

*LIGO Laboratory / LIGO Scientific Collaboration*

LIGO-E1000487-v7

*LIGO*

May 16, 2011

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**aLIGO BSC-ISI Testing Procedure,  
Phase II : Integration process.**

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Distribution of this document:  
Advanced LIGO Project

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## ***Introduction***

The BSC-ISI testing is made of three phases:

- Phase I, Assembly validation (E1000486)
- Phase II, Integration (E1000487)
- Phase III, Control commissioning (E1000488)

This document summarizes chamber per chamber the various steps of the BSC-ISI Phase II testing (integration).

By "integration" we mean "assembly with other sub-systems", including:

- Mating with suspensions, optics, auxiliary systems...
- Installation, insertion in the chamber (cartridge installation)

In other word, they are all the steps done after the assembly validation, and before the chamber is closed for pump-down and control commissioning in final configuration (phase III).

At the end of Phase II:

- The BSC-ISI is on the chamber's support tubes
- All the suspensions, optics and other auxiliary equipments are installed and in final configuration (no more change will be done on the optical layout)
- A two days final check is performed
- A report is produced and posted in the DCC and data results will be posted on the SVN
- The SEI team validates the Phase II testing of the unit
- The chamber can be closed and pumped down. Phase III, control commissioning can start.

Phase II is divided in 2 steps:

- Phase II-a: Tests before cartridge
- Phase II-b: Tests after cartridge installation
- Phase II-c : Tests before closing the chamber

Phases II-a, II-b and II-c will be validated with the check-up sequence.

In some cases, some extra tests may be added.

During Phase II, the commissioner-tester must update:

- The test report
- The log book
- The excel spreadsheet in which lots of test results are posted

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## I. Testing sequence

The testing sequence is a series of test that can be performed to evaluate the state of health of the ISI. Performing the testing sequence should last a maximum of 2 days if no problems are detected.

### 1. Watchdog check (to do once per electronic rack – model update)

There are 3 main watchdogs that can prevent the ISI from driving:

- The SUS watchdogs can trip the ISI. If the SUS WD trips. It will trip the ISI watchdog (switch + IOP Kill)
- There is the ISI WD
- There is the CDS watchdog that uses OSEMs channels at the IOP level. If the CDS watchdogs trips, both ISI and SUS models won't be able to send output signals (DACKILL part at the IOP Level)

These manifold watchdogs can be tested using one of the two extra channels in the BSC-ISI models.

- Drive an offset (3276counts – 1V) on the test channels (IFO:ISI-OPTICS\_TEST1)
- Visualize the 1V offset on the AI output
- Trip on of the three watchdogs at the time. The voltage should go to zero.

### Acceptance Criteria

The output voltage of the test channels should go to zero when the watchdogs are tripped.

### 2. Pressure sensors

Read and report the absolute and the relative pressures read by the pressure sensors

There are two functions:

- Pressure\_Sensor\_Check\_Calibrated\_BSC\_ISI(IFO,Optics,Computer\_name,Unit\_ID). It gives the pressure once calibrated
- Pressure\_Sensor\_Check\_Raw\_BSC\_ISI(IFO,Optics,Computer\_name,Unit\_ID). It gives the pressure read by the ADC (RAW)

Sensors	Pressure (count)		
	Corner 1	Corner 2	Corner 3
ST1-L4C-D			
ST1-L4C-P			
ST1-GS13-D			
ST1-GS13-D			
ST1-T240-P			

Table - Sensor pressure (Counts)

**Acceptance criteria:**

- The absolute pressure on the L4Cs and the GS13s must be 24700 +/- 500 counts (100 +/- 2 KPA)
- The differential pressure on the L4Cs and the GS13s must be <2400 counts (2 KPa)
- The absolute pressure on the T240 must be 14300 +/-300 counts (100 +/- 2 KPA)

**The tests report must contain:**

- 1- The table “Sensors pressures”
- 2- Issues/difficulties/comments regarding this test
- 3- Test result (Passed: \_\_\_ Failed: \_\_\_ )

**3. Sensor spectra**

Spectra have to be measured with the table unlocked. The matlab function can be used to measure and calibrate the spectra:

ASD\_Measurements\_Local\_BSC\_ISI(IFO,Optics,GPS\_TIME,F\_resolution,Overlap\_per\_cent,Average,Unit\_ID\_Title,Unit\_ID,State)

**Acceptance criteria:**

- All sensors must be working
- No single frequency component with large amplitude at low frequency (synchronization cable)
- Noise floor of the ST1 CPS at  $5e-10$  m/sqrt(Hz)
- Noise floor of the ST2 CPS at  $5e-11$  m/sqrt(Hz)

**4. Balancing check after level checking– Offset locked vs unlocked**

Write down the mean values and standard deviation in the table below (call the Matlab functions Offset\_STD\_CPS\_BSC\_ISI(IFO,Optics) in the locked and the unlocked configuration

**Acceptance criteria:**

- In the locked position, all mean values must be lower than 400 counts for stage 1 CPS and 1600 counts for stage 2 CPS on Dataviewer (a bit less than .0005”).
- In the locked position, all standard deviations below 5 counts for stage 1, 20 counts for stage 2
- Absolute values of the difference between the unlocked and the locked table must be below:  
**Stage 1**
  - 1600 cts for horizontal sensors (~0.002”)
  - 1600 cts for vertical sensors (~0.002”)**Stage 2**
  - 6500 cts for horizontal sensors (~0.002”)
  - 6500 cts for vertical sensors (~0.002”)
- Considering the acceptance criteria of step 2, all mean values must be lower than

**Stage 1**

- 2000 cts for horizontal sensors (~0.0025")
- 2000 cts for vertical sensors (~0.0025")

**Stage 2**

- 8000 cts for horizontal sensors (~0.0025")
- 8000 cts for vertical sensors (~0.0025")

**Note:** The locker offset is set to +2 mils in step I.11.

**The tests report must contain:**

- 1- The table “Capacitive position sensors readout after gap set-up”
- 2- When the gap between the sensor head and the target gets larger MEDM counts increases
- 3- Issues/difficulties/comments regarding this test
- 4- Test result (Passed: \_\_\_ Failed: \_\_\_ )

**5. Static tests (local basis)**

This test verifies three points:

- Actuators-sensors readout chains
- Static main coupling
- Actuators power (driving signal and actuator response)
- Actuators plug sign

**Procedure to follow for this test:**

- Run the script Static\_Test\_Local\_Basis\_BSC\_ISI
- Copy the table automatically generated
- Make sure that the value in the table Comparison with reference don't exceed 50 counts

**Acceptance criteria:**

- Main couplings readout must be positive
- Comparison with the reference table:
  - Main coupling differences mustn't exceed 200 counts
  - Cross coupling differences mustn't exceed 50 counts

**The tests report must contain:**

- 1- The table “Main and cross coupling - Static”
- 2- Issues/difficulties/comments regarding this test
- 3- Test result (Passed: \_\_\_ Failed: \_\_\_ )

## **6. Resistance check (Actuators – cables resistance)**

The resistance of the couple Actuators and cables can be measured using the matlab function:  
Actuators\_Resistance\_BSC\_ISI(IFO,Optics,Unit\_ID,Note\_User)

### **Comparison with the measurement realized in the staging building:**

#### **Cable resistance:**

14 AWG:0.00253ohm/foot

16 AWG:0.00402ohm/foot

150feet cables (16AWG) => 0.602ohm

#### **Acceptance criteria:**

- For the actuators of stage 1, the measured resistance between the middle pin and one side pin must be 6.3 +/-0.5 ohms
- For the actuators of stage 2, the measured resistance between the middle pin and one side pin must be 10.3 +/-0.5 ohms

### 7. Range of motion

In this step, range of motion of the two stages is checked when applying a local drive on actuators.

#### Matlab

A Matlab function is used to execute the “Range of motion – Local drive test”

Follow the steps below:

- 1- Run Range\_Motion\_BSC\_ISI(IFO,Optics,Unit\_ID>Note\_Range\_Motion)
- 2- Copy and paste the table in the test report as it is

Range\_Motion\_X1\_BSC\_ISI.m drives a +/-30000 counts offset in a single actuator and get the Local range of motion.

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1					
ST1 - H2					
ST1 - H3					
ST1 - V1					
ST1 - V2					
ST1 - V3					
ST2 - H1					
ST2 - H2					
ST2 - H3					
ST2 - V1					
ST2 - V2					
ST2 - V3					

Table 1 - Range of motion - Local drive

#### Acceptance criteria:

- Amplitude must be at least 30000 counts (+/-0.038”) for Stage 1 CPS H
- Amplitude must be at least 26000 counts (+/-0.03”) for Stage 1 CPS V
- Amplitude must be at least 30000 counts (+/-0.0055”) for Stage 2 CPS H
- Amplitude must be at least 26000 counts (+/-0.0065”) for Stage 2 CPS V
- Signs of actuators drive and sensors read out have to be the same

#### The tests report must contain:

- 1- The table “Range of motion – Local drive”
- 2- Issues/difficulties/comments regarding this test

Test result (Passed: \_\_\_ Failed: \_\_\_ )



### 8. Linearity test

The linearity of the triplet Actuators - BSC-ISI - Sensors is evaluated during the following test. This test is carried out using Matlab and awgstream.

#### Matlab

A Matlab function is used to execute the “Linearity Test”

Follow the steps below:

- 1- Open the Matlab script Linearity\_Test\_Awgstream\_BSC\_ISI
- 2- Copy and paste the table Slopes\_Offset in the test report as it is
- 3- Paste the figure in the report
- 4- Edit the script to replot the linearity curve

Linearity\_Test\_Awgstream\_BSC\_ISI.m performs the linearity Test. It plots the linearity test and computes the slopes)

**Note:** Perform this test when assembly area is quiet (BSC-ISIs bounce much more than HAM-ISI)

Report slopes in this table

	Slope	Offset	Average slope	Variation from average(%)
ST1 - H1				
ST1 - H2				
ST1 - H3				
ST1 - V1				
ST1 - V2				
ST1 - V3				
ST2 - H1				
ST2 - H2				
ST2 - H3				
ST2 - V1				
ST2 - V2				
ST2 - V3				

Table - Slopes and offset of the triplet Actuators - BSC-ISI - Sensors

#### Acceptance criteria:

- Horizontal and vertical slopes of the triplet actuators x BSC-ISI x sensors: Average slope +/- 1.5%
- Typical Average slopes are 0.56 for ST1-H; 0.42 for ST1-V; 0.32 for ST2-H; 0.38 for ST2-V

#### The tests report must contain:

- 1- The table “Slopes and offset of the triplet Actuators – BSC – ISI - Sensors”
- 2- Figures that shows linearity on vertical and horizontal axis
- 3- Issues/difficulties/comments regarding this test
- 4- Test result (Passed: \_\_\_ Failed: \_\_\_ )

## ***9. Transfer functions measurements in the local basis – Recombined in the Cartesian basis***

Transfer functions are measured in the local basis. Transfer functions are recombined in the Cartesian basis.

Generic scripts are used to realize the measurements. They can be found in the SVN at /seismic/BSC-ISI/Common/Transfer\_Functions\_Scripts/

- Run\_TF\_L2L\_750Hz\_1000Hz\_BSC\_ISI
- Run\_TF\_L2L\_500Hz\_750Hz\_BSC\_ISI
- Run\_TF\_L2L\_300Hz\_500Hz\_BSC\_ISI
- Run\_TF\_L2L\_200Hz\_300Hz\_BSC\_ISI
- Run\_TF\_L2L\_100Hz\_200Hz\_BSC\_ISI
- Run\_TF\_L2L\_10Hz\_100Hz\_BSC\_ISI
- Run\_TF\_L2L\_100mHz\_700mHz\_BSC\_ISI
- Run\_TF\_L2L\_10mHz\_100mHz\_BSC\_ISI
- Run\_TF\_L2L\_700mHz\_10Hz\_BSC\_ISI

For quick evaluation, the high frequency transfer function can be measured using the two following scripts in the [100; 1000]Hz frequency band.

- Run\_TF\_L2L\_100Hz\_500Hz\_BSC\_ISI
- Run\_TF\_L2L\_500Hz\_1000Hz\_BSC\_ISI

The Cartesian transfer functions can be measured using the following scripts

- Run\_TF\_C2C\_100Hz\_1000Hz\_BSC\_ISI
- Run\_TF\_C2C\_10Hz\_100Hz\_BSC\_ISI
- Run\_TF\_C2C\_100mHz\_700mHz\_BSC\_ISI
- Run\_TF\_C2C\_10mHz\_100mHz\_BSC\_ISI
- Run\_TF\_C2C\_700mHz\_10Hz\_BSC\_ISI

Note: The adjustment gains must be set for each new teststand/cleanroom. The [0.7; 10]Hz frequency band is subjected to the major gain changes.

## ***10. Comparisons with previous transfer functions (staging building)***

The transfer functions measured in the staging building and in the LVEA can be compared using matlab scripts” like the one used for ISI-BSC6:

- BSC-ISI/H2/ETMY/Scripts/Misc/Comparison\_TF\_L2L\_LHO\_ISI\_BSC6.m
- BSC-ISI/H2/ETMY/Scripts/Misc/Comparison\_TF\_C2C\_LHO\_ISI\_BSC6.m

## **II. Generic testing procedure – Phase II-a – After installing the BSC- ISI on the teststand**

Even if ISIs receive different types of payload, a generic tests that need to can be performed during Phase II-a. Test specific to each units will also be performed.

### ***1. Hardware changes***

#### **a. CPS – E1100369**

Report if a CPS is changed or regapped and update E1100369.

#### **b. GS13 – E1100740**

Report if a GS13 is changed and update E1100740.

#### **c. L4C – E1100740**

Report if a L4C is changed and update E1100740.

#### **d. T240 – E1100740**

Report if a T240 is changed and update E1100740.

#### **e. Cables – E1100822**

Report if a in-vacuum cable is changed and update E1100822.

#### **f. Misc**

Report any kind of hardware change that could affect the dynamic of the ISI (blades, Vibration absorbers, TMD, Viton pads, lockers, etc...)

## 2. *Electronic Inventory*

Fill the table below:

Hardware	Ligo reference	S/N
Interface Chassis Pod 1	D1002432	
Interface Chassis Pod 2	D1002432	
Interface Chassis Pod 3	D1002432	
Anti-aliasing Chassis Pod 1	D1002693	
Anti-aliasing Chassis Pod 2	D1002693	
Anti-aliasing Chassis Pod 3	D1002693	
Anti-image Chassis	D1000305	
Binary Input Chassis 1	D1001726	
Binary Input Chassis 2	D1001726	
Binary Output Chassis	D1001728	
T240 Interface Pod 1	D1002694	
T240 Interface Pod 2	D1002694	
T240 Interface Pod 3	D1002694	
Anti-image Chassis	D1000305	
Coil driver Pod 1	D0902744	
Coil driver Pod 2	D0902744	
Coil driver Pod 3	D0902744	
Expansion chassis		

Table 2 - Electronic inventory

## 3. *Models Modifications*

Report the models modifications.

**4. Mass distribution**

**a. Seismic**

The ballast and adjustment masses installed on stage 1 and 2 are reported in the tables below:

**Stage 1:**

Location	Mass Type	Weight (lb)	Weight (Kg)
Corner 1	D0902616 - 2,3,4,4		
Corner 2	D0902616 - 2,2,2,3,3,1		
Corner 3	D0902616 - None		
	6 vibration absorbers (66Kg)		

**Stage 2:**

Location	Mass Type	Weight (lb)	Weight (Kg)
Corner 1	D071200		
Corner 2	D071200		
Corner 3	D071200		
	Keel Masses (D1003136)		
	Ballast Masses (6x50lb)		
	<b>Total</b>		

**b. SUS**

The weight of the various suspension components must be reported in this paragraph.

**c. Misc**

The weight of the miscellaneous hanging from stage 2 must be reported in this paragraph.

**d. Total**

Nominal mass hanging on stage 0-1 blades (without stage 2): 912Kg – 2010lb

Nominal mass hanging on stage 1-2 blades: 2830Kg – 6239lb

Nominal payload on stage 1: 109Kg – 240lb

Nominal payload on stage 2: 1185Kg – 2612lb

**The tests report must contain:**

- 1- Comparison with the payload in staging building (difference must be lower than 10Kg on stage 1 and 25Kg on stage 2)
- 2- Test result (Passed: \_\_\_ Failed: \_\_\_ )

### ***5. Testing sequence***

The testing sequence in chapter 1 must be performed and all tests must pass.

### ***6. Comparison with transfer function in the staging building***

The transfer functions measured on the teststand during the side chamber testing can be compared with the transfer functions measured in the staging building.

They should be pretty similar.

Main differences visible on the stage 1 CPS are due to the different type of teststand. The teststands with short legs have resonances at 33.4Hz, 57.3Hz and 69.4Hz. The teststands with long legs have resonances at 19.6Hz, 21.4Hz and 29.6Hz.

The stage 2 payload is also creating new resonances.

### ***7. Validation before cartridge installation***

## **III. Generic testing procedure – Phase II-b – After installing the BSC- ISI in the chamber**

### ***1. Installation of the damping components***

### ***2. Testing sequence***

### ***3. Comparison of the transfer functions without the damping components***

Make sure the damping components are effective.

## **IV. Generic testing procedure – Phase II-c – Before closing the BSC- ISI in the chamber**

### ***1. Testing sequence***