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Advanced LIGO Project Closeout Acceptance

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1 Executive Summary

The purpose of this memo is to indicate the successful completion of acceptance of the Advanced LIGO project and to recommend to the Directorate and Site Heads that the Project be declared complete, modulo the activities in Data Computing and Storage via a no-cost extension to September 2017. The Project Acceptance requires completion of all of the following steps:

1. Subsystem Fabrication Acceptance Reviews; the requirements are defined in M1100282, and the pointer into the set of review reports is at LIGO-L1400006
2. Installation Subsets Acceptance Reviews; the requirements are defined in F1300019 . The Hanford Installation Acceptance is documented in LIGO-L1500019 , the Livingston Installation acceptance at LIGO-L1400082
3. Long Term Storage Acceptance Reviews; the requirements and Form: M1300455 and the completed documents are at LIGO-M1300164
4. The Integrated Test Team delivers a document that summarizes the state of the L1 and H1 instruments for the two-hour-lock milestone, indicating success for the Integrated Test elements of INS. For L1, that document is LIGO-L1400119 ; for H1 it is LIGO-L1500028.
5. The Project Controls activities must be verified to be completed according to the form at M1300455. Note: this document cannot be completed until all contracts have been closed, and so will not finalize until April 2015.
6. The System Acceptance Reviews Requirements and Form are given in F1300020 and the completed document for L1 and H1 is found in LIGO-E1400371; the Review Report is found in LIGO-L1500032
7. Project Closeout and Acceptance must be documented; the Requirements are found at LIGO-M1300468 and this document represents that report.

With the exception of the project Closeout, each of these types of reviews has multiple instances. The Systems Acceptance Reviews (one for each of the two installed and integrated interferometers) are meta-reviews that include top-level review of all fabrication and installation instance acceptance reviews; there are two phases of the System Acceptance for each interferometer: one for meta-Installation complete (transferring maintenance to Operations), and one for final Systems Acceptance. This document summarizes the process and requirements for each of the reviews and points to the documents for the process.

The Project management finds that the requirements for Project Acceptance have been fulfilled. There are activities that could not be completed because of the disruption it would cause to the Operations Commissioning activity, but the components needed for those punch-list items have been completed and staged for implementation when appropriate. In addition, the Project has identified a number of follow-up actions to improve the sensitivity and availability of the instruments, and those are appropriately documented.

The Project Management recommends that the Advanced LIGO Project be accepted as complete, modulo the Data and Computing Storage activities planned for the no-cost extension of the Project.

2 Subsystem Fabrication Acceptances

2.1 Description

Each instance of each major assembly of each fabrication subsystem has a Subsystem Fabrication Acceptance (leading to a substantial number of reviews), Each fabrication acceptance review covers the subsystem's scope, with regard to the associated major assembly, up to the point of hand-off to the Installation effort/team, including assembly and all pre-installation testing. Hand-off for the elements of the 3rd interferometer is to the Long Term Storage Team.

The requirements for the Subsystem Fabrication Acceptance Review are defined in M1100282. These requirements include (but are not limited to):

- Test rationale, plans, and data for each unit must be documented as described in M1000211 (the Testing plan), but only to the point of 'phase1' pre-installation testing.
  N.B.: No results or design or documentation updates after completion of pre-installation testing are required at this point in the acceptance process.
- The 3rd interferometer assemblies, and all surviving in-process spares, must also be carried through to this point of documentation and testing, including Bills of Material needed for the 3rd interferometer.

In addition to the technical content captured in the Fabrication Acceptance Document, Project Controls requires verification of the following to close out the subsystem:

- All scheduled WBS Level II subsystem tasks 100% complete.
- Confirmation of completion of the defined WBS scope.
- Confirmed delivery of all subsystem components for Long Term Storage.
- All open procurements reconciled and closed.
- Cost book brought up to date.
- All cost accounts closed.

For both Fabrication and Project Controls Acceptance, we require:

- Listing of all outstanding 'punch list items'

A punch list document must be created for any tasks (equipment, testing, documentation, project controls) that are not complete. The punch list will name individuals responsible to resolve each task.

The pointer into the set of review reports is at LIGO-L1400006 . The reviews are complete and indicated successful execution of the acceptance process.

2.2 Scope

Fabrication Acceptance Reviews are required for all subsystems, except Installation and Integrated Testing (INS). Long Term Storage Acceptance is also required in order that the subsystem meet the programmatic closeout.

Not included are the Installation Acceptance and the Systems Acceptance Reviews which cover the technical and programmatic closeouts for INS. The PM (Project Management) and PM-Systems Engineering Subsystem will be reviewed at the end of the project. It has infrastructure

modifications for long term storage as well as contamination control deliverables which fall under the technical review requirements.

2.3 Status

The pointer into the set of review reports is at LIGO-L1400006 . The reviews are complete and indicate successful execution of the acceptance process.

3 Installation Acceptances

3.1 Description

The installation of the interferometer elements are covered by a number of reviews based upon logical groups or subsets of installed elements. These subsets are generally associated with vacuum chambers. For each chamber the elements installed within the chamber as well as the electronics associated with each chamber, up to the connection to DAQ and power, is included with the 'chamber'. Elements not associated with a chamber are reviewed as given in the table below:

DCS	Contents of each building at each site (LLO, LHO, CIT, MIT) to be treated as a reviewable item.
IO	Per chamber. Equipment in the PSL room to be reviewed with HAM2.
PSL	per PSL room and including the outer ISS loop.
SUS	Per chamber. Including, bonding, fiber production and welding as reviewable items.
SEI	Per chamber, with the HEPI included
COC	*No scope in the installation phase; Installation of COC optics is part of the suspension assembly or installation and so is not reviewed separately. COC metrology is covered as an aspect of the COC Fabrication Acceptance Reviews.*
Optlev	With the chamber whose optic is monitored
SLC	Per chamber, or with the closest chamber for e.g., CPB
VPs	Per chamber
TCS	Per Chamber. Include CO2P tables with associated ITM BSC chamber. Include HWS Table with HAM4 in corner station and with ETM chamber in end stations.
TMS	Per chamber
IAS	Alignments completed per chamber.
PCal	Per end test mass chamber
ISC	Optics enclosures and contents per building; plus Chambers.
DAQ	Equipment in each VEA as a unit (end stations, vertex LVEA); remaining equipment (concentrators, framebuilders, NDS, DMT, and Operator machines) as a unit
INS	Infrastructure mods, vacuum chamber mods, and installation tooling.
FMP	*No scope in the installation phase; all FMP scope is covered in the Fabrication Acceptance Review for FMP.*
PM, SYS	*No scope in the installation phase; all PM/PM-SYS scope is covered in the Subsystem Fabrication Acceptance Review for PM or the Long Term Storage Reviews*

The requirements for each installation review are defined in F1300019 and summarized here:

- All drawings and procedures associated with the installation must be up to date in the DCC and completed.
- All of the contents of the chamber must be installed.
- All post-installation, stand-alone, in situ, checkout/testing (phase 2 and 3 per M1000211) must be completed and successful, enabling integrated testing (i.e., enabling system testing and phase 4 testing per M1000211)

In addition to the technical content captured in the Installation Acceptance Documents, Project Controls Acceptance requires the following:

- All related scheduled WBS Level II installation tasks 100% complete.
- Confirmation of completion of the defined WBS scope.
- All chamber specific procurements or contracts closed out
- Cost book brought up to date, with regard to the installation tasks.
- Installation tooling and hardware BOM created for the 3rd IFO handed off to storage team
- Punch list of incomplete tasks

3.2 Scope

All installation scope associated with each installation subset (e.g., chamber) from the handoffs/deliveries from the subsystems through stand-alone, in situ, subsystem-level testing (phase 3 per M1000211). The installation subsets are as defined above.

Not included is close out of the INS Subsystem as a whole, which cannot occur until the Integrated Testing is completed. Integrated Testing is covered under the Systems Acceptance Reviews for the installed interferometers.

3.3 Status

The Hanford Installation Acceptance is documented in LIGO-L1500019 , and the Livingston Installation acceptance at LIGO-L1400082. The reviews are complete and indicate successful execution of the acceptance process.

4 Long Term Storage Acceptances

There is a single Long Term Storage (LTS) acceptance review for each fabrication subsystem.

(Installation tooling, fabricated by INS or delivered to INS by various subsystems, will be covered by a single, combined review. INS will be responsible for preparing for this review, after all installation tooling has been received by INS.)

Each LTS review covers the following:

- Check that the Bill of Materials from the subsystem for items to be stored is complete.
- Check that all hardware detailed in the 3rd IFO storage BOMs have been received,
- Check that all punch list items related to delivery to storage for each Subsystem Fabrication Acceptance Review have been completed.
- Verify that all items have been checked into the Inventory Control System (ICS), and placed into long term storage according to the individual subsystem plans.
- Verify that ownership and monitoring has been assigned.

The requirements for each long term storage review are defined in M1300455 as is the template for the report.

Note that acceptance is accomplished on a subsystem-by-subsystem basis. As soon as a subsystem has been accepted, the ownership and responsibility for hardware in long term storage is transferred to the operations group. The project closeout of the long term storage activities for planning, facility mods, and storage will be reviewed and signed off in the PM Fabrication Acceptance Review.

Items that are still in use at the close of the project but are destined for the 3rd interferometer must be checked into LTS and then checked out and assigned to a responsible individual who will return the items to storage before shipment to the 3rd IFO site.

4.1 Scope

All scope associated with long-term storage from the point of hand-off from the fabrication subsystem through placement into storage. Planning and modification/preparation of storage spaces will be included in the PM Subsystem Fabrication Review.

Not included are Data Computers and Storage (DCS) and Facilities Mods and Prep (FMP) which do not have items placed in LTS.

4.2 Status

The 3rd Interferometer Acceptance is documented in LIGO-M1300164. The reviews are complete and indicate successful execution of the acceptance process.

5 System Acceptances

There are two System Acceptance Reviews, one for each observatory (LHO and LLO). The LHO System Acceptance Review covers system level documentation and test results. In addition this review is a "meta-review", because it also covers the following:

- Check that all punch list items for each Subsystem Fabrication Acceptance Review have been resolved (i.e., closed or appropriately recommended for resolution by Ops post-Project).
- Check that all punch list items for each Installation Instance Acceptance Review have been resolved.
- Check that any changes which have occurred during the course of installation, integration and commissioning have been captured (ECRs, DCNs, etc.)
- Check that the interferometer has achieved a documented satisfactory ability to be locked for two or more hours and that the strain readout functions.

A single acceptance team covers all aspects of the System Acceptance.

Project Controls Acceptance requires the following information in order to complete the installation acceptance and close out the associated installation activities per chamber or area:

- All scheduled WBS Level II installation tasks 100% complete.
- Confirmation of completion of the defined WBS scope for INS.
- All INS procurements or contracts closed out
- Cost book to be brought up to date, with regard to the installation tasks.
- Punch list of incomplete tasks

This Project Controls Acceptance Report is documented by completing one copy of the form M1300455 for L1 and H1. Note that close out of the INS Subsystem as a whole, including Integrated Testing, is accomplished by this programmatic acceptance.

5.1 Overall Installation acceptance

Once all chambers or equivalent have been accepted, an over-arching review to establish that Installation is complete is determined by the Project with concurrence from the Observatory Heads. The criterion will be that installation is sufficiently complete and the subsystems sufficiently well understood that full-interferometer integrated test can start in earnest. There may be some elements of some subsystems not yet installed (e.g., a baffle or a final optic) and some elements not completely characterized (e.g., alignment sensing). The Installation Complete milestone transfers the responsibility for maintenance to Operations and allows the LSC to start working on tuning subsystems (under the direction of the Project Integrated Test team). See Section **Error! Reference source not found.** above for details.

5.2 Systems acceptance

For each interferometer, an Instrument Acceptance review is carried out once the Project top-level requirements are fulfilled (stable, repeatable 2 hour lock) and punch list items have been substantially addressed. The review team is chaired by an Observatory head and is assembled from

Lab and LSC members with appropriate expertise. The review covers the hardware status and requires that installation and integrated test be completed to a satisfactory level and quality; documentation must also be substantially complete. A punch list document must be created for any tasks that are not complete. The punch list will name individuals responsible to complete each task and a target date for completion.

5.2.1 Scope

The scope of the System Acceptance Reviews includes system-level documentation and testing plus a meta-review of all of the Subsystem Fabrication Acceptance Reviews and all of the Installation Acceptance Reviews. It also covers, in a Project Controls Acceptance Report, the INS programmatic content not covered in the Installation Acceptance Review. There are two System Acceptance Reviews, one for L1 and one for H1.

5.2.2 Documentation

A single copy of the System Acceptance Document, representing both L1 and H1, is prepared in accordance with the requirements in M1300468 . and per the Requirements and Form at F1300020. That document must

1) Address questions and comments from the System Acceptance Review Team.
2) Resolve the "punch list" items defined by the System Acceptance Review Team.

5.3 Status

The System Acceptance Reviews Requirements and Form are given in F1300020 and the completed document for L1 and H1 is found in LIGO-E1400371. The reviews are complete and indicate successful execution of the acceptance process, as noted in the Review Report found in LIGO-L1500032

6 Project Closeout and Acceptance

6.1 Description

This closeout review and acceptance verifies that all subsystem tasks, commitments, reviews and acceptances included in the project are complete and it is ready for hand-off to operations. This entails the closeout and acceptance of all subsystems, except those planned for the no-cost-extension: Project Management (PM) and Data Computing and Storage (DCS). Note that this review verifies that all other project controls tasks are complete, all accounts and commitments are closed, and any changes since earlier acceptances have been captured. The review covers the following:

- Check that all punch list items for each Systems Acceptance Review have been resolved (i.e., closed or appropriately recommended for resolution by Ops post-Project).
- Check that all punch list items for each Long Term Storage (LTS) Acceptance review have been resolved.
- Check that any changes which have occurred since the Systems and LTS reviews have been captured (ECRs, DCNs, etc.)
- Check that PM and DCS subsystems have appropriate plans for execution and oversight.

6.2 Scope

The review covers the completion and closeout of all WBS project tasks, reviews, and acceptance reviews and the hand-off from project to operations; it also covers the plan for the no-cost extension of DCS and its oversight. It results in a single memo (this document) to the Directorate that serves as the acceptance of the entire project scope.

The aLIGO Management creates the Project Closeout Acceptance Report (this document) that summarizes the instrument, acceptance, and project management status at Project end. Sign off by the Directorate and site heads indicates acceptance of the report and completion of all project scope modulo DCS and oversight.

Any activities which the Project has determined as issues to be addressed post-Project will be noted in a “punch list” that the Project is transferring, with agreement from the Closeout Review Team, to Operations for final resolution; for example, activities which would interfere with commissioning if addressed during Project scope. This punch list is to be uploaded as an independently numbered DCC document, in an Excel spreadsheet format, named “punch list” for the DCC entry for the Project Closeout Acceptance Document.

6.3 Status

The Project management finds that the requirements for Project Acceptance have been fulfilled. There are activities that could not be completed because of the disruption it would cause to the Operations Commissioning activity, but the components needed for those punch-list items have been completed and staged for implementation when appropriate. In addition, the Project has identified a number of follow-up actions to improve the sensitivity and availability of the instruments, and those are appropriately documented.

The Project Management recommends that the Advanced LIGO Project be accepted as complete, modulo the Data and Computing Storage activities planned for the no-cost extension of the Project.