LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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Guidelines for Design Requirement Documents

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Abstract

This technical note is being generated to provide a general outline to be followed for developing a Design Requirements Document (DRD) for the LIGO Detector Group. The pages which follow provide the outline, including section/paragraph numbering and headings, along with a brief explanation (and some examples) of what is to go into each paragraph.

The basis for the outline which follows is a combination of the IEEE guide for software requirement documentation and the MIL-STD-490A guide to requirement specification. Sections 1 and 2 particularly follow the IEEE standard. The remainder of the sections are more in line with the MIL-STD format, with some extras or variations that I've found useful in the past.

This document will be moved to become a LIGO document Framemaker template. All instructions (guidelines and examples) in this document are in normal text, and should be deleted when an individual DRD is written. This document also shows "boilerplate" text which should appear in every LIGO detector DRD. This boilerplate appears in this document as italic text and should not be removed from individual DRDs.

This section (Abstract) was purposely titled without using the LIGO tech document template 'Header' paragraph format, such that the Table of Contents of this document directly reflects the outline for a DRD.

1 INTRODUCTION

1.1. Purpose

The purpose of this document and intended audience.

1.2. Scope

- Identify the item to be produced by name, such as Alignment Sensing and Control.
- Explain what the item will and, if necessary, will not do. An example of the latter, from the CDS document is: CDS specifically does not provide: 1) Personnel safety system 2) Facilities Control System 3) etc. The point is to emphasize to reviewers what the system will not do where there may be some doubt or uncertainty.
- Describe the objectives, goals of the item development.

1.3. Definitions

Define all terms used in the document as necessary to interpret its contents. For example, a CDS specification may make use of terminology, such as “real-time software”, which is subject to interpretation. This section should specifically define what “real-time software” means in the context of this document.

NOTE: This should include all standard names used in interface discussions/drawings.

1.4. Acronyms

List all acronyms and abbreviations used in the document.

1.5. Applicable Documents

List all documents referenced. Include only those expressly mentioned within this document.

1.5.1. LIGO Documents

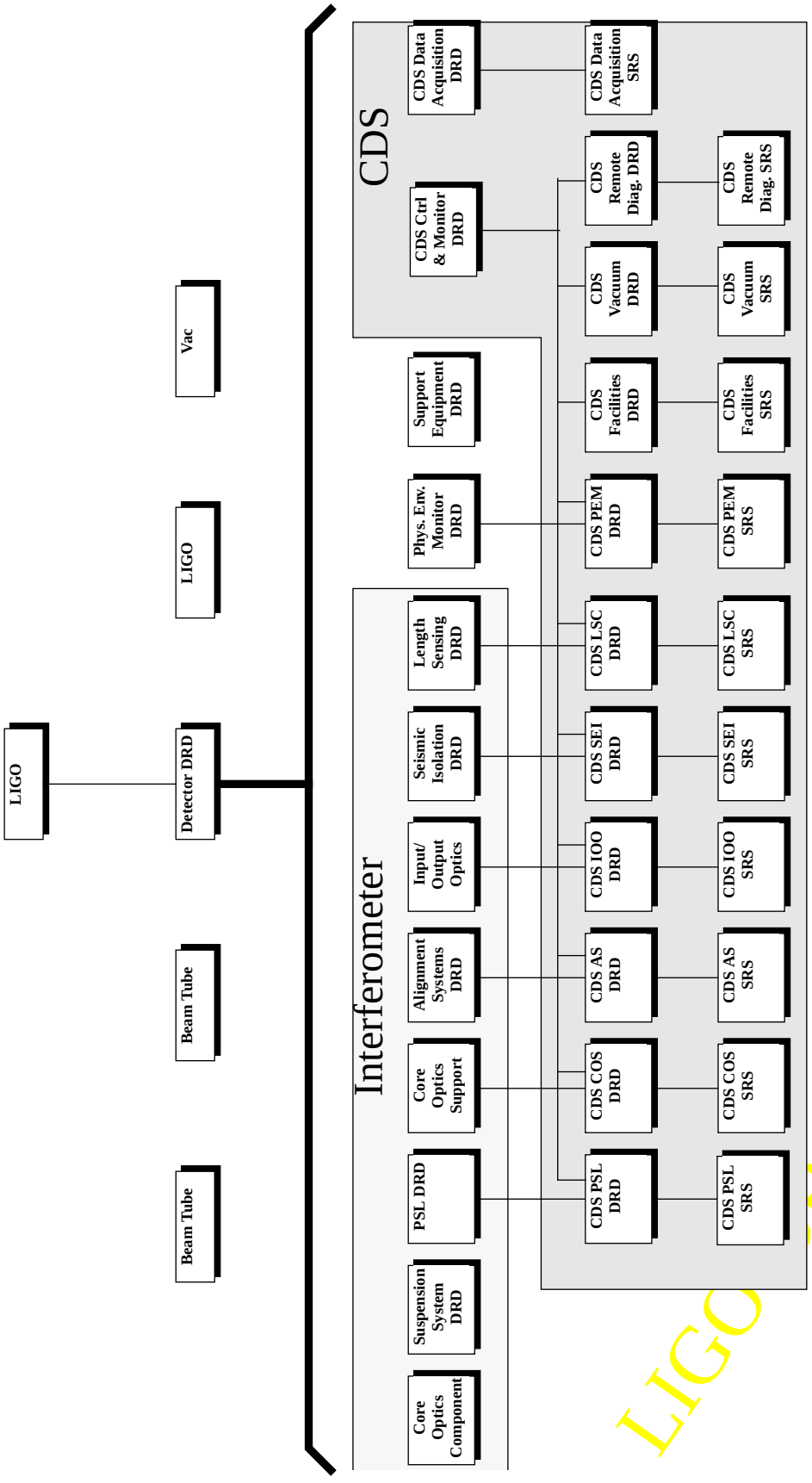
1.5.2. Non-LIGO Documents

2 GENERAL DESCRIPTION

This section (Section 2) should describe the general factors that affect the product and its requirements. This section does not state specific requirements; it only makes those requirements easier to understand.

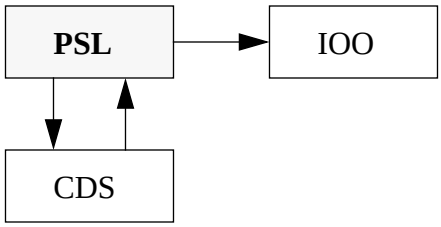
2.1. Specification Tree

This document is part of an overall LIGO detector requirement specification tree. This particular document is highlighted in the following figure.


LIGO
Detector DRD
Beam Tube
Beam Tube
LIGO
Vac
Interferometer
Core Optics Component
Suspension System DRD
PSL DRD
Core Optics Support
Alignment Systems DRD
Input/ Output Optics
Seismic Isolation DRD
Length Sensing DRD
Phys. Env. Monitor DRD
Support Equipment DRD
CDS
CDS Ctrl & Monitor DRD
CDS Data Acquisition DRD
CDS PSL DRD
CDS COS DRD
CDS AS DRD
CDS IOO DRD
CDS SEI DRD
CDS LSC DRD
CDS PEM DRD
CDS Facilities DRD
CDS Vacuum DRD
CDS Remote Diag. DRD
CDS Data Acquisition SRS
CDS PSL SRS
CDS COS SRS
CDS AS SRS
CDS IOO SRS
CDS SEI SRS
CDS LSC SRS
CDS PEM SRS
CDS Facilities SRS
CDS Vacuum SRS
CDS Remote Diag. SRS

2.2. Product Perspective

This section should show how this specified item relates to the rest of a larger system. For instance, a general block diagram would go here which shows the item to be developed and its relationship to the larger system.



2.3. Product Functions

This section should provide a summary of the functions that the specified item will perform. This should just be general statements, not the detail which will go into the requirements section (Section 3).

2.4. General Constraints

This section should give a general description of any other items that will limit the designer's options, such as general policies, design standards, interfaces, etc. This subsection should not be used to impose specific requirements or specific design constraints on the solution. This subsection should provide the reasons why certain specific requirements or design constraints are later specified as part of Section 3. A CDS example for the CDS PSL document might be:

The overall CDS system is being developed using VME based systems as the standard interface. Therefore, all I/O modules being developed for the PSL will be constrained to this format.

Another general example might be:

LIGO must operate continuously, therefore this subsystem must be designed with high reliability and low mean time to repair. (Note that this is a general statement, and the MTBF and MTTR will be exactly specified in Section 3).

2.5. Assumptions and Dependencies

This section should list factors that affect the requirements i.e. certain assumptions have been made in the writing of the requirements, and, if these change, then the requirements will have to be changed. For example, it is assumed that green light wavelengths will be used as the basis for optics requirements. If this is changed to infrared, then the requirements which follow will need to change.

3 REQUIREMENTS

This section contains the specific requirements of the product to be developed. This is the most important part of the document. It must be:

Unambiguous: every requirement listed has only one interpretation

Complete: Inclusion of all significant requirements

Verifiable: A requirement is verifiable if and only if there exists some finite cost-effective process whereby the final product can be checked/tested to meet the requirement. If no method can be devised to determine if the product meets a particular requirement, either (1) the requirement should be removed, or (2) a point in the development cycle should be identified at which the requirement can be put into a verifiable form.

Consistent: No two requirements should conflict with each other.

Modifiable: The structure and style should be such that any necessary changes can be made easily, completely, and consistently.

Traceable: Backward (references to source of requirements, such as a higher level specification, design, or standards) and Forward (unique numbering of requirements such that they can be identified/referenced in design and test documentation).

Usable during operations and maintenance: often items are modified during commissioning and maintenance periods. The requirements should specifically call out critical areas (such as failure of this component to meet this requirement can cause severe injury), and other such items, such that this fact s not lost to maintenance personnel.

3.1. Introduction

Requirements flow down tree from Detector DRD should be included in this section.

3.2. Characteristics

3.2.1. Performance Characteristics

This section should contain all functional and performance characteristics that the product must fulfill i.e. what is expected of the product.

3.2.2. Physical Characteristics

This area contains any physical requirements or constraints on the product: dimensional and weight limitations, acceptable materials or properties of the materials, durability factors, transportation and storage requirements, etc.

3.2.3. Interface Definitions

Specify all interfaces to other systems/subsystems/components and the characteristics (electrical/ mechanical/optical) of those interfaces. Note that these are all requirements placed on the item specified, NOT requirements this item places on other systems.

3.2.3.1 Interfaces to other LIGO detector subsystems

3.2.3.1.1 Mechanical Interfaces

3.2.3.1.2 Electrical Interfaces

3.2.3.1.3 Optical Interfaces

3.2.3.1.4 Stay Clear Zones

3.2.3.2 Interfaces external to LIGO detector subsystems

3.2.3.2.1 Mechanical Interfaces

3.2.3.2.2 Electrical Interfaces

3.2.3.2.3 Stay Clear Zones

3.2.4. Reliability

Mean Time Between Failures (MTBF), Availability

3.2.5. Maintainability

Mean Time To Repair (MTTR); Qualitative requirements for accessibility, modular construction, test points, etc.

3.2.6. Environmental Conditions

Environments that the equipment is expected to experience in shipment, storage, service or use. Subparagraphs should include, as necessary, climate, shock, vibration, noise, etc.

3.2.6.1 Natural Environment

3.2.6.1.1 Temperature and Humidity

Example:

Table 1: Environmental Performance Characteristics

Operating	*Non-operating (storage)*	*Transport*
+0 C to +50 C, 0-90%RH	-40 C to +70 C, 0-90% RH	-40 C to +70 C, 0-90% RH

3.2.6.1.2 Atmospheric Pressure

3.2.6.1.3 Seismic Disturbance

3.2.6.2 Induced Environment

These are environmental conditions induced by equipment. The following subparagraphs list some possible categories. Remember to list the requirements both in terms of:

- What the item to be designed must accept from its surroundings
- What environment the item to be designed is allowed to generate

3.2.6.2.1 Electromagnetic Radiation

3.2.6.2.2 Acoustic

3.2.6.2.3 Mechanical Vibration

3.2.7. Transportability

All items shall be transportable by commercial carrier without degradation in performance. As necessary, provisions shall be made for measuring and controlling environmental conditions (temperature and accelerations) during transport and handling. Special shipping containers, shipping and handling mechanical restraints, and shock isolation shall be utilized to prevent damage. All containers shall be movable for forklift. All items over 100 lbs. which must be moved into place within LIGO buildings shall have appropriate lifting eyes and mechanical strength to be lifted by cranes.

3.3. Design and Construction

Minimum or essential requirements that are not controlled by performance characteristics, interfaces, or referenced documents. This can include design standards, requirements governing the use or selection of materials, parts and processes, interchangeability requirements, safety requirements, etc.

3.3.1. Materials and Processes

Such items as units of measure to be used (English, Metric) should be listed and any other general items, such as standard polishing procedures and processes.

3.3.1.1 Finishes

Examples:

- Ambient Environment: Surface-to-surface contact between dissimilar metals shall be controlled in accordance with the best available practices for corrosion prevention and control.
- *External surfaces: External surfaces requiring protection shall be painted purple or otherwise protected in a manner to be approved.*

3.3.1.2 Materials

Requirements for materials to be used, such as out gas properties, corrosion resistance, etc. Should also reference TBD documents on LIGO Materials Standards for Vacuum and LIGO Vacuum Cleaning Standards.

3.3.1.3 Processes

List all LIGO standard processes (as appropriate) for cleaning, coating, polishing, etc.

3.3.2. Component Naming

All components shall identified using the LIGO Detector Naming Convention (document TBD). This shall include identification physically on components, in all drawings and in all related documentation.

3.3.3. Workmanship

Standard of workmanship desired, uniformity, freedom from defects and general appearance of the finished product.

3.3.4. Interchangeability

Specify the level at which components shall be interchangeable or replaceable.

3.3.5. Safety

This item shall meet all applicable NSF and other Federal safety regulations, plus those applicable State, Local and LIGO safety requirements. A hazard/risk analysis shall be conducted in accordance with guidelines set forth in the LIGO Project System Safety Management Plan LIGO-M950046-F, section 3.3.2.

3.3.6. Human Engineering

Note: For most detector subsystems, this is not applicable. This is important for CDS, however.

Specify any special or unique requirements, e.g., constraints on allocation of functions to personnel, and communications and personnel/equipment interactions. Also include any specified areas, stations, or equipment that require concentrated human engineering attention due to the sensitivity of the operation, i.e. those areas where the effects of human error would be particularly serious.

3.4. Documentation

Requirements for documentation of the design, including types of documents, such as operator manuals, etc.

3.4.1. Specifications

List any additional specifications to be provided during the course of design and development, such as Interface Control Documents (ICD) and any lower level specifications to be developed.

3.4.2. Design Documents

List all design documents to be produced, including installation and commissioning plans, standards documents, etc.

3.4.3. Engineering Drawings and Associated Lists

Any drawings to be provided and any standard formats that they must comply with, such as shall use LIGO drawing numbering system, be drawn using LIGO Drawing Preparation Standards, etc.

3.4.4. Technical Manuals and Procedures

3.4.4.1 Procedures

Procedures shall be provided for, at minimum,

- *Initial installation and setup of equipment*
- *Normal operation of equipment*
- *Normal and/or preventative maintenance*
- *Troubleshooting guide for any anticipated potential malfunctions*

3.4.4.2 Manuals

Any manuals to be provided, such as operator's manual, etc.

3.4.5. Documentation Numbering

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

3.4.6. Test Plans and Procedures

All test plans and procedures shall be developed in accordance with the LIGO Test Plan Guidelines, LIGO document TBD.

3.5. Logistics

The design shall include a list of all recommended spare parts and special test equipment required.

3.6. Precedence

This section should list the relative importance of requirements (or goals) to be achieved by the design.

3.7. Qualification

Test and acceptance criteria.

4 QUALITY ASSURANCE PROVISIONS

This section includes all of the examinations and tests to be performed in order to ascertain the product, material or precess to be developed or offered for acceptance conforms to the requirements in section 3.

4.1. General

This should outline the general test and inspection philosophy, including all phases of development.

4.1.1. Responsibility for Tests

Who is responsible for testing.

4.1.2. Special Tests

4.1.2.1 Engineering Tests

List any special engineering tests which are required to be performed. Engineering tests are those which are used primarily for the purpose of acquiring data to support the design and development.

4.1.2.2 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.

4.1.3. Configuration Management

Configuration control of specifications and designs shall be in accordance with the LIGO Detector Implementation Plan.

4.2. 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, Appendix 1 (See example in Appendix). 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:

4.2.1. Inspections

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

4.2.2. Analysis

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

4.2.3. 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.

4.2.4. 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.

4.2.5. 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.

5 PREPARATION FOR DELIVERY

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

5.1. Preparation

Equipment shall be appropriately prepared. For example, vacuum components shall be prepared to prevent contamination.

5.2. 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.

5.3. 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.

6 NOTES

This section should contain information of a general or explanatory nature, and no requirements shall appear here. This could be such items as modelling data/results, R&D prototype information, etc.

APPENDIX 1

Appendixes are used to append large data tables or any other items which would normally show up within the body of the specification, but, due to their bulk or content, tend to degrade the usefulness of the specification. Whenever an Appendix is used, it shall be referenced in the body of the specification.

Appendix 1 shall always contain a table which lists the requirements and the method of testing requirements. An example table follows. Additional appendixes can contain other information, as appropriate to the subsystem being specified.

Table 2: Quality Conformance Inspections

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