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**Guidelines for Advanced LIGO
Detector Construction Activities**

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Advanced LIGO

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Introduction

This document provides programmatic guidelines for the development phases of the advanced LIGO project from the requirements and conceptual design phase through fabrication. This document supersedes the initial LIGO document, M950090-A, Guidelines for Detector Construction Activities.

DESIGN REQUIREMENTS PHASE

- *Requirements definition* — Identify and document (in a Design Requirements Document) the information necessary to define a particular detector subsystem and quantify its relationship to other subsystems. Typical contents of the Design Requirements Document include:
 - Scope and objectives of subsystem development activities
 - Interface requirements
 - Functional and performance requirements
 - Physical and environmental requirements
 - Documentation requirements
 - Design considerations
 - Testing criteria
 - Principal safety hazards and design implications

Quantification of some items listed in the Design Requirements Document may be deferred until the preliminary design phase. These are listed with values To Be Determined (TBD).

- *Conceptual design* — Generate a conceptual design of the subsystem in sufficient detail to show that the subsystem is completely characterized by the entries in the Design Requirements Document and is understood well enough to proceed with preliminary design.
- Before the Design Requirements Review, the Design Requirements Document is signed off by the subsystem task leader (draft issue).

DESIGN REQUIREMENTS REVIEW (DRR) The Design Requirements Document and conceptual design are presented to a design review board appointed by the System Scientist. Normally the System Scientist chairs the Design Review Board. Guidelines for the review are outlined in Appendix A. The review board may approve the Design Requirement Document, agreeing that it is complete and sufficient to proceed with preliminary design, or conditionally approve it with recommended modifications (defined by the review board in specific Action Items).

Following the DRR, the Project Leader issues written authorization for proceeding with the Preliminary Design Phase, specifying any changes to be incorporated into the document (by reference to the DRR-recommended Action Items).

PRELIMINARY DESIGN PHASE

- Develop the subsystem to the point where *all design issues are resolved*, lacking only the detailed engineering drawings, specifications and contract documents needed for implementation.
- Complete those detailed specifications/engineering drawings needed for long-lead procurements (at the PDR, provide justification to proceed with these items before the Final Design Review).
- Complete the Design Requirements Document by quantifying all "TBD" items and incorporating changes adopted from the DRR.
- Before the Preliminary Design Review, the Design Requirements Document is signed off by the subsystem task leader, the Detector systems engineering task leader, and task leaders of all other affected subsystems.

PRELIMINARY DESIGN REVIEW (PDR) The preliminary design and the completed Design Requirements Document are presented to a design review board appointed by the Project Manager, showing how the design meets all of the identified requirements. The review board either a) approves the preliminary design and Design Requirements Document as presented, or b) recommends changes to be incorporated during the final design phase (defined in specific Action Items).

Following the PDR, the Project Leader issues written authorization for proceeding with final design and long-lead procurements, directing any changes to be incorporated. Changes to the Design Requirements Document are incorporated as soon as possible; it is then signed off by the Project Manager and issued as a controlled document (Rev. A).

FINAL DESIGN PHASE

- Generate a final design package, including:
 - Detailed engineering drawings/specifications
 - Detailed procurement specifications/contract documents
 - Detailed inspection plans/procedures
 - Detailed test plans/procedures
 - Detailed integration plans/procedures
- If a prototype was constructed, incorporate results of the Prototype Test Review into final design documentation
- Before the Final Design Review, the final design documents are signed off by the subsystem task leader.

FINAL DESIGN REVIEW (FDR) Present the final design package to a review board appointed by the Project Manager. Show that all issues raised during the PDR have been resolved. The review board either a) approves the final subsystem design or b) recommends changes to be incorporated prior to fabrication (specified as Action Items).

Upon accepting the review board's report, the Project Leader issues written authorization for proceeding with implementation, or directs changes to be incorporated immediately prior to proceeding with fabrication. After Action Items have been incorporated, the final design documents are signed off by the Project Manager and released as controlled documents (Rev. A). Fabrication may not proceed until all Action Items are closed out, final design documents have been approved and released, and written authorization to proceed is issued.

PROTOTYPE PHASE (if applicable)

- Develop prototype hardware to the point where all hardware issues are resolved for the final design
- Generate a test report documenting test procedures and results to support details of the final design implementation

PROTOTYPE TEST REVIEW The test report is presented to a review board appointed by the Project Manager showing that test results meet all design requirements and describing how test results influence the final design. The review board either a) approves the test results and recommends incorporation into the final design documentation, or b) recommends additional tests to be carried out prior to incorporating results into the final design (identified in specific Action Items).

Upon approval of the review board's report, the Project Leader issues written direction to bring the final design to review as planned or to conduct additional testing. The review board's report and responses to the Action Items are presented with the final design documentation at the Final Design Review.

FIRST ARTICLE FABRICATION/TEST PHASE (if applicable)

- Produce and test a first-article unit in accordance with the final design documents
- Generate a test report documenting test procedures and results, showing compliance with the final design documents (or proposing changes to the final design documents necessary to achieve compliance)

FIRST ARTICLE TEST REVIEW The first-article test report and any proposed design document changes are presented to a review board appointed by the Project Manager, showing that the first article meets all design requirements and complies with final design documents (or proposed revisions). The review board either a) approves the test results and any proposed design changes, or b) recommends additional tests or design changes, described in specific Action Items, to be carried out and presented for subsequent review.

Upon accepting the review board's report, the Project Leader either a) signs off on approved changes and issues written authorization to proceed with fabrication, or b) directs additional changes to be incorporated, tested and brought before a subsequent first-article test review.

FABRICATION/TEST PHASE

- Fabricate and test items as specified in the final design documents
- Document and resolve all discrepancies from approved fabrication drawings/specifications
- Document and resolve all discrepancies from approved inspection and test plans/procedures
- Package the fabricated items for shipment to the remote LIGO sites

PRESHIPMENT REVIEW The fabrication and test records, along with all reports of problems encountered during fabrication and testing and documentation of their resolution, are presented to a review board appointed by the Project Manager. The review board either a) recommends shipment of the items, or b) recommends additional actions to close out open issues (specified as Action Items).

Upon acceptance of the review board's report, the Project Leader issues written authorization for shipment, or directs additional actions to be taken.

APPENDIX A: REVIEW RESPONSIBILITIES AND PROCESS

1) Project Manager:

- Issue memo (or email) appointing review board, conveying charge, date and location for the review four weeks before the review

For DRR, System Scientist:

- Appoints Design Requirements Review Panel
- Chairs Design Requirements Reviews

2) Subsystem Leader(s):

- Develop documentation for the review
- Submit proposed review agenda to review board chairman three weeks before review
- Ensure that review documents and presentation materials are consistent with the review objectives and agenda
- Distribute review documents to review board members two weeks before review

3) Review Board Chairman:

- Iterate the review agenda with the Subsystem Leader

Appoint a secretary for the review board (from among members) (to record board comments and action items)

- Announce review date, materials, and telecom information to the Advanced LIGO team
- Convene review board one week before review to assemble questions for discussion at the review; deliver questions to Subsystem Leader
- Conduct the review, which is geared toward answering the committee's questions (i.e. not a presentation of all of the review reports).

4) Review Board members:

- Study the review documents before the review board meetings
- Participate in review board meeting(s)
- Document action items initiated by board member
- Participate in the creation of the review board report

5) Subsystem Leader(s):

- Ensure that the subsystem team provides answers to the review committee's questions at the review meeting

6) Review Board Chairman:

- Develop a list of action items
- Generate and distribute the review board report to the impacted subsystem and the AdL leadership

7) Project Leader:

- Issue written authorization to proceed based on review process, or directs additional actions to be taken

8) Project Manager:

- Receive review board report, assign, and track action items

9) Subsystem Leader(s):

- Recommend to the Project Leader disposition of recommended action items in the review board report
- Monitor action item status and closeout
- Assemble the review archive document

10) Project Manager:

- Ensure action items resolved
- Close out review by delivering a copy of the review archive document (reviewed documents, presentation material, review board report and action item closeout memoranda) to the project document control center

APPENDIX B: REVIEW CHECKLISTS¹

Design Requirements Review (DRR) Checklist

General performance requirements

Preliminary technical specifications

Requirements allocation for

- Physics parameters
- Engineering requirements
- Conventional construction requirements

Adequately identified/defined

- Subsystem and its relationship to the total system
- Function(s) of subsystem and its contribution to the achievement of the requirements and goals of the overall system
- Functions required from outside of the system in order for the system (or subsystem) to accomplish its function(s)

Pictorial representation of the subsystem function(s) presented and discussed

One or more options presented for review

- Pros and cons of each option

Selection of the option most likely to satisfy the requirements made

- Data and trade studies were presented to substantiate the selection

Proposed hardware approaches adequately satisfy the defined subsystem function(s)

An adequate set of draft hardware requirements presented

Interfaces identified with draft functional requirements

Safety hazards identified: personnel and equipment

Cost estimate presented

Schedule presented

Documentation requirements presented

Risk and abatement strategy for

- Cost risks
- Schedule risks
- Technical performance risks

Lessons learned documented, circulated

Problems and concerns

¹ Modified from DIII-D Design Review Process, General Atomics, Tooker and Cary

Preliminary Design Review Checklist

System Design Requirements, especially any changes or refinements from DRR

Subsystem and hardware requirements, and design approach

Justification that the design can satisfy the functional and performance requirements

- Subsystem block and functional diagrams
- Equipment layouts
- Document tree and preliminary drawings (information issued)
- Modeling, test, and simulation data
- Thermal and/or mechanical stress aspects
- Vacuum aspects
- Material considerations and selection
- Environmental controls and thermal design aspects
- Software and computational design aspects
- Power distribution and grounding
- Electromagnetic compatibility considerations
- Fault Detection, Isolation, & Recovery strategy

Resolution to action items from DRR

Interface control documents

Instrumentation, control, diagnostics design approach

Fabrication and manufacturing considerations

Instrumentation, control, diagnostics design approach

Preliminary reliability/availability issues

Installation and integration plan

Environment, safety, and health issues

- Mitigation of personnel and equipment safety hazards
- Reflected in equipment design and procedures for use

Human resource needs, cost and schedule

Any long-lead procurements

Technical, cost & schedule risks and planned mitigation

Test plan overview

Planned tests or identification of data to be analyzed to verify performance

- In prototyping phase
- In production/installation/integration phase

Identification of testing resources

- The test equipment required for each test adequately identified
- Organizations/individuals to perform each test identified
- QA involvement

Test and evaluation schedule, prototype and production

Lessons learned documented, circulated

Problems and concerns

Final Design Review Checklist

Final requirements – any changes or refinements from PDR?
Resolutions of action items from PDR
Subsystem block and functional diagrams
Drawing package (assembly drawings and majority of remaining drawings)
Final parts lists
Final specifications
Final interface control documents
Design analysis and engineering test data
Software detailed design
Final approach to safety and use issues
Production plans
Plans for acquisition of parts, components, materials needed for fabrication
Installation plans and procedures
Preliminary hardware test plans
Preliminary software test plans
Cost
Fabrication, installation and test schedule
Lessons learned documented, circulated
Problems and concerns