LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Generic Requirements & Standards for Detector Subsystems

LIGO Systems

Distribution of this document: LIGO Science Collaboration
This is an internal working note of the LIGO Project.

* ***N.B.: This document was erroneously referred to as E010123-00 in the past.***

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1 Introduction

At this point the document is mostly a template to indicate the intended content and scope. The content will be developed mostly by pulling together scattered documentation from initial LIGO. However, there is an intent to impose some new requirements and standards, where the initial LIGO requirements required improvement.

1.1 Purpose

This document defines the generic requirements and standards for all subsystem designs for the Advanced LIGO (AL) detector. The AL detector is currently defined as a single major upgrade to the initial LIGO Detector. These requirements apply even for more modest upgrades to the initial LIGO Detector.

1.2 Scope

This document defines, or refers to, the requirements and standards that transcend any particular subsystem and are thus generic. More detailed requirements or standards are referenced where applicable. The scope includes all aspects (mechanical, electrical, optical, etc.) and all phases (design, analysis, test, fabrication, assembly, installation) of the Detector.

1.3 Definitions

Numerous TBD

1.4 Acronyms

Lots TBD

1.5 Applicable Documents

1.5.1 LIGO Documents

Document Number	Title
T980044-A	Determination of Global and Local Axes for the LIGO Sites
E950111-A	LIGO Naming Conventions
D980226-00	HAM Chamber Port Designations
D980227-00	BSC Chamber Port Designations
D980229-00	BSC Chamber Door Port Designations
D980228-00	Adaptor Port Designations
E960022-A	LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures
M950090-A	Guidelines for Detector Construction Activities

L960237-00	LIGO Document Change Notice
L960641-05	Electronic Submissions to the Document Control Center
G960249-00	Electronic Submissions to the Document Control Center
	Document Change Notice (DCN) Form
L950003-B	LIGO Document Numbering System
E960036-A	LIGO EMI Control Plan and Procedures
E960110-00	LIGO Cable and Connector Marking Standard
T950065-01	Guidelines for Design Requirement Documents
	Inspection Form
	Traveler Form

1.5.2 Non-LIGO Documents

2 Review Requirements

2.1 Design and Test Reviews

The required design reviews are defined in the Guidelines for Detector Construction Activities as follows:

- Design Requirements Review (DRR)
- Preliminary Design Review (PDR)
- Final Design Review (FDR)
- Prototype Test Review (if applicable)
- First Article Test Review (if applicable)
- Pre-shipment Review

This document defines the nature and requirements of each review, as well as the manner in which they are conducted. These reviews are applicable to each subsystem and to the overall Detector system.

In addition to these standard reviews, the Detector management may require special design reviews if they deem it appropriate.

2.2 Approval & Release Process

While most technical documentation is uncontrolled and unreleased (which does not mean it is not valuable), the documentation associated with contracting and fabrication is controlled so that the effect of changes (on cost, schedule, interfaces, etc.) can be ascertained. This documentation applies to all engineering specifications, drawings, procedures, development plans, test plans, interface control documents, etc. Generally in the LIGO document numbering scheme, it is the E and D documents which are approved for release and are controlled through the Document Change Notice (DCN) process (though all documents can be handled with a DCN). Once a document is formally released, all changes must be recorded with new revisions through additional DCNs.

3 Configuration Control

3.1 Design Configuration Control

3.2 Interfaces Definition & Control

3.3 Physical Configuration Control

4 Documentation Requirements

4.1 Documentation Numbering & Electronic Filing

All documents shall be numbered and identified in accordance with the LIGO documentation control numbering system LIGO document TBD

All documents shall be filed electronically in the LIGO Document Control Center (DCC) database in Adobe AcroBat (*.pdf) form

All documents shall be filed in Adobe AcroBat version 3.0 format.

4.2 Source Files

All source files for all released engineering documentation (drawings, specifications, procedures, etc.) shall be archived in the DCC. If there is a one-to-one correspondence between a source file and a drawing, then both can be submitted at the same time with the approved DCN for release.

For drawing source files associated with more than one released LIGO drawing, the procedure for submittal, and the guidelines for naming, are pending. In the interim, CDROM collections, with a descriptive title, can be submitted and given a LIGO document number by the DCC.

4.3 Design, Analysis & Test

4.3.1 Design Requirements Document (DRD)

4.3.2 Conceptual Design Document (CDD)

4.3.3 Preliminary Design Document (PDD)

4.3.4 Final Design Document (FDD)

4.3.5 Technical Design Memorandum

4.3.6 Test Plans and Procedures

4.3.7 Prototype Test Plans & Results

4.4 Fabrication and Process Specifications

4.5 Engineering Drawings and Associated Lists

A complete set of drawings suitable for fabrication must be provided along with Bill of Material (BOM) and drawing tree lists. The drawings must comply with LIGO standard formats and must be provided in electronic format. All documents shall use the LIGO drawing numbering system, be drawn using LIGO Drawing Preparation Standards, etc.

4.6 Technical Manuals and Procedures

4.6.1 Procedures

Procedures shall be provided for, at minimum,

- Initial assembly and check-out of equipment
- Initial installation and setup of equipment
- Normal operation of equipment
- Normal and/or preventative maintenance
- Test of new equipment
- Troubleshooting guide for any anticipated potential malfunctions

4.6.2 Manuals

Any manuals to be provided, such as an operator's manual, shall be provided with delivery of the detector subsystem equipment.

5 Testing Requirements

5.1 Fit Check

Every item shall be fit checked in assembly tests before delivery to the installation effort.

5.2 Assembly

Assembly tooling and procedures shall be developed for each subsystem and tested prior to delivery of first article and production hardware.

5.3 Function

Every

5.4 Performance

5.5 Self-Test

5.6 Installation

6 Mechanical Characteristics & Standards

6.1 Naming Conventions

6.2 Part Numbers

All fabricated LIGO parts shall have a part number designation. The part number is identical to the drawing number, including the revision letter.

6.3 Serial Numbers

Parts for which data is to be collected for individual items (inspection data, performance data, characteristics, etc.) need to have individual serial numbers.

6.4 Coordinate Systems

The coordinate system definition shall be in accordance with LIGO-T980044

6.5 Materials and Processes

6.6 Welding and Brazing

6.7 Bolted Joints & Threaded Fasteners

6.8 Drawing Standards

6.9 CAD Standards

6.10 Interchangeability

6.11 Workmanship

6.12 Human Engineering

6.13 Preparation for Delivery

Packaging and marking of equipment for delivery shall be in accordance with the Packaging and Marking procedures specified herein.

6.13.1 Preparation

- Vacuum preparation procedures as outlined in LIGO Vacuum Compatibility, Cleaning Methods and Procedures (LIGO-E960022-00-D) shall be followed for all components intended for use in vacuum. After wrapping vacuum parts as specified in this document, an additional, protective outer wrapping and provisions for lifting shall be provided.

• Electronic components shall be wrapped according to standard procedures for such parts, including electrostatic protection, as appropriate.

6.13.2 Packaging

Procedures for packaging shall ensure cleaning, drying, and preservation methods adequate to prevent deterioration, appropriate protective wrapping, adequate package cushioning, and proper containers. Proper protection shall be provided for shipping loads and environmental stress during transportation, hauling and storage. The shipping crates used for large items should use for *guidance* military specification MIL-C-104B, Crates, Wood; Lumber and Plywood Sheathed, Nailed and Bolted. Passive shock witness gauges should accompany the crates during all transits.

For all components which are intended for exposure in the vacuum system, the shipping preparation shall include double bagging with Ameristat 1.5TM plastic film (heat sealed seams as practical, with the exception of the inner bag, or tied off, or taped with care taken to insure that the tape does not touch the cleaned part). Purge the bag with dry nitrogen before sealing if the components absorb water.

6.13.3 Marking

Appropriate identification of the product, both on packages and shipping containers; all markings necessary for delivery and for storage, if applicable; all markings required by regulations, statutes, and common carriers; and all markings necessary for safety and safe delivery shall be provided.

Identification of the material shall be maintained through all manufacturing processes. Each component shall be uniquely identified. The identification shall enable the complete history of each component to be maintained (in association with Documentation “travelers”). A record for each component shall indicate all weld repairs and fabrication abnormalities.

For components and parts which are exposed to the vacuum environment, marking the finished materials with marking fluids, die stamps and/or electro-etching is not permitted. A vibratory tool with a minimum tip radius of 0.005" is acceptable for marking on surfaces which are not hidden from view. Engraving and stamping are also permitted.

All component parts shall be marked with their part number and, if appropriate, serial number.

6.14 Assembly

6.15 Installation

7 Electrical Characteristics & Standards

7.1 Naming Conventions

7.2 Grounding & Shielding

7.3 EMI

7.4 Cabling

7.5 Connectors

7.6 Bus Architecture

7.6.1 EPICS control interface

7.6.2 Workmanship

7.6.3 Software Characteristics & Standards

7.7 TBD

7.8 GUI Human Engineering

8 Vacuum Compatibility Requirements

8.1 Tribology

8.2 Materials

8.3 Qualification

8.4 Fabrication

8.5 Cleaning

9 Earthquake Requirements

9.1 Structural Integrity

9.2 Alignment

9.3 Operation

10 Quality Assurance

This section includes all of the examinations and tests to be performed in order to ascertain if the product, material or process conforms to the requirements.

10.1 Quality conformance inspections

Design and performance requirements identified in this specification and referenced specifications shall be verified by inspection, analysis, demonstration, similarity, test or a combination thereof per the Verification Matrix (Section 10.2). Verification method selection shall be specified by individual specifications, and documented by appropriate test and evaluation plans and procedures. Verification of compliance to the requirements of this and subsequent specifications may be accomplished by the following methods or combination of methods:

10.1.1 Inspections

Inspection shall be used to determine conformity with requirements that are neither functional nor qualitative; for example, identification marks.

10.1.2 Analysis

Analysis may be used for determination of qualitative and quantitative properties and performance of an item by study, calculation and modeling.

10.1.3 Demonstration

Demonstration may be used for determination of qualitative properties and performance of an item and is accomplished by observation. Verification of an item by this method would be accomplished by using the item for the designated design purpose and would require no special test for final proof of performance.

10.1.4 Similarity

Similarity analysis may be used in lieu of tests when a determination can be made that an item is similar or identical in design to another item that has been previously certified to equivalent or more stringent criteria. Qualification by similarity is subject to Detector management approval.

10.1.5 Test

Test may be used for the determination of quantitative properties and performance of an item by technical means, such as, the use of external resources, such as voltmeters, recorders, and any test equipment necessary for measuring performance. Test equipment used shall be calibrated to the manufacture’s specifications and shall have a calibration sticker showing the current calibration status.

10.2 Quality Conformance Verification Matrix

Table 1 Verification Matrix

Paragraph	Title	I	A	D	S	T
3.2.1	Performance Characteristics					X
3.2.1.1	Controls Performance		X			
3.2.1.2	Timing Performance‘		X			X

11 Reliability

11.1 Reliability Requirements

Each subsystem shall derive requirements on the reliability of their subsystems from system level imposed availability requirements. These derived requirements shall further be compared to the expected reliability of the subsystem designs by assessing the reliability of the components which are likely to limit availability of the subsystem. A complete failure effects and modes analysis (FEMA) is not required, as long as simple bounding analyses indicate that the required subsystem availability is adequate.

11.2 Reliability Testing

Reliability evaluation/development tests shall be conducted on items with limited reliability history that will have a significant impact upon the operational availability of the system.

12 Maintainability

TBD

13 Transportability

TBD

14 Safety

TBD