LIGO Laboratory / LIGO Scientific Collaboration

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aLIGO BSC-ISI, Pre-integration Testing report,

Unit 6 - Phase I (post-assembly)

E1100299 – V4

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Distribution of this document:
Advanced LIGO Project

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Introduction

The BSC-ISI testing is performed in three phases:
1) BSC-ISI, Pre-integration Testing, Phase I (post-assembly)
2) BSC-ISI, Pre-integration Testing, Phase II: Tests done after Transport (and possible storage), during mating phase with Suspensions, before insertion.
3) BSC-ISI, Integration Phase Testing: Procedure and results related to the commissioning in the chamber.

This document presents the series of tests (Phase I) performed on the fourth BSC-ISI assembled at LHO.

The testing procedure document E1000486-v5 was used.

All results are posted on the SVN at:
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/X1/Unit_6/

The following type of document can be found in the SVN:
- Excel spreadsheet (.xls)
- Data location
- Figures location
- Masses distribution scheme (ppt)

I. Pre-Assembly Testing

- ***Step 1 - CPS Test and calibration – E1100369***

CPS sensors are tested (calibration and noise test) at MIT before being cleaned and baked at LHO. The list of installed sensors used for testing (phase I) are reported in step II.3.

All data related to the CPS testing can be found in the SVN at
/svn/seismic/Common/Data/aLIGO_BSC_ISI_CPS/

Test result: **Passed: _X_** **Failed: ___** **Waived :**

- ***Step 2 - GS13 – Inspection/Assembly – E1000058 – E1100740***

GS13 are tested and podded at LLO.

We had several GS-13s fail on this unit. Initially, 1h and 1v, then another vertical. A third vertical failed after a transfer function with too high drive.

The list of installed sensors used for testing (phase I) are reported in step II.3.

All the data related to GS-13 post podding testing can be found in the SVN at :
/svn/seismic/Common/Data/aLIGO_GS13_TestData/PostMod_TestResults_PDFs

E1000058 and E1100740 spreadsheets provide the status of each individual GS-13 at LLO site for HAM-ISI and BSC-ISI and the installation location of the geophones.

Test result: **Passed: _X_** **Failed: ___** **Waived :**

- ***Step 3 - L4C – Inspection/Assembly – E1000136 – E1100740***

L4C are tested and podded at LLO. The list of installed sensors used for testing (phase I) are reported in step II.

One vertical L4C failed.

All the data related to L4C post podding testing can be found in the SVN
at : /svn/seismic/Common/Data/aLIGO_L4C_TestData/TestResults_PDFs/

Test result: **Passed: _X_** **Failed: ___** **Waived :**

- ***Step 4 - T240 – Inspection/Assembly - E1100326 – E1100740***

T240 are tested and podded at LLO. We haven't had to replace the T240s on this Unit, and these are the ones with the new Voltage Regulator, it seems that they are working fine and keep the pressure sensor from dying. The list of installed sensors used for testing (phase I) are reported in step II.3.

All the data related to T240 post podding testing can be found in the SVN at :
seismic/Common/Data/aLIGO_T240_TestData/AsReceived_TestResults_PDFs.

E1100326 and E1100740 spreadsheets provide the status of each individual T240 at LLO site for BSC-ISI and the installation location of the geophones.

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- ***Step 5 - Actuators - T0900564 - T1100234 – E1100741***

The list of installed sensors used for testing (phase I) are reported in step II.2
Large actuators data can be found at: T0900564. Actuator inventory is made at Section II – Step 2.
Small actuators data can be found at: T1100234. Actuator inventory is made at Section II – Step 2.

Test result: **Passed: _X__** **Failed: ___** **Waived :**

II. Tests to be performed during assembly

o *Step 1 - Test stand level*

The Test Stand was transformed and re-leveled to dock a BSC-ISI.

Test result: **Passed: _X_** **Failed: ___** **Waived :**

o *Step 2 - Actuators Inventory*

The actuators S/N are reported in the table below. Further information can be found in T0900564 and T1100234.

Stage 1		Stage 2	
Actuator	**Actuator S/N**	**Actuator**	**Actuator S/N**
ST1 - H1	130	**ST2 - H1**	77
ST1 - H2	22	**ST2 - H2**	99
ST1 - H3	100	**ST2 - H3**	2
ST1 - V1	164	**ST2 - V1**	9
ST1 - V2	163	**ST2 - V2**	91
ST1 - V3	162	**ST2 - V3**	104

Table 1 - Actuators' inventory

Test result: **Passed: _X_** **Failed: ___** **Waived :**

o *Step 3 - Sensors Inventory*

The sensors S/N are reported in the table below.

CPS Stage 1	CPS S/N	ADE board serial #
H1	13199	
H2	13423	
H3	13195	
V1	13203	
V2	13427	
V3	13181	

Table 2 - Capacitive position sensors' inventory – Stage 1

CPS Stage 2	CPS S/N	ADE board serial #
H1	13202	
H2	13420	
H3	13179	
V1	12908	
V2	13416	
V3	13193	

Table 3 - Capacitive position sensors' inventory – Stage 2

Geophones GS13	Serial Number	POD
H1		97
H2		45
H3		59
V1		7
V2		42
V3		69

Table 4 - GS13 inventory

Geophones L4C	Serial Number	POD
H1		22
H2		44
H3		28
V1		39
V2		155
V3		27

Table 5 - L4C inventory

Geophones T240	Serial Number	POD
1		38
2		8
3		35

Table 6 - T240 inventory

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- ***Step 4 - Electronics Inventory***

Write down in the table below all serial numbers all the electronic equipment:

Hardware	**Ligo reference**	**S/N**
Interface Chassis - Corner 1	D1002432	S110223
Interface Chassis - Corner 2		S1102224
Interface Chassis - Corner 3		S1102218
Anti-Alliasing Chassis - Corner 1	D1002693	S1102693
Anti-Alliasing Chassis - Corner 2		S1102694
Anti-Alliasing Chassis - Corner 3		S1102679
Anti-image Chassis	D070081	S1000250
Binary Input Chassis	D1001726	S1101309
Binary Input Chassis		S11031308
Binary Output Chassis	D1001728	S1101347
T240 Interface - Corner 1	D1002694	S1101040
T240 Interface - Corner 2		S1101838
T240 Interface - Corner 3		S1101839
I/O Chassis	n/a	
Coil driver Pod 1	D0902744	S1000266
Coil driver Pod 2		S1000269
Coil driver Pod 3		S110692

Table 7 - Electronic equipment

Note:

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- ***Step 5 - Check level of Stage 0 after top-bottom plate assembly***

Note: This test has not been performed. The test stand was leveled before assembly began.

Test result: **Passed: ___** **Failed: ___** **Waived : X**

- ***Step 6 - Check gaps under the blade posts***

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- ***Step 7 - Blade post shim thickness***

This table shows the shims thickness installed under the lockers.

Stage 0-1		Stage 1-2	
Lockers	**Shim thickness (mil)**	**Lockers**	**Shim thickness (mil)**
Corner 1	122	**Corner 1**	125
Corner 2	124	**Corner 2**	122
Corner 3	120	**Corner 3**	126

Table 8 - Shims thickness

Acceptance criteria: Both D0901805 Stage 0-1 Locker Shims & D0902551 Stage 1-2 Locker Shims goes from .110” up to .130” with an increment of .001”.

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- ***Step 8 - Blade 0-1 post launch angle***

Test result: **Passed: __** **Failed: ___** **Waived : X**

- ***Step 9 - Gap checks on actuators***

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- ### *Step 10 - Mass budget*

Note: The second version of the blade spacers was used. Consequently, the additional payload is expected to be close from design.

Six vibration absorbers were installed on stage 1. Masses on stage 2 are resting on Viton pads.

Stage 1:
The stage 1 payload is reported in the table below:

Corner 1	Empty
Corner 2	2 vib + 1x D0902613 +1x Type1 +1x Type4
Corner 3	1 vibration absorber + 1x Type 1 +1x Type 3 +1x Type 4 +1x Type 5

Stage 1	
Location	**Weight (lb)**
Corner 1	0
Corner 2	53
Corner 3	25.5
Total	78.5

Table 9 - Payload Stage 1

Nominal payload on stage 1: 109Kg – 240lb
Additional payload on stage 1 is 48 kg (107lb) less than expected but good enough.
Nominal mass of stage 1=916Kg - 2019lb

Stage 2:

The stage 2 payload is reported in the table below:

Mass Budget	Quantity	Weig ht	Unit	Weight (lb)
	3	610	lb	1830
	2	233	lb	466
type 0	0		lb	0
type 1	1		lb	1.1
type 2	1		lb	2.2
type 3	0		lb	0
type 4	2		lb	15.8
type 5	7		lb	109.2
type 6	6		lb	163.2
				2587.5

Table 10 - Payload Stage 2

Nominal payload: 1183.4Kg – 2609lb
Total nominal mass of Stage 2: 2913.9Kg – 6424lb
Additional stage 2 payload is 30lb lighter than the design.

Error mass on stage 0-1 blades: -(30+107)/(6424+2019) = -1.6%

The Overall error on the weight of the payload is really low.

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- ***Step 12 – Cables inventory – E1100822***

The final Class A cables have been used for the testing of this Unit.

DCC Number	Description	Serial Number	Location	Inventory date	Tested
D1100154	25-pin M-to-two 9-pin F straight		L4C corner2		YES
D1100155	25-pin M-to-two 9-pin F straight		GS-13 corner2		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 V3		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 V2		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 H3		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 H2		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 H2		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 H3		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 V3		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 V2		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 V1		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 H2		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 H1		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 H2		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 V2		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 H3		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 V3		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 V1		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St H1		YES
D1100152	25-pin F-to-25-pin F		T240 corner3		YES
D1100152	25-pin F-to-25-pin F		T240 corner1		YES
D1100152	25-pin F-to-25-pin F		T240 corner2		YES
D1100153	25-pin F-to-25-pin F		L4C corner2		YES
D1100153	25-pin F-to-25-pin F		GS-13 corner3		YES
D1100153	25-pin F-to-25-pin F		L4C corner3		YES
D1100153	25-pin F-to-25-pin F		GS-13 corner2		YES
D1100153	25-pin F-to-25-pin F		L4C corner1		YES
D1100153	25-pin F-to-25-pin F		GS-13 corner1		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 V3 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 H1 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 V1		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 H3 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 H1 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 V2 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 V1 ext		YES
D1100154	25-pin M-to-two 9-pin F straight		L4C corner1 ext		YES
D1100155	25-pin M-to-two 9-pin F straight		GS-13 corner1		YES
D1100155	25-pin M-to-two 9-pin F straight		GS-13 corner3		YES
D1100154	25-pin M-to-two 9-pin F straight		L4C corner3		YES

Test result: **Passed: _X_** **Failed: ___** **Waived:**

- ***Step 13 - Cable routing***

The final Class A cables have been used for the testing of this Unit.
The cabling has been done following E1101027 aLIGO BSC-ISI Cable Routing Manual.

Test result: **Passed: _X_** **Failed: ___** **Waived :**

III. Tests to perform after assembly

- ***Step 1- Geophones pressure readout***

Raw pressure measured by the geophones is reported in the table below:

	Pressure (kPa)		
Sensors	**Corner 1**	**Corner 2**	**Corner 3**
ST1-L4C-P	69.2	69.8	69.6
ST1-L4C-D	0.8	-1.3	-0.05
ST1-GS13-P	71.7	70.6	71.7
ST1-GS13-D	-0.00	0.78	-0.44
ST1-T240-P	38.8	37.7	39.8

Table 11 - Raw Pressure

A screenshot of the MEDM pressure screen is saved in the Misc directory for Unit 6

Note: The T240's chassis has the old gain for the pressure sensors.

Test result: **Passed: _X_** **Failed: ___** **Waived :**

- ### *Step 2- Set up sensors gap – Locked vs unlocked position*

During this step, sensors gap are adjusted. This step considers that the lockers have been finely setup during assembly.

	Table locked		Table unlocked		Difference locked - unlocked	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**mil**
ST1 - H1	207	4	-820	21	1028	1.22
ST1 - H2	5	9	73	14	-71	-0.08
ST1 - H3	621	11	-41	13	662	0.79
ST1 - V1	-115	8	-1260	12	1145	1.36
ST1 - V2	510	12	346	11	163	0.19
ST1 - V3	44	14	111	12	-67	-0.08
ST2 - H1	515	61	105	20	410	0.12
ST2 - H2	463	40	-262	24	726	0.22
ST2 - H3	-31	59	-135	19	104	0.03
ST2 - V1	297	93	-365	28	663	0.2
ST2 - V2	-239	46	-1505	24	1266	0.38
ST2 - V3	269	74	843	24	-574	-0.17

Table 12 - Capacitive position sensors readout after gap set-up

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 25 counts for stage 1, 100 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 CPS will be readjusted once SUS will installed

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- ***Step 3 - Measure the Sensor gap***

Test Failure mitigation:
This test was not performed. The sensor gaps have not been measured. These sensors have already been tested at LASTI. Moreover, risks of scratching the target are so high that we preferred not performing this test. In the future, this test will be removed from the testing procedure.

Test result: **Passed: __** **Failed: ___** **Waived : X**

Step 4- Performance of the limiters

- ***Step 4.1 - Test Nº1 - Push "in the general coordinates Z/RZ"***

Test result: **Passed: __** **Failed: ___** **Waived : X**

- ***Step 4.2 - Test Nº2 – Push "locally"***

Sensors	Push in negative direction	Push in positive direction	Mil	Mil	Railing	Actuator Gap Check
ST1 - H1	-17000	19000	-20	23		X
ST1 - H2	-20000	20000	-24	23		X
ST1 - H3	-19000	20000	-23	24		X
ST1 - V1	-26000	25000	-31	30		X
ST1 - V2	-26000	25000	-31	30		X
ST1 - V3	-25000	24000	-30	29		X
ST2 - H1					X	X
ST2 - H2					X	X
ST2 - H3					X	X
ST2 - V1					X	X
ST2 - V2					X	X
ST2 - V3					X	X

Table 13 - Stages range of motion – "Push locally"

Acceptance criteria:

- The vertical sensor readout must be positive when the optical table is pushed in the +Z direction
- The horizontal sensor readout on Stage 2 must be positive when the optic table is pushed in the +RZ direction
- **Step 4.2**
  - Absolutes value of all estimated motions must be higher than 15000counts for stage 1 (~0.018")
  - Absolutes value of all estimated motions must be higher than 32000counts for stage 2 (~0.010")

Test result: **Passed: _X_** **Failed: ___** **Waived :**

- *Step 5 - Sensors spectra*

The geophones spectra have been measured and can be found in the SVN:

seismic/BSC-ISI/X1/UNIT_6/Data/Spectra/Undamped/

- X1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2014_02_13_115246.mat (Unlocked)
- X1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2014_02_13_151143.mat (Locked)

seismic/BSC-ISI/X1/UNIT_6/Data/Figures/Spectra/Undamped/

- X1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2014_02_13_115246.fig (Unlocked)
- X1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2014_02_13_151143.fig (Locked)

Stage locked – unlocked

The spectra are measured in two different configurations:

- Stage 1 locked – Stage 2 locked
- Stage 1 unlocked – Stage 2 unlocked

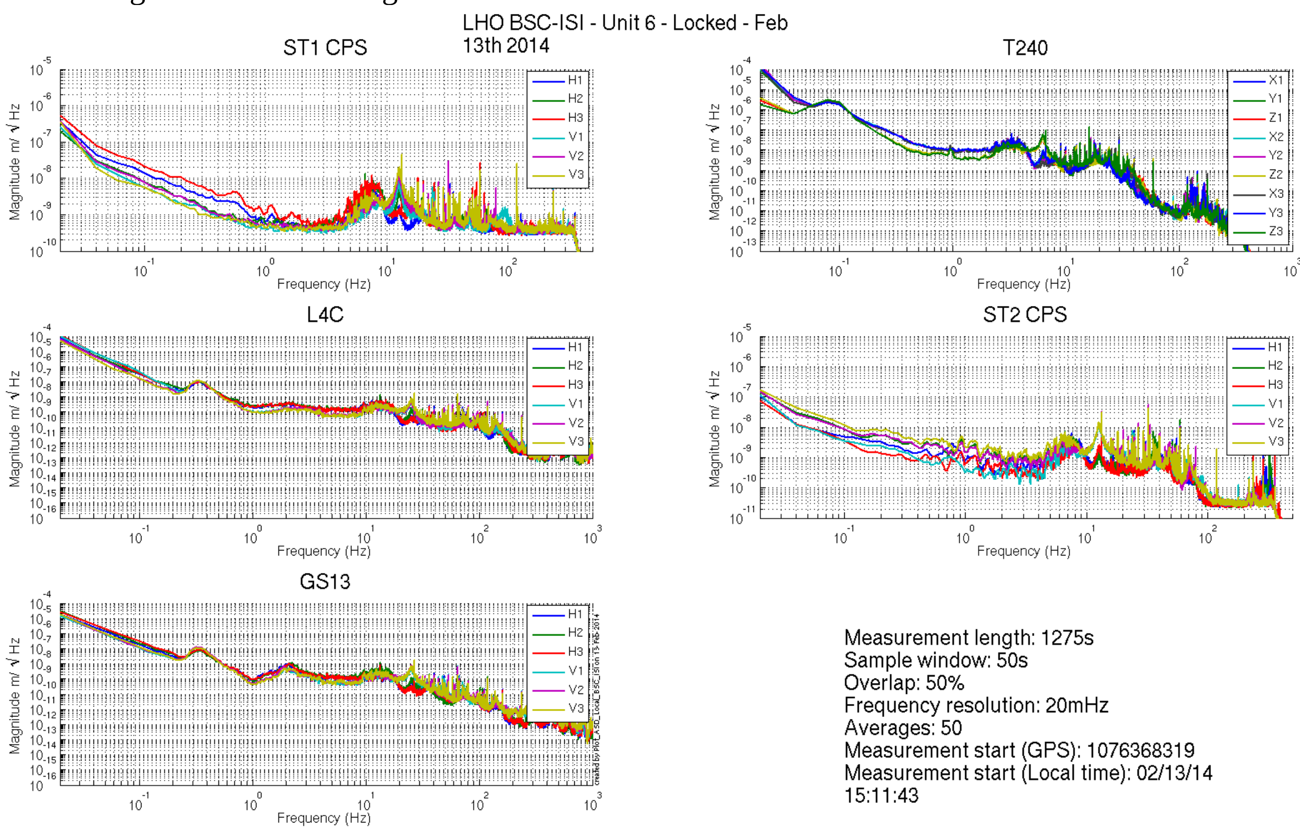


Figure 1: Calibrated Spectra Stage 1 Locked and Stage 2 Locked

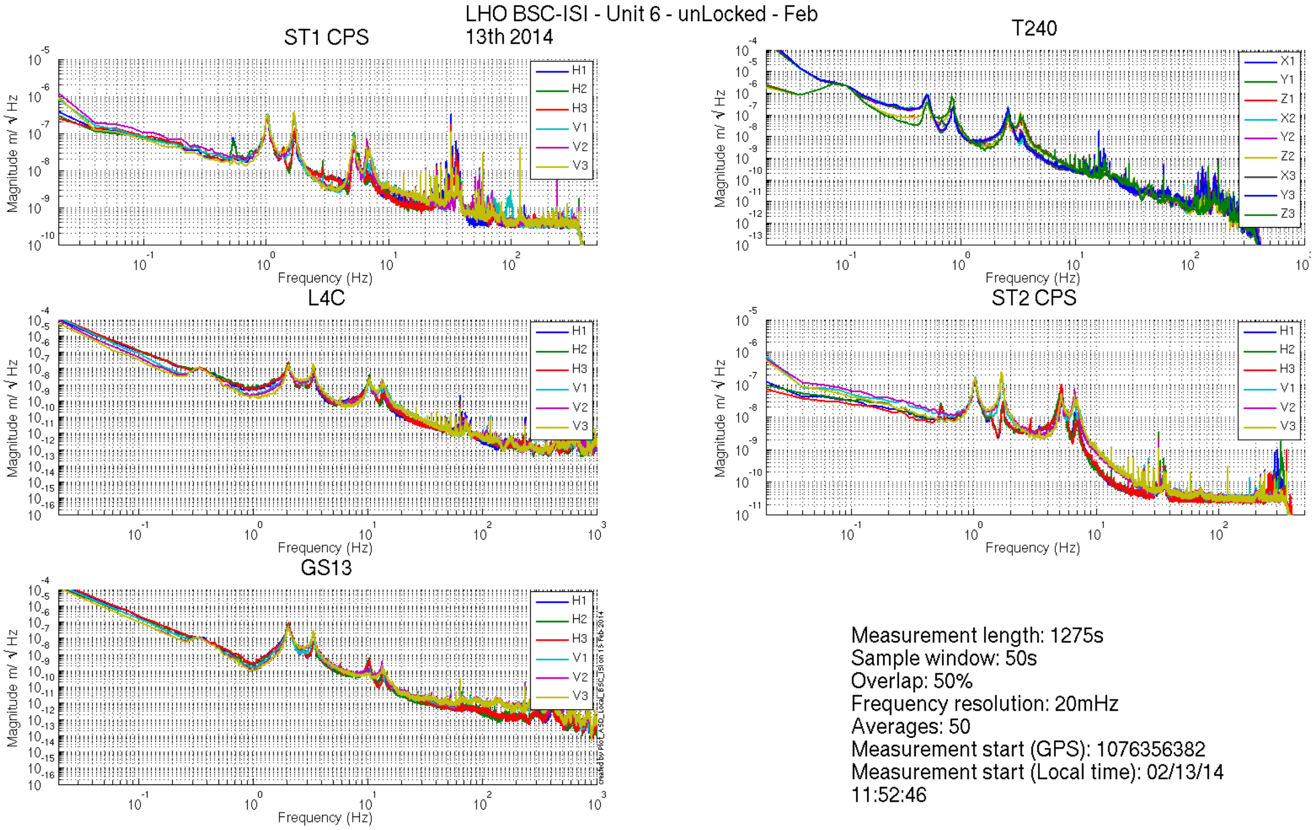


Figure 2: Calibrated Spectra Stage 1 Unlocked and Stage 2 Unlocked

Stage Tilted

The Spectra are measured when the ISI is unlocked a mass is placed on stage 2 to tilt Stage 1 and Stage 2.

The six configurations are the following in six different configurations:

- Mass placed in the actuator pocket at corner 1
- Mass placed in the pocket under the blade 0-1 at corner 1
- Mass placed in the actuator pocket at corner 2
- Mass placed in the pocket under the blade 0-1 at corner 2
- Mass placed in the actuator pocket at corner 3
- Mass placed in the pocket under the blade 0-1 at corner 3

/seismic/BSC-ISI/X1/Unit_6/Data/Spectra/Undamped/

- X1_ISI_ITMX_ASD_m_L4C_GS13_Stage_Tilted_2014_02_13.mat

seismic/BSC-ISI/X1/Unit_6/Data/Figures/Spectra/Undamped/

- X1_ISI_ITMX_Tilted_ASD_m_LOC_ST1_L4C_2014_02_13.fig
- X1_ISI_ITMX_Tilted_ASD_m_LOC_ST2_GS13_2014_02_13.fig

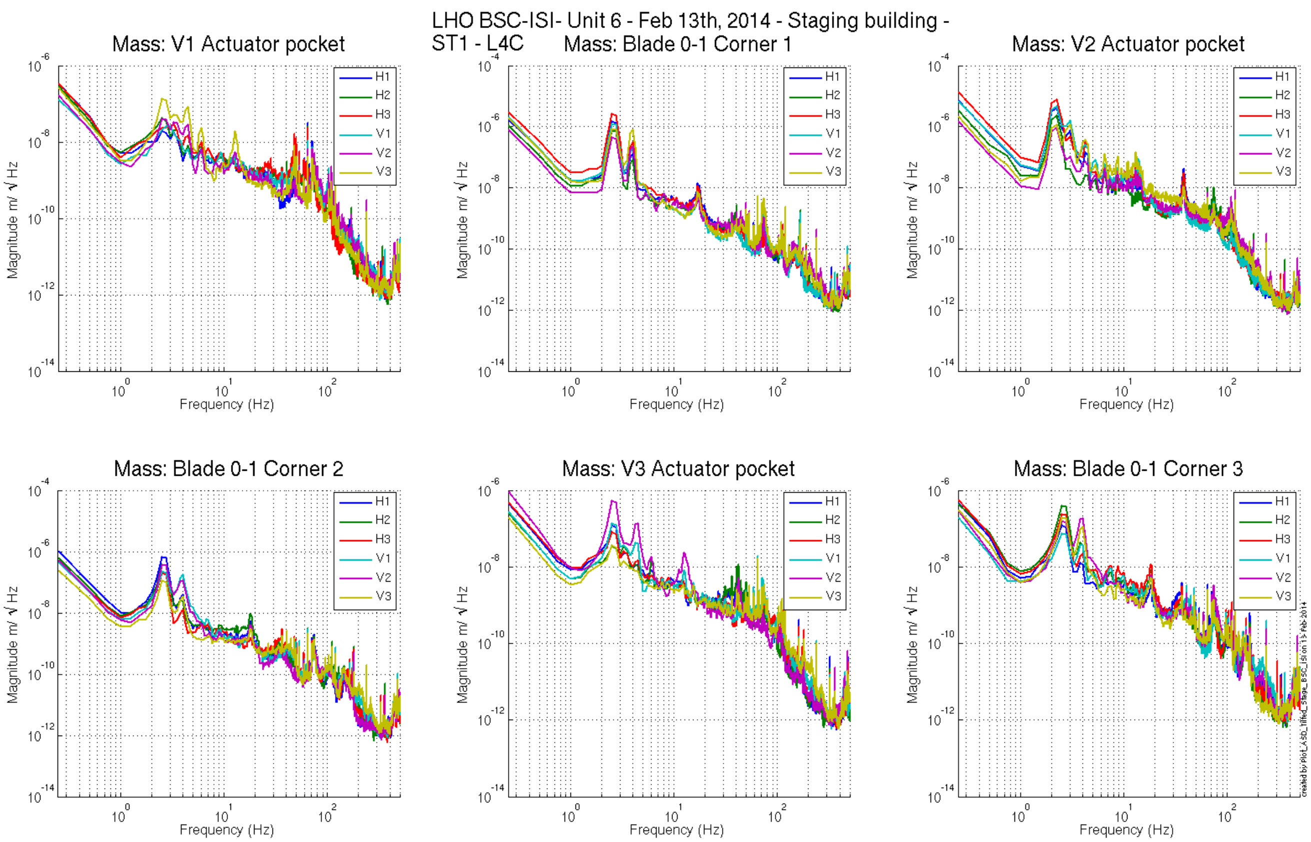


Figure 3 - ST1 L4C – Tilted

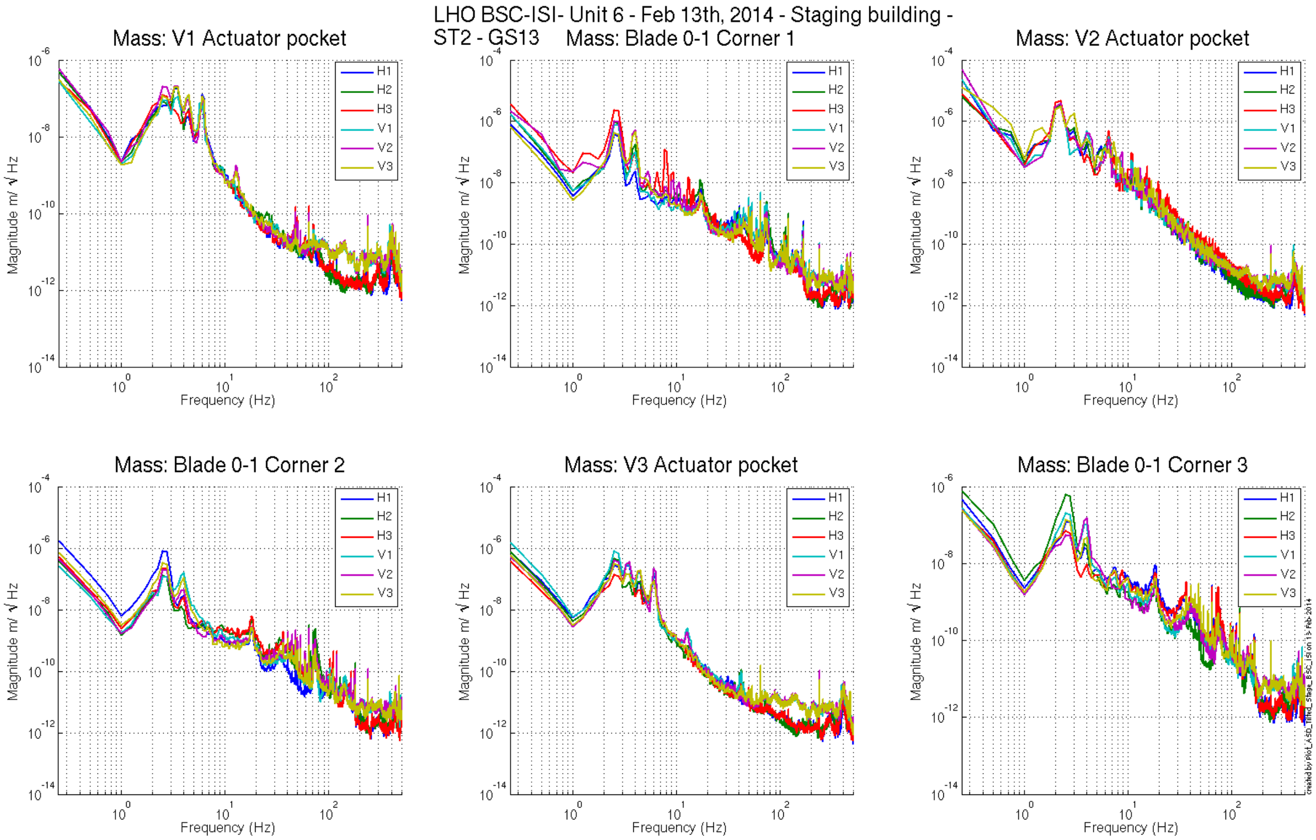


Figure 4 - ST1 GS13 – Tilted

Test result: **Passed: _X__** **Failed: ___** **Waived :**

o *Step 6 - Coil Driver, cabling and resistance check*

Resistances of the couple (actuators + in vacuum cables) were measured using the voltage and current the coil drivers read back. Resistances of the couple actuator + in-vacuum cables are reported in the table below:

Actuator	Resistance (Ω)
ST1 H1	6.2
ST1 H2	6.2
ST1 H3	6.2
ST1 V1	6.3
ST1 V2	6.2
ST1 V3	6.2
ST2 H1	9.8
ST2 H2	10
ST2 H3	10.2
ST2 V1	9.9
ST2 V2	10.1
ST2 V3	10

Table 14 - Actuator Resistance

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
- Actuator neutral pins must be connected on pin #1 (left side pin of the plug)
- Actuator drive pins must be connected on pin #2 (middle pin of the plug)
- Actuator ground shield pins must be connected on pin #3 (right pin of the plug)
- All LEDs on the coil driver front panel must be green the binary input bit must be in the upper state.

Test result: **Passed: _X_** **Failed: ___** **Waived :**

- ***Step 7- Actuators Sign and range of motion (Local drive)***
- ***Step 7.1 - Actuators sign***

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- ***Step 7.2 - Range of motion - Local drive***

In this step, range of motion of the two stages is checked when applying a local drive (30000 counts) on actuators.
seismic/BSC-ISI/X1/Unit_6/Data/Static_Tests/ :
X1_ISI_ITMX_Range_Of_Motion_20131210.mat

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-14979	-1008	17146	32125	38
ST1 - H2	-16248	-197	15626	31874	38
ST1 - H3	-16201	-120	16210	32411	39
ST1 - V1	-16090	-1355	13457	29547	35
ST1 - V2	-14542	221	15067	29609	35
ST1 - V3	-14255	277	14899	29154	35
ST2 - H1	-10101	39	10175	20276	6
ST2 - H2	-10241	-429	9434	-19675	5.9
ST2 - H3	-10133	-222	9672	1985	5.9
ST2 - V1	-12364	-106	12182	24546	7.3
ST2 - V2	-13613	-1334	10931	24544	7.3
ST2 - V3	-10837	1128	13068	23905	7.1

Table 15 - Range of motion - Local drive

Acceptance criteria:

- Amplitude p-p must be at least 30000 counts (0.035”) for Stage 1 CPS H
- Amplitude p-p must be at least 25000 counts (0.03”) for Stage 1 CPS V
- Amplitude p-p must be at least 18000 counts (0.005”) for Stage 2 CPS H
- Amplitude p-p must be at least 22000 counts (0.006”) for Stage 2 CPS V
- Signs of actuators drive and sensors read out have to be the same

Note: The motion of the platform can be computed. For a 30000 counts drive in the +Z direction, the platform should move by 12.6 mil on Stage 1 and 3.6mil on Stage 2.

In the Cartesian basis, the platform should move (calculation) by:

Stage 1 - Platform move for 32K counts drive:	12.63	mil
Stage 2 - Platform move for 32K counts drive:	3.59	mil

Note: The range of motion in the case of a "local drive" is in agreements with the measurements done on the previous units.

Test result: **Passed: _X_** **Failed: ___** **Waived :**

- ***Step 8 - Vertical Sensor Calibration***

Not done.

Test result: **Passed: ___** **Failed: ___** **Waived : X**

- ***Step 9 - Vertical Spring Constant***

This test is realized by loading the ISI when one stage is locked and using the capacitive position sensors as reference.

The stiffness measurements of the spring are reported in the tables below. The nominal blade stiffness are:

- Stage 1: 1241lb/in
- Stage 2: 1465lb/in

Blade Stage 0-1

Stage 2 Locked & Stage 1 Unlocked.

	Mean No load	Mean Load	Diff	
V1	-1927	-9774	7847	
V2	149	-7718	7868	
V3	523	7773	8295	
			8003	count
			-9.62	mil
			1145	lb/in
			7.72	%

Blade Stage 1-2

Stage 1 Locked & Stage 2 Unlocked. Stage 2 is loaded with 3 x 5Kg masses and the measurements are repeated three times (by rotating the masses).

	Mean no load	Mean load	Diff 1	
V1	-2080	-27899	25818	
V2	-1277	-27253	25976	
V3	-33	-26919	26885	
			26227	count
			-7.88	mil
			1385	lb/in
			-5.4	%

Test mitigation: Blades are softer than design.

Test result: **Passed: _X_** **Failed: __** **Waived :**

- ***Step 10 - Static Testing (Tests in the local basis)***

The static tests results are reported in the SVN at :
seismic/BSC-ISI/X1/Unit_6/Data/Static_Tests/

- X1_ISI_ITMX_Offset_Local_Drive_20130313.mat

The table below shows the main and the cross-coupling when the actuators are driven in the local basis:

		Sensors					
		ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
Actuators	ST1 - H1	4305	1737	1741	33	12	-9
	ST1 - H2	1708	4199	1699	-8	73	9
	ST1 - H3	1695	1693	4205	9	10	7
	ST1 - V1	80	-140	121	3464	-602	-609
	ST1 - V2	109	70	-148	-900	3496	-626
	ST1 - V3	-150	98	45	-615	-560	3412

Table 16 - Static test - Local to local - Stage 1

		Sensors					
		ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
Actuators	ST2 - H1	2376	382	363	17	-4	13
	ST2 - H2	340	2323	369	37	17	-13
	ST2 - H3	363	370	2329	6	-45	25
	ST2 - V1	62	150	-207	-2902	342	-69
	ST2 - V2	-193	116	127	50	2871	349
	ST2 -V3	106	-192	99	286	9	2803

Table 17 - Static test - Local to local - Stage 2

Acceptance criteria:

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

Test result: **Passed: _X__** **Failed: ___** **Waived :**

- o ***Step 11- Static Testing - In the general coordinate basis (Static test - CPS)***
- o ***Step 11.1 – Change of basis matrices from Cartesian to Local***

The static tests results are reported in the SVN at :
/seismic/BSC-ISI/X1/Unit_6/Data/Static_Tests/

- X1_ISI_ITMX_Offset_Cartesian_Drive_20130313.mat

Actuators		Sensors					
		ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	SScreenshotT1 - V2	ST1 - V3
	ST1 - X	1687	10	-1	17	9	38
	ST1 - Y	-6	1664	-11	-15	24	5
	ST1 - Z	-1	3	728	6	-6	3
	ST1 - RX	34	459	0	3038	-186	4
	ST1 - RY	-462	41	-6	191	3020	14
	ST1 - RZ	7	-3	-9	4	25	3217

Actuators		Sensors					
		ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
	ST2 - X	672	-1309	649	-14	-14	2
	ST2 - Y	1167	3	-1148	-17	-22	-3
	ST2 - Z	-8	-3	-13	1037	1037	987
	ST2 - RX	-265	-22	272	2427	2452	5
	ST2 - RY	145	-331	165	-1553	-1382	2801
	ST2 - RZ	1744	1707	1710	-33	-17	1

Table 18 - Static test - Cartesian to local - Stage 1 – Stage 2

Acceptance criteria:

- Comparison with the reference tables:
    - Differences mustn’t exceed 100 counts

Test result: **Passed:** _X_ **Failed:** ___ **Waived :**

o *Step 11.2 – Base change matrices from Cartesian to Cartesian*

The static tests results are reported in the SVN at :
/seismic/BSC-ISI/X1/Unit_6/Data/Static_Tests/

-

		Sensors					
		ST1 - X	ST1 - Y	ST1 - Z	ST1 - RY	ST1 - RY	ST1 - RZ
Actuators	ST1 - X	1687	10	-1	18	9	38
	ST1 - Y	-6	1664	-11	-15	24	5
	ST1 - Z	-1	3	728	6	-6	3
	ST1 - RX	34	459	0	3038	-186	4
	ST1 - RY	-462	41	-6	191	3020	14
	ST1 - RZ	7	-3	-9	4	25	3217

Table 19 - Static test Cartesian drive – Cartesian to local – Stage 1

		Sensors					
		ST2 - X	ST2 - Y	ST2 - Z	ST2 - RY	ST2 - RY	ST2 - RZ
Actuators	ST2 - X	1304	23	-6	6	48	6
	ST2 - Y	-2	1335	-15	-15	20	11
	ST2 - Z	-3011	11	1036	15	5	-10
	ST2 - RX	-52	286	5	3695	368	-10
	ST2 - RY	-279	-47	-50	-260	3764	-10
	ST2 - RZ	13	29	-26	-1	27	2393

Table 20 - Static test Cartesian drive – Cartesian to local – Stage 2

Acceptance criteria:

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

Test result: **Passed: __X__** **Failed: ___** **Waived :**

o *Step 12 - Linearity test*

The “Linearity test” was performed twice (rearranging the cables). The second time, all corners seemed to respond similarly.

The linearity test data can be found in the SVN at:
/seismic/BSC-ISI/X1/Unit_6/Data/Linearity_Test/
[X1_ISI_ITMX_Linearity_test_20131213.mat]

The linearity test figures can be found in the SVN at:
/seismic/BSC-ISI/X1/Unit_6/Data/Figures/Linearity_Test/
[X1_ISI_ITMX_Linearity_test_20131213.fig]

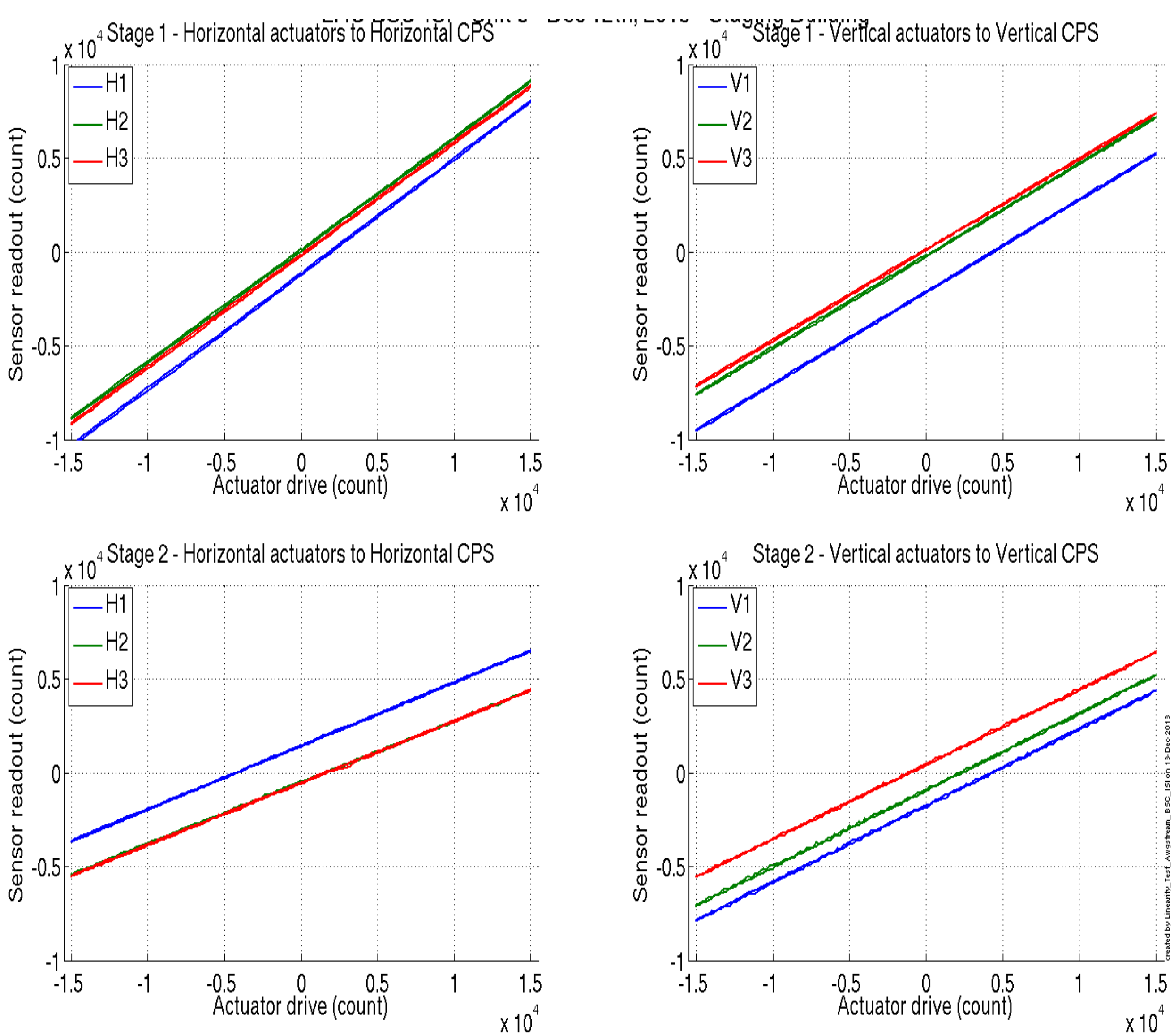


Figure 5 - Linearity Test

Slope – Offset:

		Slope	Offset	Average slope	Variation from average(%)
Stage 1	**ST1 - H1**	0.61	-1162	0.60	1.45
	ST1 - H2	0.6	109		-0.24
	ST1 - H3	0.59	-156		-1.21
	ST1 - V1	0.49	-2127	0.49	0.28
	ST1 - V2	0.49	-201		-0.13
	ST1 - V3	0.49	126		-0.15
Stage 2	**ST2 - H1**	0.34	1441	0.33	1.21
	ST2 - H2	0.33	-504		0.03
	ST2 - H3	0.33	-540		-1.24
	ST2 - V1	0.42	-1742	0.42	1.05
	ST2 - V2	0.41	-918		-0.91
	ST2 - V3	0.41	450		-.14

Table 21 - 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 +/- 2.5%

Test result: **Passed: _X_** **Failed: ___** **Waived :**

- *Step 13 – Transfer functions – Local to Local*

Note: two vibration absorbers were installed in corner 1 and 2 vibration absorbers were installed in corner 3. No TMDs were installed on the stage 0-1 blades.

Data files measurement of local to local transfer functions in SVN at:
seismic/BSC-ISI/X1/Unit_6/Data/Transfer_Functions/Measurements/Undamped/

-
-
-
-
-
-

Script file for processing and plotting local to local transfer functions in SVN at:
/seisvn/seismic/BSC-ISI/X1/Unit_6/Scripts/Control_Scripts

- Step_1_TF_L2L_10mHz_1000Hz_X1_ISI_Unit_6.m

Figures of local to local transfer functions (Main couplings) in SVN at:
/seismic/BSC-ISI/X1/Unit_6/Data/Figures/Transfer_Functions/Measurements/Undamped/

- X1_ISI_ITMX_TF_L2L_Raw_from_ST1_ACT_to_ST1_CPS_2013_12_09.fig
- X1_ISI_ITMX_TF_L2L_Raw_from_ST1_ACT_to_ST1_L4C_2013_12_09.fig
- X1_ISI_ITMX_TF_L2L_Raw_from_ST1_ACT_to_ST1_T240_2013_12_09.fig
- X1_ISI_ITMX_TF_L2L_Raw_from_ST1_ACT_to_ST2_CPS_2013_12_09.fig
- X1_ISI_ITMX_TF_L2L_Raw_from_ST1_ACT_to_ST2_GS13_2013_12_09.fig
- X1_ISI_ITMX_TF_L2L_Raw_from_ST2_ACT_to_ST1_L4C_2013_12_09.fig
- X1_ISI_ITMX_TF_L2L_Raw_from_ST2_ACT_to_ST1_T240_2013_12_09.fig
- X1_ISI_ITMX_TF_L2L_Raw_from_ST2_ACT_to_ST2_CPS_2013_12_09.fig
- X1_ISI_ITMX_TF_L2L_Raw_from_ST2_ACT_to_ST2_GS13_2013_12_09.fig

Measured of local to local transfer functions in the SVN at:
/svncommon/seisvn/seismic/BSC-ISI/X1/Unit_6/Data/Transfer_Functions/Simulations/Undamped

- X1_ISI_ITMX_TF_L2L_Sym_2013_12_09.mat

Note 1: The transfer functions are measured from the Output filter bank (excitation variable) to the input (IN1) of the input filter bank. The transfer functions presented below are raw transfer functions without any electronic compensation of the sensor electronic. The actuator and the coil driver electronic compensation are introduced in these transfer functions.

Note 2: The L4Cs are out of phase (should be -90 before 1Hz). A minus sign is added in the calibration filters that convert count to nm/s.

Note 4: The first resonance of the structure observed on stage 1 by the L4C is around 210Hz.

Note 5: There is a poor coherence on the GS13 transfer functions. It can be explained by the weak drive of the fine actuators. Moreover, the stage 2 of the ISI is strongly excited by the fans of the clean rooms. These two factors strongly affect the quality of the measurements.

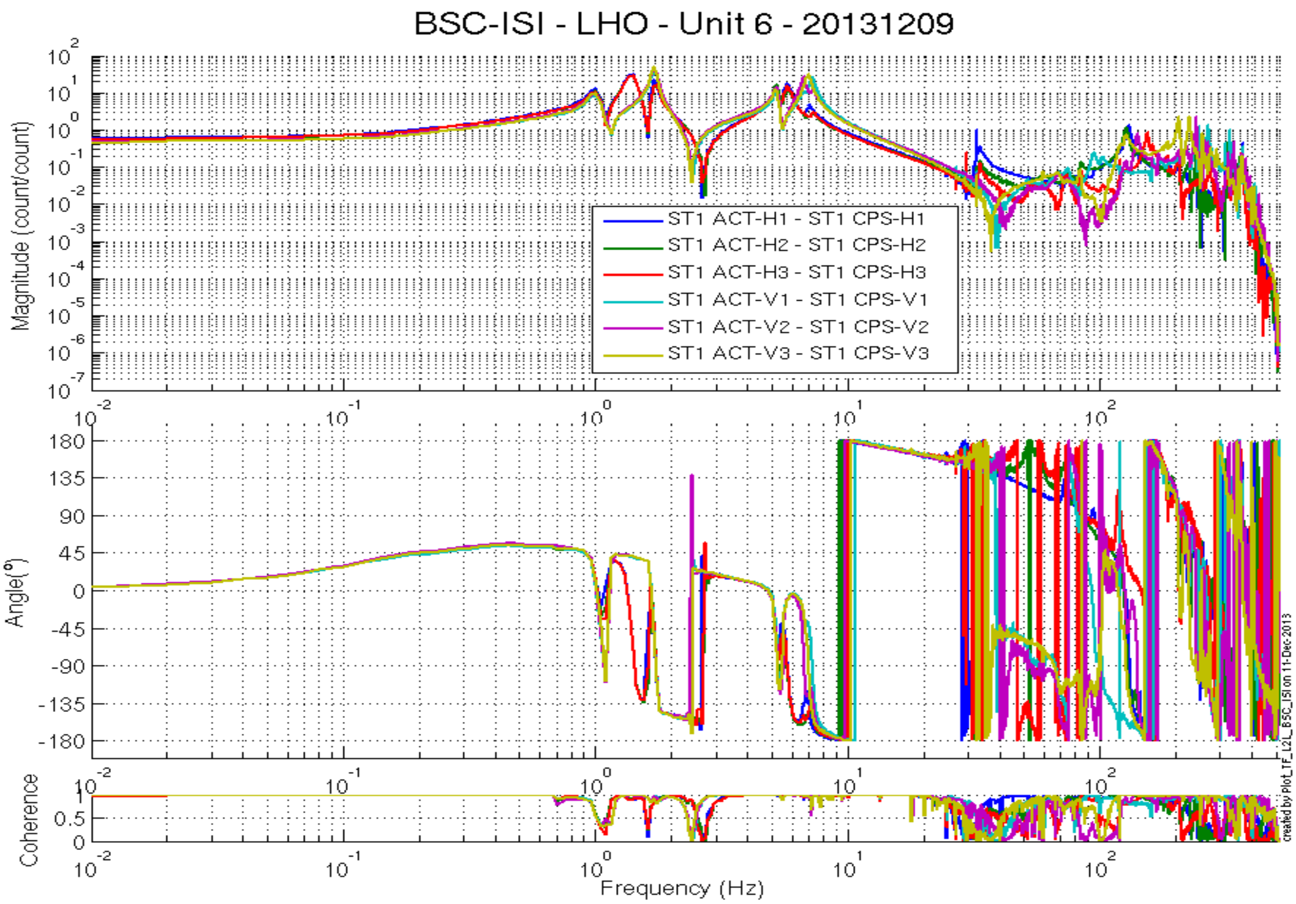


Figure 6: TF L2L Raw - ST1 Act to ST1 CPS

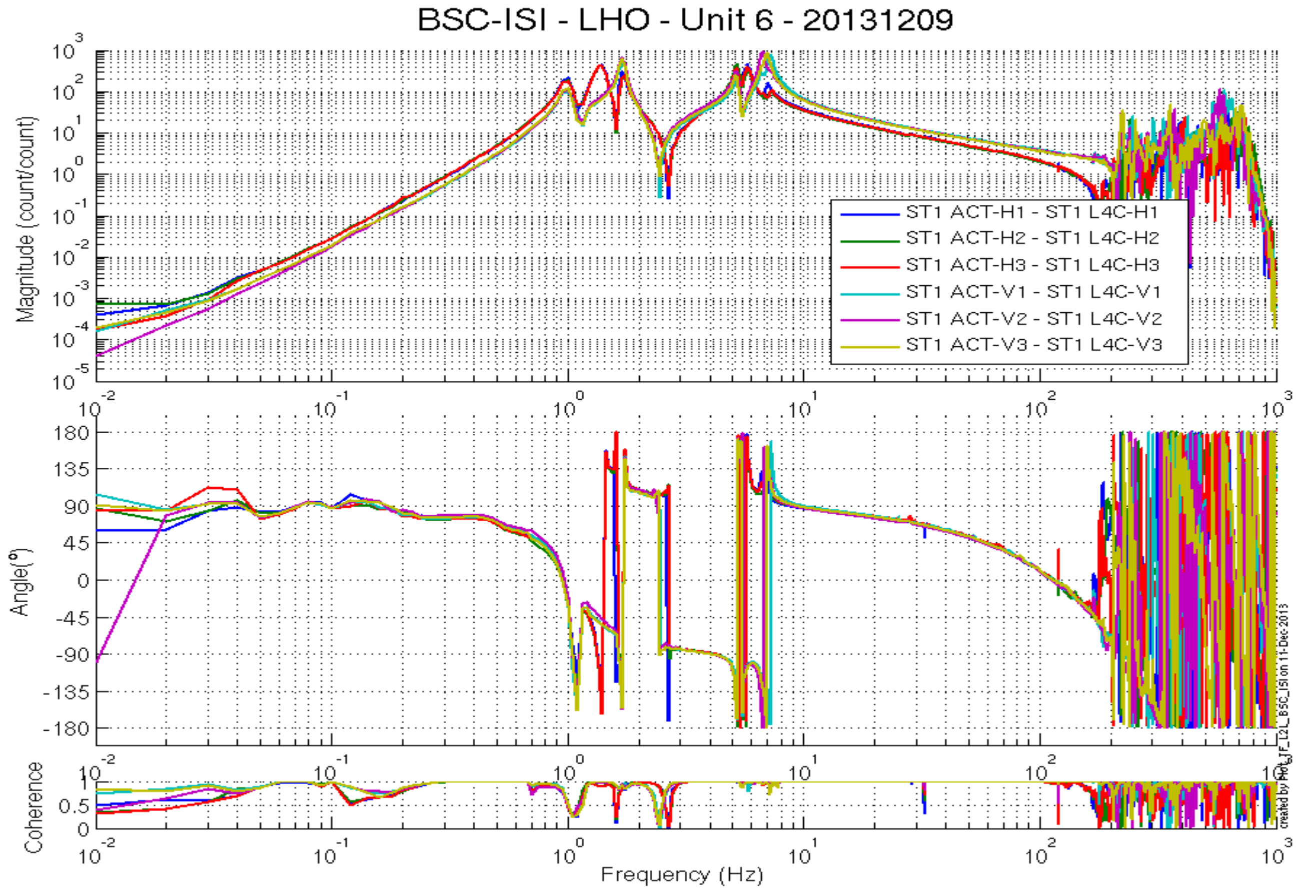


Figure 7: TF L2L Raw - ST1 Act to ST1 L4C

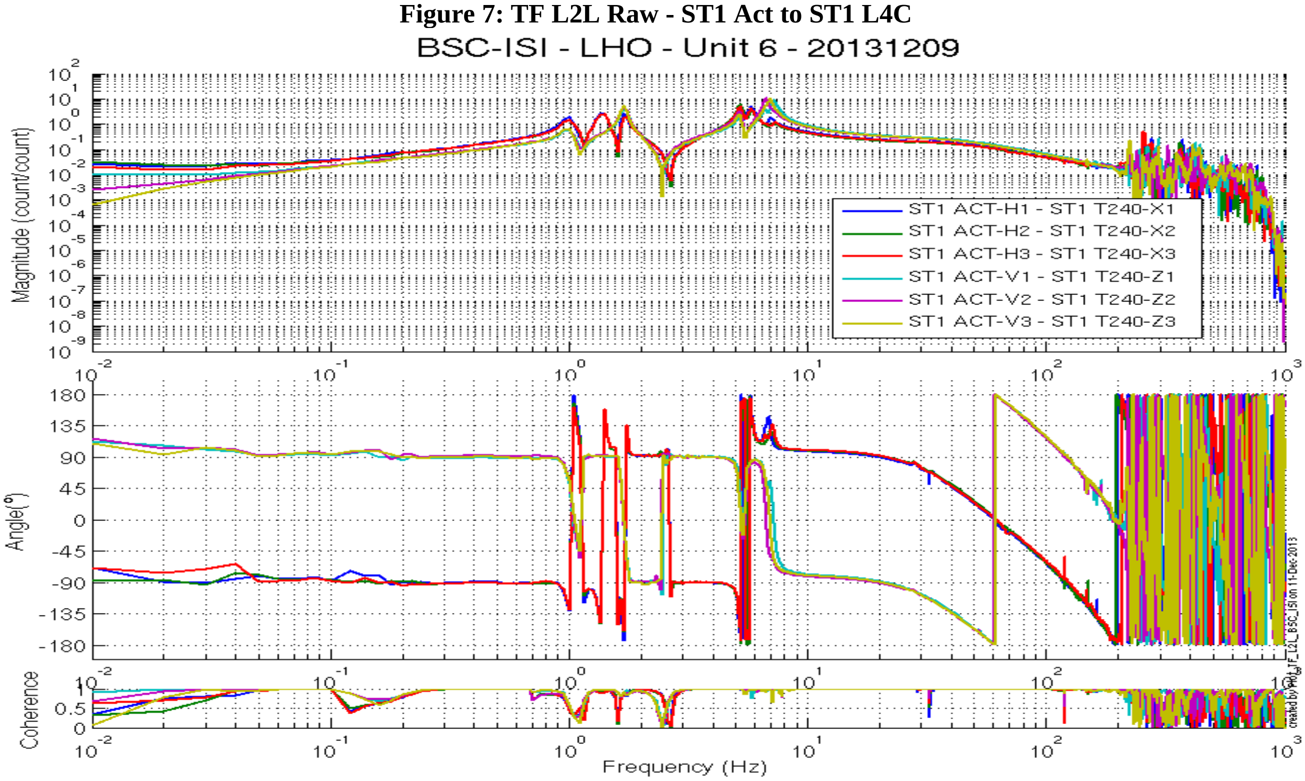


Figure 8 - TF L2L Raw - ST1 Act to ST1 T240

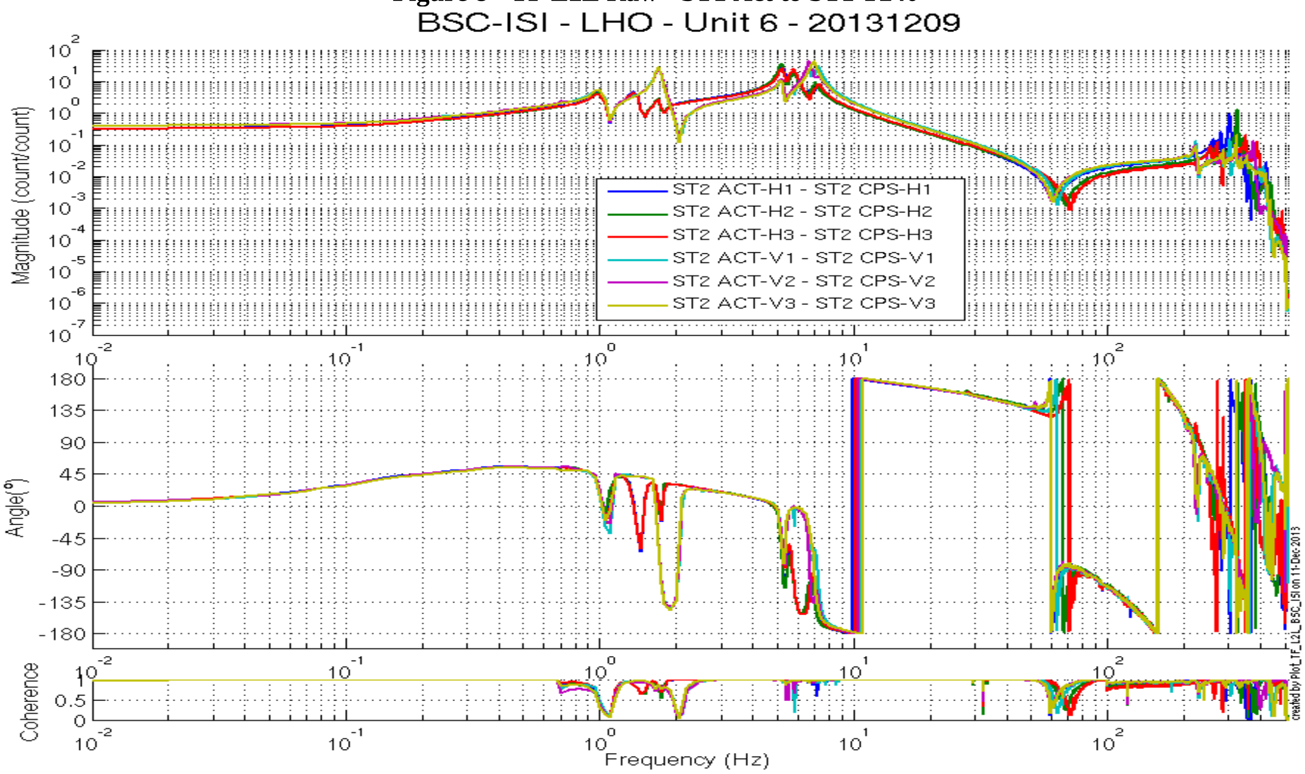
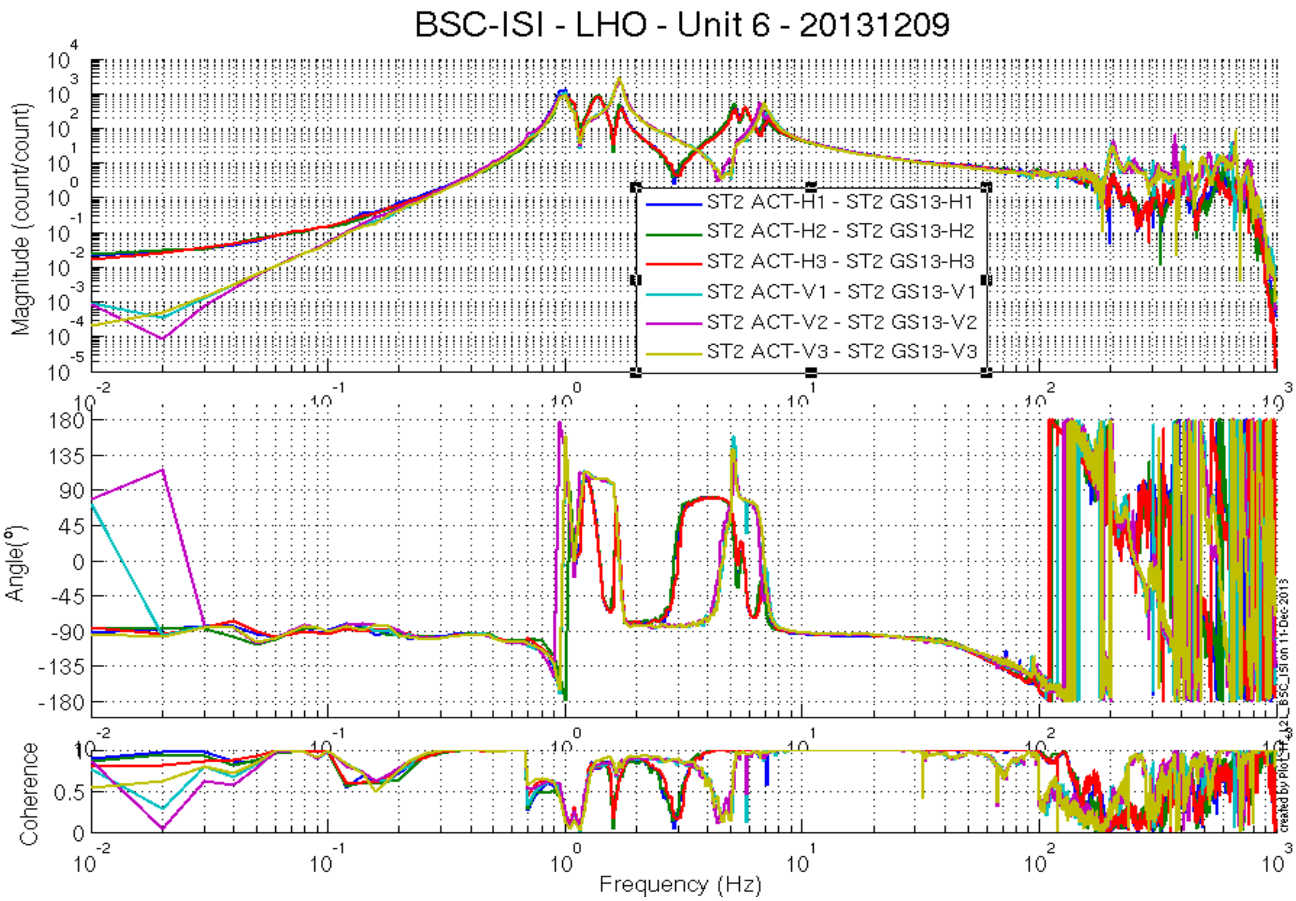


Figure 9: TF L2L Raw - ST2 Act to ST2 CPS

GPS_TIME=gps_now-.5*3600;
gpsinvert(GPS_TIME)
Unit_ID_Title='LHO BSC-ISI - Unit 6 - unLocked - Feb 6 2014- reloaded filters';
Ref=0;
F_resolution=0.02;
Overlap_per_cent=50;
Average=50;
State='Undamped'; % Undamped or Damped or Isolation Edit state to store data and figures in the right folder.
Save_flag=1;



ASD_Measurements_Local_BSC_ISI(IFO,Optics,GPS_TIME,F_resolution,Overlap_per_cent,Average,Unit_ID_Title,Unit_ID,State,Ref,Save_flag)Figure 10: TF L2L Raw - ST2 Act to ST2 GS13

Test result: **Passed: _X_** **Failed: ___** **Waived :**

- ### *Step 14 - Symmetrization – Calibration*

Not performed

Test result: **Passed: ___** **Failed: ___** **Waived : X**

- ### *Step 15 – Change of base – Cartesian to Cartesian - Simulations*

The transfer functions in the Cartesian basis can be found in the SVN at:
seismic/BSC-ISI/X1/Unit_6/Data/Figures/Transfer_Functions/Simulations/Undamped/

- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST1_ACT_to_ST1_CPS_2013_03_09.fig
- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST1_ACT_to_ST1_L4C_2013_03_09.fig
- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST1_ACT_to_ST1_T240_2013_03_09.fig
- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST22_ACT_to_ST2_CPS_2013_03_09.fig
- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST2_ACT_to_ST2_GS13_2013_03_09.fig

Note: The resonances of the structure seen at high frequencies are less visible in the Cartesian

Figure 11 – Transfer functions in the Cartesian basis – ST1 CPS

Figure 12 - Transfer functions in the Cartesian basis – ST1 L4C

Figure 13 - Transfer functions in the Cartesian basis – ST2 CPS

Figure 14 - Transfer functions in the Cartesian basis – ST2 GS13

Test result: **Passed: _X_** **Failed: ___** **Waived : X**

- ### *Step 16- Transfer functions - Cartesian to Cartesian - Measurements*

Test result: **Passed: ___** **Failed: ___** **Waived : X**

- ***Step 17 - Lower Zero Moment Plan***
- ***Step 17.1 - Stage 1 - LZMP***

Test result: **Passed: ___** **Failed: ___** **Waived : X**

- ***Step 17.2 - Stage 2 - LZMP***

Test result: **Passed: ___** **Failed: ___** **Waived : X**

- ***Step 18- Damping Loops – Transfer function – Simulations***
- ***Step 18.1 - Damping Loops – Stage 2***

Test result: **Passed: __** **Failed: ___** **Waived : X**

- ***Step 18.2 - Damping Loops – Stage 1***

Test result: **Passed: __** **Failed: ___** **Waived : X**

- ***Step 19- Damping Loops – Powerspectra***

Test result: **Passed: __** **Failed: ___** **Waived : X**

- ***Step 20- Isolation Loops – for one unit per site***

Test result: **Passed: __** **Failed: ___** **Waived : X**

IV. BSC-ISI testing Summary

This is the third “aLigo BSC-ISI” tested at LHO. The testing procedure document E1000483-v5 was used. Tests were done during in March 2013.

The LHO ISI-BSC Unit 5 is validated per the tests presented in this report. All results are posted on the SVN at:
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/X1/Unit_6/Data

FAILED AND WAIVED TESTS

1- List of tests that failed/waived and won’t be redone

- **Step III.9 – Spring constant –** The blades are slightly softer than the design. However, the blade softness’s are in good agreements with what was measured on the other units.

2- List of tests that failed/waived, that need to be re-done during phase 2

3- List of tests skipped that won't be performed because not feasible during phase II (i.e. stage 0 leveling)

- **Step II.5 –** Check level of Stage 0 after top-bottom plate assembly
- **Step II.8 –** Blade 0-1 Post Launch Angle – No need for this test, the budget mass looks good and we already reposition the Blades after noticing a gap between the Blade and its Spacer on Stage 0-1 (see comment on Step 9 – Vertical Spring Constant).

4- List of tests skipped that we won't do because they are not essential (i.e. redundant with another test)

- **Step III.3 – Measure the Sensor gap -** This test was not performed. The sensor gaps have not been measured. These sensors have already been checked at LASTI. Moreover, risks of scratching the target are so high that we preferred not performing this test. In the future, this test will be removed from the testing procedure.
- **Step III.8 – Vertical sensor calibration -** The test is not realized in a proper way to evaluate accurately the calibration of the vertical CPS.

5- Lists of tests skipped that needs to be done during phase II.

- **Step III.14 – Symmetrization – Calibration**
- **Step III.17 – Lower Zero Moment Plan**
- **Step III.18.1 – Damping Loops – Stage 2**
- **Step III.18.2 – Damping Loops – Stage 1**
- **Step III.20 – Isolation loops**