults in these spawned script processes.

	Guardian release differences, which should decrease over time. As commissioning continues on the aLIGO interferometers the use of Guardian to capture and integrate operator and commissioner tasks into the supervisory control will continue. Some suggested future enhancements are defined in T1400461. T1300884: aLIGO Automation Requirements G1400016: aLIGO Guardian Overview and User Manual T1400461: aLIGO Guardian Progress and Remaining Tasks
7.2 Operation Manual(s)/ Guide(s):	The primary documentation which serves as operation manuals (aka operator's manuals, user's manual, or guides) are listed by subsystem[10] in the table below. Within the subsystem documentation trees are links to copies[11] of product manuals for commercial components which we've integrated into our system. Although training is beyond the scope of the aLIGO project, it is worth noting here that the principal operator training document is E1400250: "Training of Detector Engineers and Operations Specialists", and tutorials can be found linked from the Detector Engineering Group wiki: https://wiki.ligo.org/DetectorEngineeringGroup/WebHome

Subsystem	***Operation Manual/Guide***
ISC and Systems	M080334: LIGO Observatory Extended Shutdown Procedure E1200197: aLIGO, ISC, Operations Manuals/Guides, especially: T1300903: ISC End Station User's Manual T1500012: L1 OMC Controls E1500161: OMC: Overview of the realtime model and screens T1300991: PRMI Locking Procedure T1400728: ISC tuning for lock acquisition and noise reduction
IO	T1300476: Operation Manual for the IO Faraday Isolator T1200096: Light pipe operation T1300031: IO HAUX Software and User's Manuals M1200041: IO PSL Power Control - Standard Operating Procedure T1300126: IMC Autolocker
PSL	Section 8 of E1200039: aLIGO PSL Acceptance, especially: T0900646: LIGO 35W MOPA laser - user guide T0900641: User Manual 200W laser T0900133, T0900579: PSL Diagnostic Breadboard Manuals T1100383: High Power Laser Quick Start Guide Plus

[10] Note that the following aLIGO WBS/subsystems do not require manuals: FMP, AOS/SLC and AOS/VP. AOS/TMS is covered under SUS.
[11] Copies of product manuals uploaded to the DCC are preferred over URL links which rely upon the company maintaining documentation. However access to these manuals must remain restricted to the LSC since we generally do not have the right to disclose/publish these manuals.

		T1200259: PSL Startup and Shutdown Procedures G1400717: LLO Laser Power Recovery
	SUS[12]	E1200633: aLIGO SUS Operations Manual This manual is a snapshot of this wiki site: https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual
	SEI	E1500146: aLIGO SEI Operation Guides/Manuals/Tutorials, especially: E1200762: User interfaces Overview and restart procedure of the Seismic systems
	DAQ/CDS	CDS LLO website: https://llocds.ligo-la.caltech.edu/ T1400753: LIGO DAQ Configuration Repository - DAQSVN T1400394: CDS Full Shutdown Procedure Frontend Computer Restart Procedure: https://cdswiki.ligo-la.caltech.edu/foswiki/bin/view/CDS/DAQFrontendRestart E1200653: aLIGO,DAQ,Software User Guides T080135: aLIGO CDS Realtime Code Generator (RCG) Application Developer's Guide T1100625: Real-time Code Generator (RCG) Runtime Diagnostics
	Slow Controls	E1200203: aLIGO, Slow Controls, EtherCAT Setup and Installation CDS Beckhoff wiki: https://wiki.ligo.org/Operators/LLO/Beckhoff
	TCS	E1300233: aLIGO CO2P Operations Manual E1300226: aLIGO HWS Operations Manual E1400024: Operation Manual for aLIGO TCS Ring Heaters
	OptLev	E1200443: aLIGO Optical Levers User's Guides; especially: T1200191: Optical-levers software user's manual
	PCal	T1500039: aLIGO Pcal Beam Localization System Procedures
7.3 Channels:	The aLIGO system supports two types of data acquisition frame sets: commissioning frames and science frames. The higher data rate commissioning frames include channels useful for diagnostics and instrument debugging, whereas the science frames are the reduced set of channels required for long term archival. The baseline allocation of data channels/rate in science run/operations mode is given in T1000313. The naming conventions for channels is defined in T1000649. The channel list is lengthy[13] and will remain somewhat dynamic through the commissioning period, as the front end models (subsystem application code) are revised. On-line tools for channel queries should be used to identify/find channels of interest rather than rely on static channel list captures. Nonetheless the static documentation *provides* an overview and snapshot of channels for various subsystems, including often the dictionary for these	

[12] Including the AOS/Transmission Monitoring (telescope) Suspension (aka TMS or TMTS).
[13] As of 18-Feb-2015 there were 398,831 current (extant) channels defined (and 744,892 total channels defined, including obsolete or renamed channels).

	channels. Not every subsystem has provided a document listing, or describing the channels allocated to the subsystem. Extant subsystem channel lists/descriptions are given in the document list below. For the other subsystems (such as SEI and SUS) refer to the user (RCG) model. The Channel Information System (CIS) is the best resource for finding channels and information about channels: • CIS: https://cis.ligo.org/ Using this LSC developed tool one can browse a hierarchical channel tree or perform a Boolean search on channel names. For each channel the database has (in general) a complete set of metadata (subsystem name, sample rate, data type, units, etc.) including a brief channel description and the relevant user model[14]. This rich database and user-friendly, web-based interface is under active development and maintenance by the LSC. Although PEM was not part of the aLIGO scope, links for the PEM channel list and information (http://pem.ligo.org/) are included here for completeness. • ER6 PEM list: https://wiki.ligo.org/DetChar/ER6DetcharChannels • PEM interactive maps: http://pem.ligo.org/channelinfo/index.php The PEM Channel Information web site is another rich database with a user-friendly, web-based interface which is under active development and maintenance by the LSC. Relevant documentation: T0900400: aLIGO Input Optics Channel list for CDS T1000313: Fast Channel Data Rate Estimate for aLIGO T1000649: aLIGO CDS Channel Naming Standards T1100472: ADC and DAC Channel Usage for ISC E1100674: LLO - PSL DAQ channels after installation T1200039: HAM Table Oplev Channel Allocation T1200089: End Station Channels for ISC, PEM, P-Cal and TCS T1200092: aLIGO PSL channel list E1300176: LHO - H1 PSL DAQ channels after installation T1300742: Science Frame Data for the SEI Subsystem E1400381: ECR: … to accommodate Pcal channels. T1400768: Science frame sample rates for PEM channels T1500014: LSC subsystem science frame channels T1500023: LIGO Vacuum Controls System Upgrade, Channel Name Changes E1300794: ECR: New naming scheme for OMC channels
***7.4* Control Room Tools/System:**	Some useful resource of links and information for control room operation can be found on these pages: • LLO CDS web site: https://llocds.ligo-la.caltech.edu/ • LLO Operators wiki site: https://wiki.ligo.org/viewauth/Operators/LLO/WebHome

[14] In CIS the user model is referred to as a Simulink model.

The control room software tools for support of operations (many of which are summarized in G1400854) consist (principally) of the following:

- DataViewer (DV): a X-windows client, utilizing the grace graphics package and the NDS1 interface only, for plotting channel data vs time.
- Global Diagnostic System (GDS), including DTT (Diagnostic Test Tool), Data Monitoring Tool (DMT), awggui, diag, diagui, foton, etc.
- awgstream: is C/C++ code which supports command –line injection of signals (only within the CDS network) used extensively in test scripts (and is available with a Matlab API).
- GWData: An improved version of mDV (get_data; G070375) to get data for use in Matlab. GWData handles a variety of time specifications (GPS, local, GMT, ...), multiple channels, resampling, etc. It also deals with Kerberos automatically. Available from the remote data access wiki: https://wiki.ligo.org/pub/RemoteAccess/MatlabTools/GWData.m
- ligoDV: a Matlab program to view and analyze channel data on the NDS servers (https://wiki.ligo.org/LDG/DASWG/LigoDV, G1200127)
- ligoDV-web (ldvw): a web based tool to search channels and produce basic plots and analysis of any LIGO data available via NDS2 (https://wiki.ligo.org/LDG/DASWG/LigoDVweb, https://ldvw.ligo.caltech.edu, G1400626)
- gwPY: a Python package of tools for studying common time-domain and frequency-domain data produced by LIGO (https://github.com/gwpy/gwpy).
- Conlog: (Configuration Logger) Logs changes in the value, alarm status and alarm severity of EPICS process variables to a database and provides a web and command line interface to search the database. (G1401113)

In addition to the standard control room tools listed above, the LSC detector characterization group (DetChar) has developed a few more tools that are likely to be of use to operators as well:

- Seismon (G1400811, T1400487) makes predictions of earthquake phase arrival times and amplitudes based on USGS low latency notices
- Detchar summary pages (built with NDS2 for data access and gwPY for data processing, plotting, and summary page creation): https://ldas-jobs.ligo-la.caltech.edu/~detchar/summary/
  Tutorials on how to read and understand the DetChar summary pages are available (G1400062, G1401357)
- LIGO Channel Activity Monitor (LigoCAM, G1300189) is a diagnostic tool for monitoring auxiliary channels. The utilities include locating a malfunctioning channel, graphic information of channel's time series and spectral data, and spectral change to understand various band-limited environmental disturbances of non-astrophysical origin. LigoCAM link (currently PEM and SUS only):

	https://ldas-jobs.ligo-wa.caltech.edu/~dtalukder/Projects/detchar/LigoCAM/LigoCAM_host/LigoCAM_PEM_LLO.html
7.5 Remote Data Access:	Remote access to the data available in the control rooms at the observatories is not within aLIGO project scope. However this access is very important to LSC engineers and scientists who are not in the control room to enable contributions to commissioning and parallel research. These access tools build upon aLIGO infrastructure. The principle source of information on remote access tools is this wiki page, https://wiki.ligo.org/RemoteAccess/WebHome, which includes a list of the software tools. Data viewer tools for off-site data access and include ligoDV, gwpy, or ligoDV-web. All are NDS2 clients.

8 Integrated System Testing

Note: All post-installation, stand-alone, in situ, checkout/testing of subsystem assemblies (phases 2 and 3 per M1000211) must be completed, be successful and be documented and reviewed as part of the installation reviews:

- *phase 2: pre-installed, post-storage, test results for the assembly (testable item)*
- *phase 3: stand-alone, in situ test results for the assembly (testable item)*

The integrated testing (phase 4 testing per M1000211) is covered under this system acceptance review. For each of the integrated tests listed in the table below, a list of documents covering test plans/procedures and a test report are required.

The top-level integrated system test plan is:

- T1200437: Advanced LIGO Interferometer Integration

The one arm test conducted on the H2 Y-arm was the first integrated system test for the aLIGO project. This test demonstrated the basic functionality and interoperability of a few essential subsystems (IAS, quad suspensions, BSC ISI seismic isolation, TCS ring heater, optical levers, ALS, ISC). In particular this was the first test of the ALS system which is essential for robust and reliable lock acquisition. While in principle this one arm test has been repeated on each subsequent arm cavity (for H1 and L1), only the initial proof-of-principle test has a stand-alone report.

The L1 Input Mode Cleaner (IMC) test was the first integrated system test on the L1 interferometer, and the first test at high power (120 W). The IMC represents a significant subset of the overall aLIGO system by incorporating the PSL and the IMC, including many single, double and triple suspension systems on the HAM-ISI seismic isolation systems. Since the time of this report, the intensity stabilization servo (ISS) performance has been improved significantly and the MC absorption was found to be acceptable (and much less than thought at the time of the report).

The primary result of the L1 Dual Recycled Michelson Interferometer (DRMI) test was to achieve robust locking on the RF sidebands using the 3-f error signals, as this is an early step in the planned full lock acquisition scheme.

The Half Interferometer (HIFO-Y) test conducted on H1 was a continuation of the one-arm test and demonstrated arm length locking on both green and infrared laser light and allowed a check of the relative stability. While in principle this HIFO test has been repeated on each subsequent arm cavity (for H1 and L1), only the initial proof-of-principle test has a stand-alone report.

The aLIGO Project milestone of a stable lock (multiple instances of > 2 hours duration) in the full interferometer configuration—meaning a power- and signal-recycled interferometer with arm cavities – was achieved on the L1 interferometer in July 2014. Since that time further commission work has demonstrated Binary Neutron Star (BNS) sensitivity of 63 MPc range (L1 elog #16589).

Each major system integrated test configuration has a test plan and an associated test report, as listed in the table below.

Test Configuration	Test Plan	Test Report
Single Resonant Arm Cavity, or "One Arm Test"	T1100080 (see also E1300627)	L1200261 (H2)
Resonant Input Mode Cleaner Cavity	T1100201 (see also E1300628)	L1300018 (L1)
Dual Recycled Michelson Interferometer (DRMI)	T1300558 (see also E1300631)	T1400053 (L1)
Arm Cavity with Power Recycling Cavity (PRC), or Half-Interferometer (HIFO)	T1300174 (see also E1300629, E1300630)	L1300176 (H1)
Full Interferometer	T1200437 (see also E1300632)	L1400119 (L1) L1500028 (H1) P1400105

9 Unresolved Installation/Integration Issues

If/as applicable, provide a hyperlinked list of integration issues [other than pending or incomplete Engineering Change Requests (ECRs)]. See M1300323 for a description of the Integration Issue and ECR Tracker.

9.1 Significant Issues

The potentially significant technical issues that we have not resolved for the aLIGO system are as follows (ordered from the most to least significant[15]):

1. Electrostatic Charging [bug 948, bug 81]: Charging was thought to not be an issue based on testing at LASTI and LSC charging research. However recent testing on both L1 and H1 have demonstrated that the ion pumps cause (mostly positive) electrostatic charging of the ETMs, and that residual (negative) charge can result from First Contact™ (FC) removal. The aLIGO Project:
   - has implemented an improved discharging procedure for FC induced charging;
   - is producing the necessary number of discharging units based on a prototype design (T1100332, T1400535);

[15] The ranked ordering from most to least significance is debatable, and depends on the implicit merit function employed. This particular ranking is the judgment of the Systems Engineer and is intended to give some sense of relative importance even if the ordering is uncertain, or at least subject to re-ordering depending upon the criteria used to judge.

- is purchasing Non-Evaporable Getter (NEG) pumps to place on the ETM chambers and new ion pumps to place ~280 m from the ETMs on the beam tubes, so that the large ion pumps currently in proximity to the ETMs can be kept off during operation;

Operations will be responsible for installing the new pumps and for developing chevron shielding to be added to the ion pumps (on the beam tube and in the corner station) in order to reduce the emission of soft x-rays and UV light which cause the charging.

Electro-static charging of the TM reduces the control authority of the electro-static drive (ESD) actuator and couples length and angle. In addition the residual TM charge causes cross-coupling with stray electro-magnetic fields. These stray EM fields are brought into proximity of the test mass by the ring heater and potentially improperly grounded cable shields.

2. Parametric Instability (PI): Research (on Operations funding) into a passive control of parametric instability (PI) (e.g. T1400738, P1400257, G1001023 and G080541) was, and still is, being pursued. Since the time of the Systems FDR, and in fact fairly recently, an error was found that potentially increases our exposure to PI. Until very recent experimental observation of PI (L1 elog entry #15934 and P1400254) on the L1 interferometer, G1401131 was the most up to date assessment of our risk of experiencing PI. LIGO Ops has taken on, with the LSC, the endeavor to identify an approach to mechanically damping the modes. In short, it is still an issue, but is now in the domain of Ops to address. Note that we have demonstrated the capability to shift the optical resonance frequencies away from PI by changing the test mass radius of curvature with the ring heater. With the ring heater we have demonstrated sustained, stable locking at 25W, the power level intended for the first science run.

3. Electrostatic Actuation for the L1 ITMy is Inoperative [bug & waiver 20]: The Compensation Plate (CP) in the L1 ITMy quadruple suspension cannot be readily used to provide electrostatic actuation. While this is not a problem for locking the interferometer, it does limit the capability to deal with PI modes associated with the L1 ITMy optic.

4. Drifts in Initial Alignment: [bug 974] A significant amount of commissioning time is spent in tweaking the initial alignment of the cavity optics in order to enable cavity lock acquisition. The system has angular drifts which are large compared to the required angular stability. While the cause is not known for sure, the thermal sensitivity of quad suspensions is suspected. Possible (speculated) solutions might include the addition of a Multi-Layer Insulation (MLI) barrier to mitigate radiative exchange to the quad suspension from the chamber walls, and/or temperature feedback to suspension DC alignment control and/or an automated alignment search algorithm implemented in Guardian.

5. Particulate-initiated, Laser-induced, Coating Damage: The iLIGO IMC optics have pin holes in their coatings which microscopic examination reveal are thermal ablation of the coating. We can create similar damage in coatings in the lab at surface particulate locations under fluence levels below the maximum for aLIGO. Repeated vent/purge/pump-down cycles will cause cumulative coating damage. Once the optical loss gets too high the optics will have to be replaced. Insufficient data has been collected to make a reliable estimation of the likely number of allowed vent/purge/pump-down cycles before replacement. Under Operations funding the lab is performing tests to ascertain the optical coating damage thresholds versus operational variables. Our estimate is that the present level of in situ particulate cleanliness is commensurate with operation at the initial science run (O1) power level of 25W. It should also be noted that the L1 IMC (where fluence levels are highest) has been operated once at high power (120W input level; LLO elog #5932) without a measureable increase in optical loss.

6. HEPI is not fully functional: The R&D phase for the Hydraulic External Pre-Isolation (HEPI) system was accelerated so that it could be deployed early for iLIGO and eLIGO for the L1 interferometer, in order to mitigate logging noise which disrupted iLIGO operations; Without HEPI L1 would not have been able to perform adequately for iLIGO. So it is ironic that HEPI is not fully operational for L1 in aLIGO. Currently for L1 HEPI is only operational for the HAM1 chamber and recently the end station BSC chambers (and mechanically shorted for all other chambers), whereas for H1 it is operational for all chambers except HAM1. To date we have achieved excellent performance with L1 in this condition and so have been reluctant to spend the time commissioning the HEPI system for L1, which will disrupt or delay the continued commissioning work to improve interferometer performance (aka "noise hunting"). Recently commissioning of the end-station HEPIs has begun for L1 to enable HEPI compensation of tidal motion. Nonetheless eventually (perhaps after O1) we are likely to require all HEPI units for additional active isolation in 1Hz - 10 Hz range and passive damping of the pier/cross-beam resonances near 10 Hz.
7. Downtime due to power interruptions [bug 950]: Frequent, short duration power interruptions occur particularly at LLO. The system downtime impact of these frequent momentary interruptions is estimated to be at least ~1% for the LLO interferometer. LIGO Operations has undertaken a technical evaluation of Uninterruptible Power Supply (UPS) solutions as a likely means to mitigate this problem.
8. Temporary SRM: The installed SRM is a composite optic (small optic in a metal carrier) with ~35% transmission. This is a long term, but temporary situation. Eventually a full size, monolithic, SRM with 20% transmission (optimum for BNS) will be installed, but not until after O1. The aLIGO project has delivered these final SRM optics, but deliberately choose to install temporary optics for ease in initial commissioning.
9. Gas Damping: The low frequency noise performance of test mass suspensions may be compromised by increased gas damping (aka squeezed film damping in the literature) due to the small gap between the end test mass and the reaction mass (T0900582). The performance impact is (for example) an estimated reduction in the NS-NS inspiral range from 190 Mpc to 178 Mpc. To mitigate this noise term will likely require either a reduction in the end station pressure (more pumps) or a redesign of the end reaction mass.
10. Low frequency, low noise performance of the suspension systems had not been proven: The interferometer performance has not yet achieved full aLIGO sensitivity at low frequency. There are no indications at this point that there are problems; the stationary losses of the suspensions are acceptable (the measured Qs to date are high), and there are no indications to date that there are non-stationary noise contributions. Further commissioning will be needed to determine the suitability of the suspensions to reach the design expectations, but the Project considers the question closed for its scope. Related to the low noise performance of the suspensions are one outstanding ECR (#944, low noise, low voltage ESD) and one issue (#954, ambient magnetic field coupling to the quad UIM magnets)
11. Better Test Mass Optics are on the Shelf: The installed test mass optics in the L1 and H1 interferometers failed to meet all of their specifications or goals (see section 11 regarding waivers):
    a) High green light transmission of the HR coatings of the both L1 & H1 ETMs: This deviation from design complicated the Arm Length Stabilization (ALS) system for lock acquisition. Further commissioning may discover that the benefits for replacing the ETMs for lower green light transmission exceed the risk and down-time impact.

b) High AR coating reflectivity of both L1 & H1 ITMs: This deviation results in higher power in the ghost beams and scattered light and may lead to higher scattered light noise. Further commissioning may justify ITM replacement, or the addition of improved scattered light control.
c) High spatial frequency ripple of the ETMs: The coating process left a high spatial frequency, "Spirograph" pattern in the HR coating (which though within specification, was not intended). This pattern will scatter some light in a cone toward the Beam Tube walls and baffles. Calculations (T1300354) estimate that the excess scattered light noise at a ~14 Hz mode of the beam tube may exceed the aLIGO strain sensitivity, but there is much uncertainty in the calculation. Measurements on the L1 interferometer (LLO elog #16020) suggest that the scattered light noise will be borderline near ~14 Hz, and below the noise floor elsewhere.

Systems Engineering issued waivers for these optics since calculations indicated that we are likely to achieve, or be close to achieving, aLIGO performance goals (and to reject their installation would cause significant project delay and cost). The subsequently fabricated (in-process spare) test mass optics have better performance characteristics. We may find in the course of commissioning that the interferometer performance is in fact limited by the installed optics, in which case the LIGO Operations team may opt to install one or more of these delivered spare core optics. The installation of a core optic entails some risk and non-trivial schedule (up time) impact since vacuum vents are required. No test mass swaps are planned prior to the first observing run (O1).

These potentially significant issues relate to primary risk factors as indicated in Table 2.

Table 2: Risk Factors for the Potentially Significant Issues

The risk factors are defined as follows:

- Impact: potential for significant cost or schedule impact to operations (e.g. requiring a vacuum vent, lengthening commissioning time)
- Performance: potential to limit performance, or key functionality
- Reliability: potential to limit duty cycle
- Safety: potential for unsafe conditions (personnel or machine)

No	H1	L1	Summary	Risk Factor Comment	Impact	Performance	Reliability	Safety
1	✓	✓	Electrostatic Charging	Residual electrostatic charge has the potential to limit noise performance. The aLIGO project is procuring pumps and test mass discharging systems which can be installed with minimal downtime (impact).		✓		
2	✓	✓	Parametric Instability (PI)	Uncontrolled PI will limit the maximum interferometer power (performance). If control requires Acoustic Mode Dampers (AMD), then there is a schedule impact to install (after R&D has been completed).	✓	✓		
3		✓	Electrostatic Actuation for the L1 ITMy is Inoperative	May be required for PI control (performance). Will require chamber incursion (schedule impact).	✓	✓		
4	✓	✓	Drifts in Initial Alignment	Constant re-alignment as the temperature drifts will cause decreased duty cycle (reliability).	✓		✓	

No	H1	L1	Summary	Risk Factor Comment	Impact	Performance	Reliability	Safety
				May opt to install means to mitigate drift (after R&D) which will require chamber incursion (cost & schedule impact).				
5	✓	✓	Particulate-initiated, Laser-induced, Coating Damage	If particulate densities coupled with vent/pump-down cycles cause unacceptable cumulative damage, then there will be cost & schedule impacts to replace optics and/or to install in situ air knife/nozzle systems (after R&D has been completed).	✓			
6	✓	✓	HEPI is not fully functional	Low frequency performance is likely to suffer eventually without HEPI. When HEPI is commissioned it will delay other interferometer commissioning efforts (schedule impact).	✓		✓	
7	?	✓	Downtime due to power interruptions	Power interruptions cause protracted down-time. A UPS system would improve the duty cycle.			✓	
8	✓	✓	Temporary SRM	Performance for NS-NS inspirals can be optimized by replacing the SRM. Will require chamber incursion (schedule impact).	✓	✓		
9	✓	✓	Gas Damping	Low frequency performance will suffer somewhat unless end station pumps are added or the ERM is replaced (after R&D).	✓	✓		
10	✓	✓	Low frequency, low noise performance of the suspension systems has not been proven	Until the low frequency performance goal for aLIGO has been demonstrated there is a risk that the quad suspension will require redesign or rework.		✓		
11	✓	✓	Better Test Mass Optics are on the Shelf	On the basis of noise performance commissioning we may conclude that the ETMs and/or ITMs should be replaced with the spares.	✓	✓		

9.2 Other Issues

In addition to the above "significant" issues, there are a number of generally less significant, "open" (unresolved) integration issues or ECRs (aka "bugs"), available from the following URL links. Some of these are redundant (or overlap with) the significant issues above. As of this report's date, there are 121 open (unresolved) issues and/or ECRs[16]:

	All	aLIGO	ECR	H1	L1
All IFO open	121	45	44	16	16

[16] Not including the chamber 'place holder issues' – an issue/bug report which is simply a collections of bugs related to a single chamber, for ease in planning vent incursions into a chamber.

The open (unresolved) issues which are not related to ECRs (already covered in section 5) can be found at this URL:

- open non-ECR

As of the date of this report the list totals 77 issues (which are given in the Appendix, section 13). Of these 77 issues:

- 16 are unique to L1; 16 are unique to H1; and 45 apply to both H1 & L1 (aLIGO)
- 10 have been completed for L1
- 2 have been completed for H1
- 1 is not in aLIGO scope (#142; applies to PEM and not listed below),
- 1 is a test on H1 to see if it merits incorporation into the baseline (#923), and
- 12 are deemed “Key” (or “somewhat significant”)

These “key” issues relate to primary risk factors as indicated in Table 3.

Table 3: Risk Factors for Key Issues

A filtered list from the Integration Issue and ECR Tracker. See M1300323 for a description. WHEN = WHENVENT status, waiting for an opportunity during a vacuum vent; PEND = PENDING status, being actively worked to a resolution. The risk factors are defined as follows:

- Impact: potential for significant cost or schedule impact to operations (e.g. requiring a vacuum vent, lengthening commissioning time)
- Performance: potential to limit performance, or key functionality
- Reliability: potential to limit duty cycle
- Safety: potential for unsafe conditions (personnel or machine)

ID	Status	H1	L1	Summary	Risk Factor Comment	Impact	Performance	Reliability	Safety
760	PEND	✓	✓	CDS Real-time System Parameter Configuration Contro	System complexity in commissioning and operations is exacerbated by lack of visibility in parameter changes.	✓			
848	WHEN		✓	ISS Picomotor Nonfunctional	Necessary for proper alignment into the ISS PD Array. Requires a vacuum vent to repair.	✓	✓		
857	WHEN		✓	L1 ETMY (QUAD) L2 (PUM) UR channel actuation failure	Redundancy allows operation. Requires a vacuum vent to repair.	✓		✓	
871	WHEN		✓	L1 ITMY (QUAD) L1 (UIM) UR channel actuation failure	Redundancy allows operation. Requires a vacuum vent to repair.	✓		✓	
929	WHEN	✓		H1 ETMX (QUAD) L2 (PUM) UL channel excess sensor noise	Redundancy allows operation. Requires a vacuum vent to repair.	✓		✓	
930	WHEN	✓		H1 SR2 M2 UL Coil Does Not Actuate -- In-vac Problem	Redundancy allows operation. Requires a vacuum vent to repair.	✓		✓	
931	WHEN	✓		SEI/SUS IOPs Intermittently Turn Off DAC Output	Reduces up-time.			✓	
935	WHEN	✓		H1 SRM osems (LF RT SD and	Noise may ultimately be found to	✓	✓		

ID	Status	H1	L1	Summary	Risk Factor Comment	Impact	Performance	Reliability	Safety
				T3) have excess noise	be unacceptable. Requires a vent to repair.				
945	PEND	✓	✓	Zero-crossing discontinuity in 18-bit DACs	Injects glitch noise.		✓		
964	PEND	✓	✓	ISC Anti-Alias Chassis is very hot	Potential for reduced lifetime			✓	
974	PEND	✓	✓	Sensitivity of optic alignment to building temperature	Reduces up-time			✓	
997	PEND		✓	Ring heater electronics produce lines that show up in DARM	Noise injected by RH		✓		

10 Fabrication & Installation Acceptance Reviews

This System Acceptance review is also a meta-review of all of the preceding Subsystem Fabrication Acceptance Reviews and all of the Installation Instance Acceptance Reviews. Consequently a check that all of the reviews have been completed and that all of the essential or important "punch list items" (action items) have been addressed is necessary.

Subsystem Fabrication & Installation Acceptance Reviews	State of Completeness
aLIGO Fabrication Acceptance Reviews	The Subsystem Fabrication Acceptance reviews are defined in M1300468. These reviews are summarized at a top level in L1400006, and at a more detailed level in G1300115.
aLIGO Installation Acceptance Reviews	The L1 acceptance review documents are all linked to DCC entry E1400153.

11 Waiver Log

Provide a link to a single DCC entry where one can find a compilation of all waivers issued by the project.

A log of all the aLIGO project waivers issued is collected at this DCC entry:

- E1500147: aLIGO, Waiver Log

Some of the potentially most significant waivers from a performance standpoint are the subset of waivers which involve core optic components (COC), which are collected at this DCC entry:

- E1500134, aLIGO COC Waivers

The spreadsheet filed at this DCC entry indicates for each optic whether a waiver was granted, the nature of the waiver and the documented basis for the waiver.

Waivers which were granted as part of the resolution of integration issues are tagged in the Integration Issue and ECR Tracker. A filtered list of issues associated with waivers can be obtained at this URL:

- waivers

At the time of this report there are 8 such waivers, which are summarized in the table below:

Table 4: Waivers issued to resolve integration issues

A filtered list from the Integration Issue and ECR Tracker. See M1300323 for a description. WHEN = WHENVENT status, waiting for an opportunity during a vacuum vent; PEND = PENDING status, being actively worked to a resolution. CLOSED = issue has been resolved.

ID	Status	H1	L1	Summary	Waiver
4	CLOSED		✓	L1 ITMx (ITM04) & ITMy AR coatings are out of spec	
20	CLOSED		✓	ECR: Change the CP design (wedge angle direction) in the ITMy suspension assembly	TRB report (L1200291) recommendation: Due to the fact that the CP ITMy was already installed (Oct 2012) we will flip the CP ITMy in-situ and cut the ESD cabling thus making the ESD un-available for L1 ITMy. We propose to then leave the LLO ITMy as is, without the ESD function, for duration of project. This is possible because the ESD is not needed on the ITM’s for locking. This is a waiver request that the TRB recommends and aLIGO Systems Engineering approves.
46	CLOSED	✓		Reversal of wedge orientation for hanging PR3-01 in H1	This optic was damaged (small cracks) when a metal prism was knocked off. Options for how to proceed were discussed in T1200494. We concluded that the best way forward was to hang the optic upside down relative to the design orientation to avoid regluing a prism on a weakened area. It was confirmed with the IO group that this has no negative implications for the position of any transmitted beam and associated baffling since there is no appreciable transmitted beam from this optic and hence no baffling is used. Systems Engineering approved the ECR E1201105.
57	CLOSED		✓	Do we accept Beamsplitter AR coatings with absorption at the 1.8 ppm level?	Both the H1 and L1 BS optics have higher than specified AR coating absorption (1.7 ppm L1, 1.4 ppm H1 vs < 1 ppm specified). An revised analysis (E1500055), taking into account the as-built absorption of the other interferometer optics, indicates that up to 2 ppm absorption should be acceptable for the BS AR coating. On this basis Systems Engineering waived installation of these BS optics.
195	CLOSED	✓		crack in PUM in ETMX suspension at LHO while welding	While welding fibers to a penultimate mass (PUM) for the H1 ETMx suspension, a crack formed in the PUM. The welding procedure was changed, based on the TRB report (T1300632). Strength and thermal noise considerations indicated that the crack would not be problematic, so Systems Engineering granted a waiver to install this PUM.

ID	Status	H1	L1	Summary	Waiver
614	CLOSED	✓		ETM HR coating for green out of spec	The ETM coating transmission at 532nm wavelength is ~38% rather than 4% as specified. This was discovered after the ETMs were installed. ISC has demonstrated the capability to routinely lock on the green beam even with the very high 532 nm ETM transmission. Systems Engineering has decided to accept the waiver on the installed ETM green transmission values given the very significant time, cost and risk to replace the ETM optics.
621	CLOSED	✓		LHO ITM03 crack	While de-bonding an "ear", an accident caused a small crack in the ITM03 optic. The de-bonding process was changed. Systems Engineering granted a waiver to install ITM03 as the H1-ITMx optic for the following reasons: (a) schedule concerns, (b) no spares available at the time, (c) the location and size of crack were estimated to cause little effect.
805	CLOSED		✓	IM3 (HAUX) first structural mode resonance non-compliance	The somewhat lower (133 Hz) than nominally required (150 Hz) structural resonance of this small HAUX suspension is not likely to be a problem. We will not fix until/unless shown to be a problem during commissioning.

12 Appendix: Open ECRs

All of the open (unresolved, incomplete) ECRs, as of the date of this report, are summarized below. The "key" (or somewhat significant) ECRs are discussed in section 5.5.

Table 5: Open ECRs

A filtered list from the Integration Issue and ECR Tracker. See M1300323 for a description. WHEN = WHENVENT status, waiting for an opportunity during a vacuum vent; PEND = PENDING status, being actively worked to a resolution.

ID▲	**Resolution**	**Key**	**Title**	**Status**
81	WHEN		add vacuum hardware to TM chambers for future instruments without venting	To be used for de-ionizer (bug 948). Not yet installed on all TM chambers at both sites.
97	PEND		Add direct wire connection between RT and EtherCAT systems	Waiting for completion of install at LLO. **Completed for H1.**
484	PEND		ECR: Adding h1psl0 to the Dolphin network	Under investigation.
505	WHEN	✓	drift of BS pitch during PRMI carrier lock	Baffles to shield BS wires from beam heating have been fabricated. **Completed for H1.** Pending a vent for L1.
619	PEND		Implementation of interface for PSL temperature box and replacement of reference cavity heater power supply	Still pending. Not urgent.
630	PEND	✓	CPS cross talk	Basic fabrication completed. First set tested OK at LLO week of 10/20/2014. Some minor power supply and cabling changes being made, then will install everywhere..
659	WHEN	✓	options to ameliorate spot size issues with ISS PD arrays in HAM2 chambers	**Completed for H1.** For L1 install parts are being gathered. Will install when convenient to vent vertex.

ID▲	Resolution	Key	Title	Status
696	PEND		Adding auto-alignment for ALS	**Hardware was installed on both H1 & L1**. Need updated block & wiring diagrams.
716	PEND		Add a relay switch for ALS laser noise eater	Tests successful. ECR pending.
746	PEND		ECR: store suspension mis/alignment values separately in EPICS database	Approach decided. Coding and testing are pending.
777	PEND		Low signal strength for green PFDs	**Completed for H1**, 3rd ifo parts in hand. LLO implemented for DIFF, but not yet for COMM.
870	PEND		Possible OpLev beam scattering	Threat of ECR; Evaluation/decision pending.
873	PEND		Add GigE cameras to ISCT1 and ISCEX & ISCEY tables.	**Completed for L1.** Documentation update pending. H1 implementation pending.
907	WHEN	✓	universal & long-term solution to the systemic ESD shield-to-center conductor shorting problem	Partial implementation on H1 and on L1.
910	PEND		L1 ETMY ISI readout of in-chamber temperature sensors	Test on one chamber on L1.
912	PEND		ECR: Additional ITM Spool Camera Viewports	**Completed for H1.** Pending on L1.
913	PEND		ECR for Adding calibration models to front ends	Implemented on L1 except holding off on the gamma model as we investigate whether we have enough computational power in a single core. Not yet implemented on H1.
917	---		ECR - Acquisition of FSS RFPD DC signal	Completed on H1. Pending for L1.
921	PEND		Removal of old Guardian infrastructure from SUS models and MEDM screens	The vestigial guardian material must still be removed from the triple suspensions (BSFM, HLTS, and HSTS) at both sites. **Completed for L1.** A little work remains for H1.
927	PEND		ECR for Picomotor Collar Retrofit	Partial implementation for both H1 & L1. To be retrofitted on a chamber by chamber basis as vent opportunities become available.
936	PEND		Increase Versatility of Recycling Cavity Suspension Control (H1 ONLY)	**ECR applies to H1 only.** Most of the changes have been completed. Task remains to install an independent path from LSC to PRM, SRM, PR2, SR2 M2 stages for MICH compensation.
942	---		ECR: Clean Up Corner Station Ground STS2 Readout System	**Completed for H1.** Pending for LLO.
944	PEND	✓	ECR for a low-noise, low voltage electrostatic driver	In design (on LIGO Ops). Will procure hardware on aLIGO funds by end of Mar 2015. Subsequent installation will be on LIGO Operations.
946	PEND		ECR- Convert PSL laser to medium power mode	**Completed for both H1 & L1**. Documentation updates are pending.

ID▲	Resolution	Key	Title	Status
947	PEND		ECR for redundant Data Concentrator, h(t) generation	Testing at L1 test stand successful so far. Testing on larger LHO test stand pending. Not implemented for either H1 nor L1 as yet.
948	PEND	✓	Test Mass Charge Prevention and Neutralization	Design review completed. Procurement/fabrication underway.
949	PEND		Inadequate Current Limitation to In-Vacuum Wiring?	A concern raised, but no actionable ideas/tasks defined as yet. (ECR threat)
950	PEND	✓	Facility Class UPS	Under study; No recommendations as yet. Likely to purchase & install UPS system
954	PEND		ECR: Modifications to quad UIM magnet/flag assembly and coil driver	Testing to date does not indicate an ambient magnetic field coupling above requirements. This ECR is on hold pending further testing at LLO.
955	PEND		ECR for dedicated CPU cores for PCal front-end models	**Completed for H1.** Pending on L1.
956	PEND		ECR: Addition of one ADC card and one AA chassis at each end station to accommodate Pcal channels.	**Completed for H1.** Pending on L1.
960	WHEN		ECR to add a beam splitter in the L1 OMC REFL path	**Completed on L1**. Pending on H1.
961	PEND		Low pass filter needed on periscope piezo to limit noise injected into the interferometer	**Completed on L1**. Pending on H1.
968	PEND		addition of a second RAID array for increased frame look-back time	**Completed for H1.** Pending on L1.
970	PEND		Intermodulation Mixing on Broadband Photodetectors	Fixed differently for H1 and L1. Need to come up with common (pending) solution.
971	PEND		Install QPD.mdl library part inside the HAM-ISI model (don't calculate or store "butterfly" signal)	Pending for H1 & L1.
975	WHEN		In-vacuum beam dump for IM4 reflection sample beam	Pending design/layout, fab, installation for H1 & L1, storage for 3rd IFO.
976	PEND		ECR to implement a viscoelastic, tuned mass damper on the UIM blade springs	Design has been prototyped and is in test.
998	PEND		Move IO input beam PZT-mount from periscope to PSL/IO table surface	Design new periscope mount & update assy dwgs. **Reconfiguration already accomplished for L1.**
1000	PEND		Splitting ISC models	Split the ISC models in order to reduce the front end processor load and thereby reduce the IPC error rates.
1002	PEND	✓	scattering noise in DARM from HAM6	Designed a black glass enclosure for the OMC. Getting quotes.
1006	PEND		ECR for proposed changes to the aLIGO PSL MEDM screens	Spelling corrections & color changes.
1007	PEND		ECR - Change to PSL Outer Loop Power Stabilization Electronics	Minor functional improvements in the electronics. Pending.

ID▲	Resolution	Key	Title	Status
1011	PEND	✓	Hardware Watchdog	(The Hardware Watchdog was initiated prior to imposition of the ECR process.) "Stuck" in testing/acceptance. May require some re-design. Revised technical review to be initiated.

13 Appendix: Open Issues

All of the open (unresolved) issues, as of the date of this report, are summarized below. The "key" (or somewhat significant) issues are discussed in section 9.2.

Table 6: Open Issues/Tasks

A filtered list from the Integration Issue and ECR Tracker. See M1300323 for a description. WHEN = WHENVENT status, waiting for an opportunity during a vacuum vent; PEND = PENDING status, being actively worked to a resolution.

ID	Status	Key	H1	L1	Summary	Status
9	PEND		✓	✓	SUS Coil Driver Noise Monitor Circuits Untrustworthy	*An on-going, low priority task to assess the functionality of the coil monitors; Repairs to be made when system availability permits*
17	PEND		✓		PSL/ISC racks very close	*issue to remain open until the HV supplies and the UPS are moved. Then recommend that we leave the PSL racks where they are located.*
33	PEND		✓	✓	Lack of drawings for timing diagnostics/cesium clock replacement	***Completed for L1***. *Drawing updates for H1 pending.*
242	PEND		✓		Pressure Sensing Location for the HEPI Pump Station Servo	*To make HEPI pressure sensing for H1 like it is for L1. Cables have been run. Need commissioning to allow HEPI to go offline to switch over.*
332	PEND		✓	✓	RF phase shifts when cables moved	*Make a check list for routine maintenance or inspection*
425	PEND		✓	✓	TTFSS high frequency response needs investigation	*Experiments proposed to evaluate other potential solutions.*
463	PEND		✓	✓	AA Filter Chassis Power Regulator Board Has Potential Short Circuit on -15V Rail	*We continue to upgrade filter boards to v6 and update the regulator insulators whenever we swap out an AA or AI chassis. This is ongoing.*
513	WHEN			✓	Stray reflections from HAM4 HWS in-vacuum optics are potentially corrupting the HWS return beam	*rotate the in-vacuum lenses to larger angles in LHAM4 the next time we vent that chamber*
590	PEND		✓	✓	IO PDs monitoring power at the EOM and at the periscope	*Move IO EOM & periscope PDs from fast readback ADC channels to slow controls system to enable rotation stage software to alarm on these signals.*
598	PEND		✓	✓	SMA connectors on demod chassis	*Verify that all existing SMA connectors on demod chassis are installed properly & repair if not. On-going.*
599	PEND		✓	✓	EPICS gateways	***Completed for L1***.
600	PEND		✓	✓	medm screen editing	*Idiosyncrasies and limitations of the MEDM editor when used for generic screens and sub-screens. Perhaps a revised schema will minimize editing issues?*

ID	Status	Key	H1	L1	Summary	Status
615	WHEN			✓	Unresponsive GS13 (V2) on ITMY (BSC1)	*Intermittent GS13 seismometer in the BSC-ISI for LBSC1. Requires a vent to repair or replace. This failure doesn't impact the isolation performance of this unit because we don't use the vertical GS13 to provide isolation on any unit. In the standard configuration, the vertical isolation is provided by a combination of Stage 1 sensors (RX,RY,Z) and Z sensor correction using the ground instrument. We only use X and Y on BSC-ISI Stage 2 (with 250mHZ blends).*
662	PEND		✓	✓	Use of GE FANUC RFM cards on end-station SEI, SUS front-ends	***Completed for L1***. *Pending for H1.*
668	PEND		✓	✓	DC Switch Breaker Box Install in Pier Pod and TCS ISS Power cords.	***Completed for L1***. *Pending for H1.*
713	PEND		✓	✓	AA/AI placement in End Station Remote rack	***Completed for L1***. *Rack layout drawing needs revision.*
741	PEND		✓	✓	ISC/IO tables: Lights and fan status readback	*Low priority to design Beckhoff slow controls approach and then implement.*
751	PEND		✓	✓	Op Lev Cover for lead bricks	*Covers received. In process of installing. (Used to for passive damping of OptLev structure.)*
760	PEND	✓	✓	✓	CDS Real-time System Parameter Configuration Control	*With the RCG v2.9 release we now have Settings Definition Files (SDF) and can track parameter changes and appropriate parameter settings (with Guardian). This capability does not yet extend to the Slow Controls System (Beckhoff) through the TwinCAT IOC.*
761	ONHO		✓	✓	In Situ, Visual Inspections of All Viewport Windows	*78% inspected. Further in situ inspection is not practical without a vent or some interference with commissioning, so activity is on hold.*
764	PEND		✓	✓	Second trend readback is slow	*Commissioners want faster trend data readback (currently 1 minute for 1 day).*
779	PEND			✓	HAM 2&3 and ITMX, BS & ITMY (ISI and HEPI) local models slightly differ from documentation (ADC/DAC numbering)	*Fix difference in hardware ADC/DAC numbering in reality versus documentation.*
788	PEND		✓	✓	mechanical problems with the Optical Levers (OptLev) at both sites	*Optical lever pylons are not grouted, plus a number of mostly minor installation quality issues related to the optical levers (e.g. lack of connector strain relief, missing cover, cables not dressed neatly, incorrect size grommet, etc.). Pylons are being grouted, and other issues being addressed as well.*
803	PEND		✓	✓	IM3 (HAUX) excess noise on UL channel	*IM3 LR channel switched to another AA/ADC channel. Noisy AA/ADC channel. Board to be replaced & repaired when convenient.*
804	WHEN			✓	IM1 (HAUX) excess noise on LR channel	*Source of the excess noise has been isolated to within the vacuum system. Replacement/repair requires a vent. Can continue to function due to sensing redundancy.*
830	WHEN			✓	L1 SRM (HSTS) M2 stage sensor read-back issue	*M2 stage sensor read-back problem only. Requires a vent to repair/replace.*
831	WHEN			✓	L1 SR3 (HLTS) M2 UL channel high frequency turn-up	*M2 stage sensor read-back problem only. Requires a vent to repair/replace.*

ID	Status	Key	H1	L1	Summary	Status
843	WHEN		✓		60Hz spikes in OSEM spectra for H1 PRM suspension	*Some lines gone, some diminished, some new. Leave open until we know whether this is problem or not.*
848	WHEN	✓		✓	ISS Picomotor Nonfunctional	*Picomotor is to be repaired (by method in bug 927) when the outer loop PD array for the ISS is replaced with a revised design (per ECR bug 659).*
850	PEND		✓		H1 PSL sensitive to environmental temperature changes	*Better alignment into the PMC reduced temperature sensitivity. Also working to reduce temperature fluctuations. (Not an issue for L1)*
854	WHEN		✓		Assess/tighten in-vacuum periscopes/optic mounts in MC REFL path	*To be addressed in the next vertex vent.*
857	WHEN	✓		✓	L1 ETMY (QUAD) L2 (PUM) UR channel actuation failure	*Isolated to an in-vacuum problem. Repair of OSEM at a convenient vent. Redundancy allows continued operation.*
869	PEND		✓	✓	L1 ISI Coil Driver over-temp warning indicator illuminates on power up	***Completed for L1**. Temperature reset wiring for ISI coil drivers to be checked for H1.*
871	WHEN	✓		✓	L1 ITMY (QUAD) L1 (UIM) UR channel actuation failure	*Isolated to an in-vacuum problem. Repair of OSEM at a convenient vent. Redundancy allows continued operation*
874	WHEN			✓	He leak in LHAM1, apparently from REFL-A In-vacuum detector	*Requires a vent of the LHAM1 chamber to replace unit. Not urgent.*
904	WHEN		✓	✓	ESD Signal Chain is Ill-Defined in Documentation and Therefore Inconsistently Connected On Each ETM.	*Wiring documentation issues. Need a vent opportunity to confirm reality against documentation.*
915	ONHO		✓	✓	BSC-ISI T240 Gain Switching	*Minor – there is an inconsistency in the way that we set T240 gains versus L4C and GS13s.*
919	PEND		✓	✓	v4&v5 of the AA/AI board cannot drive long cables	*On-going – use 3rd IFO v6 units to swap out units in L1 & H1 and stock in-process spares for L1 & H1. Update all v4/v5 units to v6.*
923	PEND		✓	✓	Beam centering servos for ALS WFS	*Test on H1 before deciding if it merits inclusion in the baseline (ECR). Results of testing still pending.*
924	PEND		✓	✓	Blown capacitor on TCS sled driver chassis D1200614 S/N S1301374	*Add an electrically isolated heatsink to prevent the lid from contacting the regular tab and shorting it.*
929	WHEN	✓	✓		H1 ETMX (QUAD) L2 (PUM) UL channel excess sensor noise	*Address in-vacuum cabling at next H1 end-X vent.*
930	WHEN	✓	✓		H1 SR2 M2 UL Coil Does Not Actuate -- In-vac Problem	*Address at next H1 vertex vent.*
931	PEND	✓	✓		SEI/SUS IOPs Intermittently Turn Off DAC Output	*Improved diagnostics in RCG v2.9 being used to isolate & understand the problem.*
934	WHEN		✓	✓	Beam Diverter Sticking	*Rebalance and lubricate (with Krytox) when next vent occurs.*

ID	Status	Key	H1	L1	Summary	Status
935	WHEN	✓	✓		H1 SRM osems (LF RT SD and T3) have excess noise	*Cable shield is grounded in-chamber. Fix at next vent.*
937	PEND		✓	✓	RF power amplification for modulation (EOM) drivers	*There isn't currently a dedicated EOM driver for the main modulations; we just use fixed outputs of the RF distribution. We removed this item from ISC scope fairly early on in the project, because it wasn't clear that it would be important. Now we find that we need a dedicated EOM driver.*
938	WHEN		✓	✓	As-Built versus Intended View-port & Camera layout for HAM6	***Completed the hardware changes for both L1 & H1**. The design documentation must be revised to be consistent with this as-built configuration.*
939	WHEN		✓		H1 HWSY in-vacuum lens is not correct	*A temporary solution has been implemented. Repair to the baseline design at next vent opportunity.*
940	PEND		✓		H1 ITMY arm cavity baffle diode numbering	*Update drawings to match as-built numbering/order.*
941	WHEN			✓	Installation of ESD pressure switches into LVEA chambers	*Ready for testing, but needs a vent to do so.*
943	PEND		✓	✓	change names to all uppercase in ISI2stagemaster.mdl	*In process*
945	PEND	✓	✓	✓	Zero-crossing discontinuity in 18-bit DACs	*We are implementing the manufacturer's firmware fix. (Requires de-soldering a chip from each board.)*
958	PEND			✓	increasing the beam-diameter on the IMC WFS sensors	*Increasing the beam-diameter on the WFS sensors has reduced the misalignment introduced by the motion of the beam on the WFS sensors by an order of magnitude. We will check to see that the effect is reproducible on a few month scale.*
962	PEND		✓	✓	Whitening Chassis front panel cable connector nuts are too big	***Fixed for L1.**. Problem still present on H1.*
963	PEND		✓	✓	CPS Boxes have floppy copper things and are not mounted stably	***Fixed for L1**. Drawing for brackets created. Pending for H1.*
964	PEND	✓	✓	✓	ISC Anti-Alias Chassis is very hot	*Working on a solution involving re-locating of modules within the racks. An ECR will be pursued to document the change.*
966	PEND		✓	✓	SUS Wiring Diagrams Do Not Include Field Rack Layouts	*Documentation of SUS field racks may be incomplete, or confusing.*
972	PEND		✓		The Readouts of the HAMs 2 & 3 ISI OpLevs are reversed in Pitch & Yaw	*Updated matrix values compensate – functions OK now. Not clear if the matrix values compensate for a physical mis-wiring relative to the drawing, or was the drawing in error. The design drawings may need to be updated.*
974	PEND	✓	✓	✓	Sensitivity of optic alignment to building temperature	*A lot of commissioning time is spent on (re)aligning the interferometer. A lot of this can be attributed to drifts in the quad suspensions, likely caused by building temperature changes affecting the suspension.*
978	PEND		✓	✓	Search bug in electronic logs	*Request to improve search function in the electronic log.*
992	WHEN		✓		In-vac QPD cable strain relief should be installed	***Fixed for L1**. Parts available for H1 – replace when vent opportunities arise.*

ID	Status	Key	H1	L1	Summary	Status
993	---			✓	L1 X-end PCAL Laser is Glitching	*Glitching at high power.*
994	PEND		✓	✓	brackets to lock the BSC-ISI	*Documenting parts and procedure.*
996	WHEN		✓		WHAM5 optical lever in-vac retro-reflector misaligned	*Waiting for vent opportunity.*
997	---	✓		✓	Ring heater electronics produce lines that show up in DARM	*Difference between X and Y behavior may be due to potential grounding issue on X-end RH.*
999	PEND			✓	Fix of the two LLO PMC's	*One appears to have a noisy PZT and the other has low throughput. May need to redesign PMC for improved reliability.*
1001	---		✓	✓	Timing Comparator New Code	***Code update complete for H1**. Pending for L1.*
1004	---		✓	✓	HEPI pump servo adding noise to HEPI and IFO	*Much of the noise has now been mitigated at LHO (grounding and proper pressure on accumulators). LLO iLIGO pump controllers need to be updated to aLIGO controllers.*
1005	---		✓		0.6Hz line on HAM3	*Still hunting for origin.*
1008	PEND		✓	✓	GPS synchronization for CO2 RF frequency	*Need a coax cable pulled from wherever the nearest 10MHz clock output is to the mechanical room.*
1009	---		✓	✓	CO2 laser power connectors are very flimsy at table feedthroughs	*Need strain relief design*
1010	PEND		✓	✓	HWS SLED temperature not reading back on D1200614	*Temp sensors are not used for feedback control of SLED temperature regulation – monitoring only. It's probably a wiring issue as it's common to both sites.*
1012	PEND		✓	✓	IO Photo Diodes on PSL Table at Normal Incidence	*Could lead to noise from back scattered light. Photodiodes should be rotated and reflected light directed into a beam dump.*
1013	---		✓	✓	Input Faraday Isolator performance in Vacuum	*No measurements of isolation ratio or thermal steering under vacuum at 125 W for the Input Faraday Isolators.*
1014	---		✓	✓	No remote indication when TCS CO2 AOM warning lights turn on	*Need to capture all fault conditions for EPICS alarming.*
1016	PEND		✓		ETMY and ITMX RH RTD (temperature sensors) are non-responsive	*The RTDs are only used for monitoring.*