ALIGO SYSTEM ACCEPTANCE DOCUMENT

Title: aLIGO L1 System Acceptance Document

This document covers the technical content for acceptance review of an 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.

N.B.: This version (-v1) is an initial, incomplete version, issued while the document is still being written, to permit simultaneous review by the L1 Systems Acceptance Review Committee.
Missing content is noted in red italics text.
Content which requires update or revision is noted in magenta italics.

1 aLIGO System Definition

The scope of this aLIGO System Acceptance Review is an entire interferometer detector system at a LIGO observatory. All of the documentation cited in this acceptance document must be filed electronically in the LIGO Document Control Center (DCC) and linked in a document tree accessible from the root node entered below.

Interferometer [*L1 or H1*]:	L1
DCC document tree root node:	E1200123, aLIGO Document Tree

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.

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
  (to be updated per notes field in DCC entry)

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”)
- E1101226: Proof Test Levels for Advanced LIGO Viewports

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	Quality Assurance: • M960076: Advanced LIGO Quality Assurance Plan • M080331: Advanced LIGO Supplier Quality Requirements • M080352: Quality Assurance Boilerplate for RFQ`s
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 *(to be updated per notes field in DCC entry)* • 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. *These responses will be updated to reflect current status.* • L1000439: aLIGO Systems Final Design Review Report • L1000311: aLIGO Systems Final Design Review Questions & Answers *(as-built update pending)* • L1400154: Response to Questions from the L1 Systems Acceptance Review
Reliability/ Availability: *[enter a linked list of DCC documents which address system reliability/ availability]*	• T1300519: Sparing Analysis • E1400299: aLIGO System FMEA *TBD: A complete detector system FMEA is in preparation using Reliasoft Xfmea software.* • E1400310: aLIGO Availability Estimate *(needs some minor updates based on feedback)*

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 listed at E1200562 and found linked under D0901491.

Optical Layout: *[enter a linked list of DCC documents*	The optical layouts are maintained in Zemax™. The optomechanical layouts (top level assemblies) are maintained in SolidWorks™. These layouts are not independent. Zemax

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addressing the optical layout]	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)
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

Opto-Mechanical Layouts: D0901491, aLIGO Mechanical Layout
[enter a linked list of DCC top-assembly drawings for each building and chamber.
N.B.: Chamber top-assembly drawings are reviewed in the installation acceptance reviews]

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

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. 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
Hydrocarbon Contamination: *[documents specific to hydrocarbon contamination*	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

including qualification tests for UHV compatible materials and an estimate of the residual gas load in the system]	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]. 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
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]*	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 TBD number (N) of vent/purge/pump-down cycles, before we accumulate an unacceptable level of coating damage (pin-holes). In case N is found to be operationally restrictive, an ionized gas jet

[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.

[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.

	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

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
Interfaces: *[collect a list of all interface definition]*	Interface documents are collected as a flat list of links under the DCC entry E1300955 *Needs some scrubbing -- not all of these documents are relevant and interface definition is also found in sections of design documentation, which should also be listed/captured here.*
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
Technical Review Board (TRB) Reports: *[collect a list of all RODAs issued during the project]*	Technical Review Board (TRB) reports are collected as a flat list of links under the DCC entry E1300957 *Needs some work – not all of the (in essence) TRBs are listed here. Need to cull through the DCC and collect all and make sure a report is issued for each TRB. In particular there were a number of peer reviews of detailed electronic designs at the circuit schematic level – look to see if there is documentation on these review and inclue them in the TRB list.*

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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 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 exceptions are Guardian and ISC software, because they are not mature; This software is evolving rapidly as part of the commissioning effort.

A list of ECRs is available as a filtered list of the Integration Issues and ECR Tracker:

- All ECRs
- All Open ECRs

As of this report's date, there are 149 ECRs of which 44 are still open, i.e. not fully 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 below with a brief summary of the status. Of these 44 open ECRs, there are 4 marked with status "WHENVENT" meaning that when an opportunity arises during a vent, the ECR will be implemented.

ID▲	Resolution	Title	Status
13	PEND	Cleanup polarization after fiber in end station	Only waiting on documentation from LLO
81	WHEN	add vacuum hardware to TM chambers for future instruments without venting	To be used for de-ionizer (bug 948). STATUS?
97	PEND	Add direct wire connection between RT and EtherCAT systems	Waiting for completion of install at LLO
469	PEND	ECR: New naming scheme for OMC channels	Still to do: update E1300079; T1300532; TwinCAT code.
484	PEND	ECR: Adding h1psl0 to the Dolphin network	Under investigation. To be updated.
619	PEND	Implementation of interface for PSL temperature box and replacement of reference cavity heater power supply	May be completed. To be updated.
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..
657	PEND	upgrade IOP software watchdogs to use targeted dackill	H1 install completed. L1 install pending.
659	WHEN	options to ameliorate spot size issues with ISS PD arrays in HAM2 chambers	H1 install completed. For L1 install parts are being gathered. Will install when convenient to vent vertex.
696	PEND	Adding auto-alignment for ALS	Hardware was installed on both H1 & L1. Need updated block & wiring diagrams.
714	PEND	Move the 79.2MHz doubler to ISC-R4	Installed on H1. Pending installation for L1.

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

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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	Implementation done at LHO, 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.
872	PEND	ECR - RCG Code Change Request - RCG Version 2.9	Release issued. Implemented on L1. Pending on H1.
873	PEND	Add GigE cameras to ISCT1 and ISCEX & ISCEY tables.	Completed for L1. Documentation update pending. H1 implementation pending.
907	PEND	universal & long-term solution to the systemic ESD shield-to-center conductor shorting problem	Design completed, parts ordered. Implementation pending.
912	PEND	ECR: Additional ITM Spool Camera Viewports	Implemented on 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.
922	PEND	Removal of old Guardian infrastructure from SEI models and MEDM screens	Pending for L1 & 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.
928	PEND	CM Board Modifications (green finesse)	Status?
936	PEND	Increase Versatility of Recycling Cavity Suspension Control (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	Status?
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.
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 on 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 on 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 H1. Pending on L1.
968	PEND	addition of a second RAID array for increased frame look-back time	Completed on 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	In design.
977	PEND	Auto-centering of the IMC WFS beams	Threat of an ECR. Still under evaluation by commissioning team.

6 System Performance Models

GWINC:	*TBW*
Noise Budget:	*TBW*
SIS:	*TBW*

7 Supervisory Control & Monitoring

Some of the tools referenced below were not built by the aLIGO project, but by LSC members. Credit for their development is cited. 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 key operational tools, then the maintenance, upgrades and degugging may end up being LIGO Operations tasks.

Interferometer Automation System (Guardian):	The aLIGO automation system is known as Guardian. The requirements for Advanced LIGO automation are outlined in T1300884, and an overview description and user manual for the aLIGO Guardian system is described in G1400016. The current status (T1400461) is briefly as follows: • the core Guardian engine has been developed and deployed, • the supervision infrastructure has been deployed, • the suspensions and the seismic isolation systems are fully automated with Guardian managers, • the Input Mode Cleaner (IMC) auto-locker has been implemented (on H1; nearly complete on L1) • an initial automation procedure for full lock acquisition has been demonstrated on L1 • a monitor-only, top-level Guardian node has been implemented for reporting the overall lock status to the ODC system, as part of a system state A few additional Guardian tasks have yet to be completed within the aLIGO project (defined in T1400461) including (a) adding the capability to track and set real time system parameters, (b) the capability to map Guardian nodal states (numbers) to a definition (either self-defined or against a published dictionary) and (c) improved documentation.
Operation Manual(s)/ Guide(s):	TBW Plan to cite major subsystem operation manuals (SUS, SEI, etc.) Perhaps operator training material as well.
Channel List:	Much more TBW LIGO Channel Activity Monitor (LigoCAM) 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 nonastrophysical origin. Although PEM was not part of the aLIGO scope, links for the PEM channel list are included for completeness. ER6 PEM list: https://wiki.ligo.org/DetChar/ER6DetcharChannels LigoCAM link (currently PEM and SUS only): https://ldas-jobs.ligo-wa.caltech.edu/~dtalukder/Projects/detchar/LigoCAM/LigoCAM_host/LigoCAM_PEM_LLO.html PEM interactive maps: http://pem.ligo.org/channelinfo/index.php
Control Room	TBW

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Tools/System:

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 key 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 key to 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 50 MPc range (L1 elog #15822).

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) 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.

The "significant" technical issues that we have not resolved for the aLIGO system are as follows:

1. Parametric Instability (PI): This is still an active domain. Research (on Operations funding) into a passive control of parametric instability (PI) (e.g. 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) 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.
2. 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 and
   - is planning on producing the necessary number of positive/negative discharging units based on a prototype design by Rai Weiss (T1100332, T1400535). We expect to resolve this before the completion of the Project.

A complete solution of the ETM charging issue is likely to additionally require the following tasks (which are considered Operations scope):

- relocating the large ion pumps further from the ETMs (e.g. onto the BT) and/or adding large Non-Evaporable Getter (NEG) pumps.
- Addition of shielding to the large ion pumps in order to reduce the emission of soft x-rays and UV light which cause the charging.

3. Low frequency, low noise performance of the suspension systems had not been proven: The performance has not yet been tested at the full aLIGO sensitivity. 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.
4. 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 an technical evaluation of Uninterruptible Power Supply (UPS) solutions as a likely means to mitigate this problem.
5. 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.

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.

- All detector open issues & ECRs
- All Open ECRs

As of this report's date, there are 116 open (unresolved) issues and/or ECRs (not specific to H1):

- 44 are open ECRs (covered in section 5 above)
- 25 have a status of "WHENVENT" and are not ECRs (however 11 of these are place holders for collecting actions organized by vacuum chamber when convenient to vent)
- 2 have a status "ONHOLD" and are not ECRs
- 45 are neither open ECRs nor with a status of "on hold" or "when vent".

The open (unresolved), non-ECR, issues (other than the 11 chamber place holders), which total 61 are summarized in the list below.

ID▲	Resolution	Summary	Status
9	PEND	SUS Coil Driver Noise Monitor Circuits	*Summary status TBD*

		Untrustworthy	
33	PEND	Lack of drawings for timing diagnostics/cesium clock replacement	*Summary status TBD*
85	PEND	procedure(s), safe-guards and cautions for safe/proper use and diagnosis of equipment	*Summary status TBD*
142	PEND	PEM monitoring channels need to be set up	*Summary status TBD*
332	PEND	RF phase shifts when cables moved	*Summary status TBD*
425	PEND	TTFSS high frequency response needs investigation	*Summary status TBD*
463	PEND	AA Filter Chassis Power Regulator Board Has Potential Short Circuit on -15V Rail	*Summary status TBD*
513	WHEN	Stray reflections from HAM4 HWS in-vacuum optics are potentially corrupting the HWS return beam	*Summary status TBD*
590	PEND	IO PDs monitoring power at the EOM and at the periscope	*Summary status TBD*
598	PEND	SMA connectors on demod chassis	*Summary status TBD*
599	PEND	EPICS gateways	*Summary status TBD*
600	PEND	medm screen editing	*Summary status TBD*
615	WHEN	Unresponsive GS13 (V2) on ITMY (BSC1)	*Summary status TBD*
644	PEND	checking electronics modules without visible over-current protection	*Summary status TBD*
662	PEND	Use of GE FANUC RFM cards on end-station SEI, SUS front-ends	*Summary status TBD*
664	---	5V regulator failing on Timing Comparators	*Summary status TBD*
668	PEND	DC Switch Breaker Box Install in Pier Pod and TCS ISS Power cords.	*Summary status TBD*
713	PEND	AA/AI placement in End Station Remote rack	*Summary status TBD*
741	PEND	ISC/IO tables: Lights and fan status readback	*Summary status TBD*
751	PEND	Op Lev Cover for lead bricks	*Summary status TBD*
760	PEND	CDS Real-time System Parameter Configuration Control	*Summary status TBD*
761	ONHO	In Situ, Visual Inspections of All Viewport Windows	*Summary status TBD*
764	PEND	Second trend readback is slow	*Summary status TBD*
779	PEND	HAM 2&3 and ITMX, BS & ITMY (ISI and HEPI) local models slightly differ from documentation (ADC/DAC numbering)	*Summary status TBD*
788	PEND	mechanical problems with the Optical Levers (OptLev) at both sites	*Summary status TBD*
803	PEND	IM3 (HAUX) excess noise on UL channel	*Summary status TBD*
804	WHEN	IM1 (HAUX) excess noise on LR channel	*Summary status TBD*

830	WHEN	L1 SRM (HSTS) M2 stage sensor read-back issue	*Summary status TBD*
831	WHEN	L1 SR3 (HLTS) M2 UL channel high frequency turn-up	*Summary status TBD*
843	WHEN	60Hz spikes in OSEM spectra for H1 PRM suspension	*Summary status TBD*
848	WHEN	ISS Picomotor Nonfunctional	*Summary status TBD*
857	WHEN	L1 ETMY (QUAD) L2 (PUM) UR channel actuation failure	*Summary status TBD*
858	PEND	REFL-A In-vacuum detector in LHAM1 non functional	*Summary status TBD*
869	PEND	L1 ISI Coil Driver over-temp warning indicator illuminates on power up	*Summary status TBD*
871	WHEN	L1 ITMY (QUAD) L1 (UIM) UR channel actuation failure	*Summary status TBD*
874	WHEN	He leak in LHAM1, apparently from REFL-A In-vacuum detector	*Summary status TBD*
904	WHEN	ESD Signal Chain is Ill-Defined in Documentation and Therefore Inconsistently Connected On Each ETM.	*Summary status TBD*
910	PEND	L1 ETMY ISI readout of in-chamber temperature sensors	*Summary status TBD*
915	ONHO	BSC-ISI T240 Gain Switching	*Summary status TBD*
919	PEND	v4&v5 of the AA/AI board cannot drive long cables	*Summary status TBD*
923	PEND	Beam centering servos for ALS WFS	*Summary status TBD*
924	PEND	Blown capacitor on TCS sled driver chassis D1200614 S/N S1301374	*Summary status TBD*
934	WHEN	Beam Diverter Sticking	*Summary status TBD*
937	PEND	RF power amplification for modulation (EOM) drivers	*Summary status TBD*
938	WHEN	As-Built versus Intended View-port & Camera layout for HAM6	*Summary status TBD*
941	WHEN	Installation of ESD pressure switches into LVEA chambers	*Summary status TBD*
943	PEND	change names to all uppercase in ISI2stagemaster.mdl	*Summary status TBD*
945	---	Zero-crossing discontinuity in 18-bit DACs	*Summary status TBD*
958	PEND	increasing the beam-diameter on the IMC WFS sensors	*Summary status TBD*
962	PEND	Whitening Chassis front panel cable connector nuts are too big	*Summary status TBD*
963	PEND	CPS Boxes have floppy copper things and are not mounted stably	*Summary status TBD*
964	PEND	ISC Anti-Alias Chassis is very hot	*Summary status TBD*
966	PEND	SUS Wiring Diagrams Do Not Include Field	*Summary status TBD*

		Rack Layouts	
967	PEND	to use HEPI or not, that is the question	*Summary status TBD*
973	PEND	ECR: Changes to PSL science frame channels	*Summary status TBD*
974	PEND	Sensitivity of optic alignment to building temperature	*Summary status TBD*
978	PEND	Search bug in electronic logs	*Summary status TBD*
991	---	Fast shutter trips HAM6 platform	*Summary status TBD*

10 Acceptance Completeness Review

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 "punch list items" (action items) have been addressed is necessary. Update the two acceptance tracking documents noted below and indicate the state of completeness in the table below.

Subsystem Fabrication & Installation Acceptance Reviews

State of Completeness

aLIGO Fabrication Acceptance Review Tracking (G1300115)

The Subsystem Fabrication Acceptance reviews are defined in M1300468. The status of these reviews is summarized at a top level in L1400006, and at a more detailed level in G1300115. As of the date of this report, the status can be summarized as follows:

Subsys	Pending	Underway	Completed	Total	% complete	Punch List #
AOS	2	2	11	15	73%	53 + TBD
COC	0	1	0	1	0%	TBD
DAQ	0	0	1	1	100%	0
FMP	0	0	3	3	100%	0
IO	0	1	8	9	89%	55
ISC	7	2	7	16	44%	19
PSL	0	0	3	3	100%	7
SEI	31	18	15	64	23%	TBD
SUS	0	6	44	50	88%	2

Totals	40	30	92	162
	25%	19%	57%	

aLIGO Installation Acceptance Reviews Tracking (G1301153)

The L1 Installation Acceptance review has been completed. The L1 acceptance review documents are all linked to DCC entry E1400153. The L1 Installation Acceptance review "punch list" (E1400152) has 10 open (unresolved) actions remaining as of the

	date of this report.

11 Waiver Log

This is a new section added at the request of the L1 System Acceptance review committee. A compilation of all waivers will be created from existing documentation and files under a single DCC numbered document which will be referenced here.