



**LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY**  
*LIGO Laboratory / LIGO Scientific Collaboration*

LIGO-E1200685-v6

*ADVANCED LIGO*

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**aLIGO BSC-ISI**  
**Fabrication Acceptance Documentation**

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Distribution of this document:  
LIGO Science Collaboration

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## Purpose and general description

This document provides links to the BSC chamber Internal Seismic Isolation (BSC-ISI) system acceptance documentation package (as defined in [M1100282](#)-v2 per the format given in template [E1300457](#)-v3). This document focuses on the “common documentation”, which includes all the general documents (requirements, drawings, procedures...) which are common to all instances of the BSC-ISI system.

In contrast, the documents which are unique, or specific, to a particular unit (unit specific documentation) are typically testing reports. This document also provides links to the DCC trees used to group the “unit specific” documentation. The unit specific documentation are grouped/linked in DCC trees by module type (i.e. a DCC page containing all the testing reports related to a specific BSC-ISI).

A BSC-ISI unit is installed in each of the 5 BSC vacuum chambers.

### 1 Requirements documentation

#### a. *Design Requirements Documents (DRD)*

##### General requirements:

Displacement noise requirements for the BSC platforms are found in:

- [E990303](#), Seismic Isolation Subsystem Design Requirements Document

##### Derived requirements:

- [E030179](#), Design Requirements for the In-Vacuum Mechanical Elements of the Advanced LIGO Seismic Isolation System for the BSC Chamber.
- [E0900037](#)-v3, Statement of Work for Advanced LIGO Linear Voice Coil Actuators

#### b. *Design Requirements Review (DRR):*

The DRR was held in Jan 2001 with conclusions reported in [L010409](#).

#### c. *Supporting documents (models, analyses, ...)*

- [T0900089](#), Replacement Flexures for the GS-13 Seismometer
- [T0900135](#), Discussion of stage 0-1 Feedforward on the Tech Demo
- [P040015](#), Long term study of the seismic environment at LIGO
- [P1000029](#), Prototyping, Testing and Performance of the Two-Stage Seismic Isolation System for Advanced LIGO Gravitational Wave Detectors
- [P1200010](#), Advanced LIGO Two-Stage Vibration Isolation and Positioning Platform

### 2 Design overview and detailed design documentation

#### a) *Final Design Documentation (FDD):*

Note: the wiki pages need to be printed in pdf format and put under revision control in the DCC.

**The final design was presented at the Preliminary Design Review:**

The BSC-ISI PDR documentation is listed in the Advanced LIGO wiki: BSC-ISI Advanced LIGO Preliminary Design Review

[https://awiki.ligo-wa.caltech.edu/aLIGO/BSC-ISI\\_Advanced\\_LIGO\\_Preliminary\\_Design\\_Review?highlight=%28BSC%29](https://awiki.ligo-wa.caltech.edu/aLIGO/BSC-ISI_Advanced_LIGO_Preliminary_Design_Review?highlight=%28BSC%29)

The main document of the PDR is:

- [L0900118-v7](#), Advanced LIGO Preliminary Design Review of the BSC ISI system

The corresponding presentation is

- [G0900676-v3](#): Advanced LIGO Preliminary Design Review of the BSC ISI system

The review committee report is in the following DCC page:

- [M0900248-v2](#): Review committee report on the SEI BSC ISI PDR

### **The questions from the committee were addressed during a PDR update:**

The documentation is posted in the Part 2 of the PDR wiki page (top half of the wiki page): BSC-ISI Advanced LIGO Preliminary Design Review

The main documents are:

- [L0900182-v1](#), BSC-ISI Preliminary Design Review Update
- [G0900909](#), Advanced LIGO Update PDR of the BSC ISI system

The review committee report is in the following DCC page:

- [T0900476-v1](#): Review committee report on the SEI BSC ISI PDR Update

### **Additionally we held a tooling review:**

A tooling review was held. The main page is:

- [G1000135-v4](#) BSC-ISI Tooling review

The review committee report is in the following DCC page:

SEI BSC ISI FDR Tooling and Electronics Review committee report

#### *b) Final Design Review (FDR):*

The documentation is posted in FDR wiki page: BSC-ISI Advanced LIGO Final Design Review

[https://awiki.ligo-wa.caltech.edu/aLIGO/BSC-ISI\\_Final\\_Design\\_Review](https://awiki.ligo-wa.caltech.edu/aLIGO/BSC-ISI_Final_Design_Review)

The main documents are:

- [L0900222](#), Advanced LIGO Final Design Review of the BSC ISI system
- [G0901006](#), FDR Presentation

The review committee reports is in the following DCC pages:

- [M0900302-v1](#): Review committee report on the aLIGO SEI BSC ISI FDR  
Finally, the following page gives a summary of the Seismic Isolation Final design Reviews
- [T1200501](#) Summary of Seismic Isolation Final design Reviews

#### *c) Supporting design documents: models, analyses, specifications, etc.*

- [E0900027](#), LIGO Project Modifications to the GS-13
- [E1300548](#), Change ISI CPS offsets from local to Cartesian Basis
- [T1000388](#), aLIGO SEI Actuators and Sensors Change of Basis
- [T1300559](#), Changing the ISI CPS offsets to the Cartesian (CART) Basis

- [D1001575](#): aLIGO SEI Sensor and Actuator Electronics Chains
- [T0900089](#), Replacement Flexures for the GS-13 Seismometer
- [T0900129](#), Justification for in-pod Pressure Sensors for ISI
- [T0900449](#), Changing the op-amp for the L-4C seismometer preamp
- [T0900450](#), Sensor Noise Estimates for Advanced LIGO Seismic Isolation Systems
- [T0900457](#), LT1012 is the best op-amp for the GS13 preamp
- [T0900583](#), GS-13 Alternative Flexure Installation and Testing Procedure

c) *Drawings: cite the top level assembly drawing for each major assembly or subsystem. In the DCC, all subsidiary drawings (sub-assemblies and part drawings) must be linked in a drawing tree manner.*

The BSC-ISI top assembly is:

- [D0901182](#) Adv LIGO SEI BSC ISI Assembly

The sub-assemblies (Stage 0, Stage1 and Stage 2) are linked to this page. The sub-assemblies and parts constituting these assemblies are listed in these top assembly drawings. All the part drawings are up to date and under revision control in the DCC.

The electronics system-level schematics (wiring diagrams) are documented in the following:

- [D0901301](#): BSC SEI System Wiring Schematic

Each electronics module in the system is listed in (linked in) the related documents field for each of these system schematic drawings. In addition, the drawings for all SEI electronics modules are collected (as related document links) under [T1300173](#), “SEI Electronics Document Hub”.

e) *Bill(s) of Materials (BOM): cite any collected BOMs. If the BOMs are only to be found on the Assembly and Sub-Assembly drawing sheets, then state so.*

- [E1000025](#): Bills of Materials for BSC ISI, Advanced LIGO

f) *Interface control: cite any documents (such as RODAs) with interface definition/control and/or cite the relevant sections of the DRD and FDD.*

In addition to the optics platform interface requirements defined in the SEI requirements document ([E990303](#)), and the general CDS infrastructure interfaces (defined in [T070056](#)), the following documents define interface requirements for the BSC-ISI:

- [D047782](#), ICD STS-2 Seismometer
- [D047780](#), ICD GS-13 Seismometer
- [D047781](#), ICD L4-C Seismometer
- [E0900082](#), Interface Control Document (ICD): Seismic Isolation (SEI) – Systems (SYS)
- [E050159](#), Interface Control Document (ICD): Seismic Isolation (SEI) – Suspension, UK Scope (SUS/UK)
- [T080110](#), Facilities Requirements Matrix (defines SEI requirements on facilities)

g) *Software: cite any software design description documentation. If not applicable, or not available, then state so.*

All of the seismic isolation system software is configuration controlled and resides in the SVN repository:

<https://svn.ligo.caltech.edu/svn/seismic/>

The front end “user models” written for the Real-Time code Generator (RTG) are Simulink™-like visual diagrams which are considered to be essentially self-documenting. In addition the following documents (as well as those listed in section 8 below) describe some aspects of the software:

- [T1300732](#): ISI Checkerscript migration to the Frontend Code
- [T1100613](#): Real-Time Band-Limited RMS Filter
- [T1200126](#): Blend Switching User Guide
- [T1300073](#), The Seismic Saturable Integrator
- [T1300732](#), ISI Checkerscript migration to the Frontend Code
- [T1300742](#), Science Frame Data for the SEI Subsystem

In particular the following documents describe the software watchdog design:

- [G1301210](#), Software Watchdogs for SUS + ISI + HEPI
- [E1300256](#), Updates to ISI Master Models: MASTER Block Revision, Watchdog Display Update
- [T1200482](#), aLIGO SEI / SUS Watchdog Design

*h) Design source data:*

The BSC-ISI top assembly Solidworks Model is checked in the LIGO Caltech PDM vault, in the SEI folder:

- [D0901182](#) Adv LIGO SEI BSC ISI Assembly

All the sub-assemblies (\*.sldasm), parts models (\*.sldprt) and their corresponding drawings (\*.slddrw) are checked in the vault with this top assembly

The drawings for all SEI electronics modules are collected (as related document links) under [T1300173](#), “SEI Electronics Document Hub”. Each of the schematics has the source files (Altium, etc.) uploaded as ancillary files in the DCC entry.

### 3 Materials and fabrication specification

*Any special materials, or treatment of materials including preparation for in-vacuum use; this may be integrated into the Design documentation.*

- [E1100002](#), Cleaning and Packaging Requirements for BSC-ISI plates
- [E0900023](#), Specification: Process for Manufacturing Cantilever Spring Blades for aLIGO

### 4 Parts and in-process spares inventoried

*All elements of aLIGO must be recorded in the Inventory Control System (ICS) or in the DCC using the S-number scheme. As-built modifications for parts or assemblies should be found here.*

In general, the critical parts and sub-assemblies of the BSC-ISI system, and the BSC-ISI top-level assemblies, are all recorded in the [ICS under the assembly D0900124](#). In addition, all BSC-ISI electronics modules are recorded and tracked with the S-document, traveler system in the DCC. In general the DCC entry for each serial number (S-number) instance of an electronics module is linked

to the corresponding module D-number DCC entry. The expected number of in-process spares to survive the project and be delivered to operations is listed in:

- [T1300832](#), SEI Sparing Analysis

## 5 Assembly procedures

*All assembly procedures must be in the DCC and annotated or updated for lessons learned. Storage, if used, should be described here along with procedures to maintain the equipment in good condition (e.g., purge frequency). Transportation procedures and cautions must be noted.*

The assembly documentation is posted in the DCC page:

- [E0900357](#)-aLIGO BSC-ISI, General Assembly Procedure

This page contains:

### **The main assembly procedure**

This document details step by step how to assemble a BSC-ISI unit. It is regularly completed and updated as we build more units and find ways and needs to improve the assembly process.

Every step includes:

- A detailed description
- Snapshots of CAD models and or pictures
- List of parts/BOM
- Table/list of hardware
- Corresponding sub-assembly drawings Numbers
- Torque values
- and if necessary
- Special notes and recommendations highlighted in colors,
- References to a sub-assembly procedure.

The latest Revision is #28, posted on 13 August 2012.

### **Links to the sub-assemblies documentation**

Several sub-assemblies (pods, actuators, tooling...) must be assembled prior the beginning of the main BSC-ISI assembly. Assembly procedures have therefore been written for these instances. They are posted in the DCC and linked to this main page. The entire assembly documentation is built as a tree. The main page ([E0900357](#)) contains list to the following procedures:

- [E1000512](#): aLIGO BSC-ISI, Pods Assembly Procedures
- [E1000578](#): aLIGO BSC-ISI, Actuators Assembly Procedures
- [E1100028](#): aLIGO BSC-ISI, Position Sensors Assembly Procedure
- [E1000615](#): aLIGO BSC ISI, Lockers Assembly Procedure
- [E1100103](#): aLIGO BSC-ISI, Springs, Flexures, Safety Mechanism, and Loading Tools
- [E1100606](#): aLIGO BSC-ISI Lifting components

These pages contains themselves links/branches to sub-assemblies and useful assembly drawings. The main page ([E0900357](#)) also contains links to the other documents listed in the main assembly procedure:

- [E1000397](#): aLIGO BSC-ISI, Main Assembly Drawings

- [T1100066](#): Torque values
- [E1100034](#): aLIGO BSC-ISI, Parts Lists
- [E1000402](#): aLIGO BSC-ISI, Parts Preparation Matrix for Helicoils and Dowel Pins
- [E0900047](#): LIGO Contamination Control Plan
- [E070347](#): BSC-ISI Prototype Assembly Procedure
- [T0900570](#): Dimensioning Standards for aLIGO BSC ISI

Other relevant documents:

- [T080261](#), Building L4-C Pods
- [T1100066](#), Torque Values
- [E1100257](#), heli-coil / oversized tapped holes - instruction guide
- [T080086](#), GS-13 Modification and Pod Assembly Procedure

## 6 Installation procedures

*All installation procedures must be in the DCC and annotated or updated for lessons learned.*

- [E1200900](#): aLIGO BSC Installation Procedures (from sub-systems)
- [E1200344](#): All BSC, Install Completed Cartridge Into Chamber Procedure, aLIGO
- [E1200023](#): aLIGO Chamber (Top Level) Installation Procedures

Must be used in conjunction with relevant Top Level Installation Procedure, Cartridge Hazard Analysis, relevant Critical Lift Plan and relevant Cartridge Flight Document.

### i) TOP LEVEL INSTALLATION PROCEDURES

LIGO-[E1200023](#): aLIGO Chamber Chamber (Top Level) Installation Procedures

### ii) CARTRIDGE HAZARD ANALYSIS

LIGO-[E1200925](#): BSC Cartridge Installation Hazard Analysis, aLIGO

### iii) CRITICAL LIFT PLANS (Refer to LIGO-E1200901)

[LIGO-E1200950](#): Critical Lift Plan for the aLIGO BSC1-L1 Cartridge Installation

[LIGO-E1200328](#): Critical Lift Plan for the aLIGO BSC2-L1 Cartridge Installation

[LIGO-E1200275](#): Critical lift plan for the aLIGO BSC6 cartridge installation

[LIGO-E1100988](#): Critical lift plan for the aLIGO BSC8 cartridge installation

### iv) CARTRIDGE FLIGHT DOCUMENTS (REFER TO LIGO-E1200900)

[E1200927](#): BSC1-L1 Requirements and Procedure, Cartridge Flight and Insertion into BSC Chambers, aLIGO

[E1200322](#): BSC2-L1 Requirements and Procedure, Cartridge Flight and Insertion into BSC Chambers, aLIGO

[E1100278](#): BSC6-H2 Requirements and Procedure, Cartridge Flight and Insertion into BSC Chambers, aLIGO

[E1101016](#): BSC8 H2, Requirements and Procedure, Cartridge Flight and Insertion into BSC Chamber, aLIGO



## 7 Test documents

*Test rationale, plans, and data for each unit must be documented as described in M1000211. That tree structure should be pointed to by the overall tree structure laid out in this Acceptance prescription. The top-level objective is to make clear how the measurements performed, which often will not directly measure a required performance parameter, give confidence that the subsystem will fulfill the requirements.*

The SEI testing documentation is posted in the DCC at:

- [E1000304](#): aLIGO SEI Testing and Commissioning Documentation

This document describes how the SEI test documentation is organized. The DCC entry page for this document contains the links to the Seismic Group testing and commissioning documentation of the Advanced LIGO SEI installation. In particular, the testing page of sub-assemblies used on the BSC-ISI are collected at:

- [E1100786](#), aLIGO SEI Instruments Testing Reports and Tracking Lists

Links to test procedures and results for the BSC-ISI assemblies are collected at:

- [E1000306](#): aLIGO BSC-ISI Testing and Commissioning Documentation
- [E1000486](#): aLIGO BSC-ISI Testing Procedure, Phase I: Assembly Validation
- [E1000487](#): aLIGO BSC-ISI Testing Procedure, Phase II : Integration process
- [E1000488](#): aLIGO BSC-ISI Testing Procedure, Phase III: Control Commissioning
- [E1100989](#): aLIGO BSC-ISI, Phase I Testing Reports (Assembly Validation)
- [E1100990](#): aLIGO BSC-ISI, Phase II Testing Reports (Integration process)
- [E1100991](#): aLIGO BSC-ISI, Phase III Testing Reports (Control Commissioning)

## 8 User interface software

*User interface software, and the test routines indicating proper functioning of the software, must be described in words and have code under configuration control (SVN). Watchdog and Guardian routines must also be treated in this way.*

All of the seismic isolation system software is configuration controlled and resides in the SVN repository:

<https://svn.ligo.caltech.edu/svn/seismic/>

The following documents focus on user interface software:

- [G1300404](#), ISI Overview Screens Updates
- [G1300447](#), LHO SEI MEDM UPDATED FOR OPERATORS
- [G1300618](#), ISI Watch Dog (WD) Plots - Operator Training
- [G1400776](#)-v1 Guardian Overview
- [G1500052](#)-v2 SEI Guardian Update - BSC-ISI GS13 Gain Switching (BS Only)
- [T1300629](#)-x0 SEI Guardians

See also section 2.g above regarding software and section 9 below regarding operations manuals.



## 9 Operation Manuals

*A manual appropriate for operators, written in accordance with M1200366, covering setup/initialization, check-out, operating instructions, calibration, maintenance, operations spares plan, storage/transport and troubleshooting. It must be accessible from standard user screens.*

- [E1200762](#), User interfaces Overview and restart procedure of the Seismic systems
- [G1300447](#), LHO SEI MEDM UPDATED FOR OPERATORS
- [G1300618](#), ISI Watch Dog (WD) Plots - Operator Training
- [E1000303](#), Huddle test stand (LLO): software, electronic checks -User guide
- [T070065](#), ISI Fine/Coarse Coil Driver User Guide

Some overview and tutorial documents regarding the SEI system (including the BSC-ISI):

- [G1400093](#), SEI and SUS subsystem tutorial
- [G1400089](#), aLIGO SEI overview for Detector Group
- [G1100431](#), aLIGO Active Seismic Isolation

## 10 Safety

*Safety documentation must be in the DCC for all phases of the subsystem development, including any needed for normal use or foreseen maintenance/repair scenarios.*

The following documents cover hazard analyses associated with the assembly and installation of the BSC-ISI system:

- [E0900358](#)-v4 BSC ISI AdL Hazard Analysis
- [E1200925](#)-v3 BSC Cartridge Installation (Universal) Hazard Analysis, aLIGO
- [E1200901](#): aLIGO BSC Safety Procedures (associated with install)

## 11 Acronyms

For a list of LIGO abbreviations and acronyms, see [M080375](#).