LIGO Laboratory / LIGO Scientific Collaboration

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aLIGO BSC-ISI, Pre-integration Testing report, Unit 4 - Phase I (post-assembly)

E1100297 – V2

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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/Unit4/

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 LLO. 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 to replace one GS-13 on this Unit due to a bad feed thru, the cable screw wouldn't go all the way, leaving the cable the possibility to wobble. The feed thru is going to be inspected and tested again.
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.3.

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

- ***Step 1 - Test stand level***

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

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

- ***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	04	**ST2 - H1**	42
ST1 - H2	18	**ST2 - H2**	41
ST1 - H3	186	**ST2 - H3**	44
ST1 - V1	27	**ST2 - V1**	46
ST1 - V2	177	**ST2 - V2**	48
ST1 - V3	31	**ST2 - V3**	45

Table 1 - Actuators' inventory

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

- ***Step 3 - Sensors Inventory***

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

CPS Stage 1	CPS S/N	ADE board serial #
H1	12951	12339
H2	13235	12410
H3	12959	12384
V1	12958	12341
V2	13444	12424
V3	12895	12826

Table 2 - Capacitive position sensors' inventory – Stage 1

CPS Stage 2	CPS S/N	ADE board serial #
H1	12948	13076
H2	12961	12430
H3	13430	12576
V1	12904	12335
V2	12892	13064
V3	12945	12451

Table 3 - Capacitive position sensors' inventory – Stage 2

Geophones GS13	Serial Number	POD
H1	865	67
H2	816	92
H3	862	43
V1	668	51
V2	768	58
V3	750	72

Table 4 - GS13 inventory

Geophones L4C	Serial Number	POD
H1	1104	96
H2	1120	94
H3	961	46
V1	925	35
V2	917	125
V3	801	42

Table 5 - L4C inventory

Geophones T240	Serial Number	POD
1	107	37
2	143	34
3	103	4

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

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**	122
Corner 2	122	**Corner 2**	120
Corner 3	127	**Corner 3**	123

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:

Stage 1	
Location	**Weight (lb)**
Corner 1	50.0
Corner 2	55.0
Corner 3	34.0
Total	139.0

Table 9 - Payload Stage 1

Nominal payload on stage 1: 109Kg – 101lb
Additional payload on stage 1 is 46 kg (101lb) 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 - Mass type	Quantity	Weight	Unit	Weight (lb)
	3	610	lb	1830
	2	233	lb	466
type 0	2	0.5	lb	1
type 1	9	1.1	lb	9.9
type 2	0	2.2	lb	0
type 3	3	4.5	lb	13.5
type 4	5	7.9	lb	39.5
type 5	1	15.6	lb	15.6
type 6	8	27.2	lb	217.6
				2593.1

Table 10 - Payload Stage 2

Nominal payload: 1183.4Kg – 2609lb
Total nominal mass of Stage 2: 2913.9Kg – 6424lb
Additional stage 2 payload is 16lb lighter than the design.

Error mass on stage 0-1 blades: -120/(6424+2019)=-1%
The Overall error on the payload is really low.

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

- ***Step 11 - Lockers adjustment***

Stage 0-1		Stage 1-2	
Lockers	**Shim thickness (mil)**	**Lockers**	**Shim thickness (mil)**
Corner 1	122	**Corner 1**	122
Corner 2	122	**Corner 2**	120
Corner 3	127	**Corner 3**	123

Table 11 - Shims under lockers

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	Length (in)	Serial Number	Location
D1100154	25-pin M-to-two 9-pin F straight	48	S1104259	L4C - C2
D1100154	25-pin M-to-two 9-pin F straight	48	S1104261	L4C - C1
D1100154	25-pin M-to-two 9-pin F straight	48	S1104264	L4C - ext - C3
D1100155	25-pin M-to-two 9-pin F straight	120	S1104123	GS-13 - C3
D1100155	25-pin M-to-two 9-pin F straight	120	S1104247	GS-13 - C1
D1100155	25-pin M-to-two 9-pin F straight	120	S1104248	GS-13 - C2
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106904	ST1 - H3 - ext - C3
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106914	ST2 - V1 - ext - C1
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106916	ST2 - H3 - ext - C3
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106918	ST1 - H2 - ext
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106919	ST2 - V2 - ext
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106920	ST1 - V3 - ext
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106922	ST2 - H2 - ext
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106926	ST1 - V1 - ext
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106928	ST2 - V3 - ext
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106938	ST1 - H1 - ext
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106942	ST1 - V2 - ext
D1100150	2-wire, 14awg 2 pins to 3-pin F	40	S1107082	ST1 - H1
D1100150	2-wire, 14awg 2 pins to 3-pin F	40	S1107089	ST1 - V2
D1100150	2-wire, 14awg 2 pins to 3-pin F	40	S1107093	ST1 - H3
D1100150	2-wire, 14awg 2 pins to 3-pin F	40	S1107099	ST1 - H2 - ext
D1100150	2-wire, 14awg 2 pins to 3-pin F	40	S1107101	ST1 - V3
D1100150	2-wire, 14awg 2 pins to 3-pin F	40	S1107102	ST1 - V1
D1100151	2-wire, 14awg 2 pins to 3-pin F	60	S1107162	ST2 - V2
D1100151	2-wire, 14awg 2 pins to 3-pin F	60	S1107171	ST2 - H2
D1100151	2-wire, 14awg 2 pins to 3-pin F	60	S1107182	ST2 - V3
D1100151	2-wire, 14awg 2 pins to 3-pin F	60	S1107194	ST2 - V1
D1100151	2-wire, 14awg 2 pins to 3-pin F	60	S1107198	ST2 - H1
D1100152	25-pin F-to-25-pin F	110	S1107230	Trill - C3
D1100152	25-pin F-to-25-pin F	110	S1107236	Trill - C2
D1100152	25-pin F-to-25-pin F	110	S1107238	Trill - C1
D1100153	25-pin F-to-25-pin F	80	S1107309	GS-13 - ext - C2
D1100153	25-pin F-to-25-pin F	80	S1107320	L4C - ext - C1
D1100153	25-pin F-to-25-pin F	80	S1107321	L4C - ext - C3
D1100153	25-pin F-to-25-pin F	80	S1107322	L4C - ext - C2
D1100153	25-pin F-to-25-pin F	80	S1107323	GS-13 - ext - C3
D1100153	25-pin F-to-25-pin F	80	S1107325	GS-13 - ext - C1
D1100148	2-wire, 14awg 3-pin M to 3-pin F	80	S1106999	ST2 - H1 - ext
D1100151	2-wire, 14awg 2 pins to 3-pin F	60	S1107208	ST2 - H3

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 (counts)		
Sensors	**Corner 1**	**Corner 2**	**Corner 3**
ST1-L4C-P	-279	-254	-256
ST1-L4C-D	24769	24652	24652
ST1-GS13-P	1029	974	977
ST1-GS13-D	24540	24729	24729
ST1-T240-P	13542	13140	13142

Table 12 - Raw Pressure

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	178.4	7.7	341.5	40.0	-163	-0.19
ST1 - H2	222.8	6.8	487.9	28.1	-265	-0.32
ST1 - H3	-337.0	7.4	11.6	26.3	-349	-0.41
ST1 - V1	30.8	5.5	-439.1	30.1	470	0.56
ST1 - V2	-174.3	5.6	-274.9	32.8	101	0.12
ST1 - V3	408.3	8.2	249.5	24.9	159	0.19
ST2 - H1	-386.8	23.2	-319.3	35.5	-67	-0.02
ST2 - H2	-182.3	42.5	-257.1	37.6	75	0.02
ST2 - H3	-592.0	43.0	-265.7	55.9	-326	-0.10
ST2 - V1	16.7	31.1	-576.3	72.9	593	0.18
ST2 - V2	-125.6	40.4	96.9	83.2	-222	-0.07
ST2 - V3	-227.5	30.9	-1139.7	61.2	912	0.27

Table 13 - 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 N°1 - Push "in the general coordinates Z/RZ"***

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

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

Sensors	Push in positive direction	Push in negative direction	Mil	Mil	Railing	Actuator Gap Check
ST1 - H1	20000	-17000	24	-20		X
ST1 - H2	18000	-16000	21	-19		X
ST1 - H3	18500	-18000	22	-21		X
ST1 - V1	25000	-21000	30	-25		X
ST1 - V2	21000	-21000	25	-25		X
ST1 - V3	20000	-19000	24	-23		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 14 - 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 Powespectra***

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

seismic/BSC-ISI/X1/UNIT_4/Data/Spectra/Undamped/

- X1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2013_01_09_124251.mat (Unlocked)
- X1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2013_01_22_073717.mat (Locked)

seismic/BSC-ISI/X1/UNIT_4/Data/Figures/Spectra/Undamped/

- X1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2013_01_09_124251.fig (Unlocked)
- X1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2013_01_22_073717.fig (Locked)

Stage locked – unlocked

The powerspectra are measured in two different configurations:

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

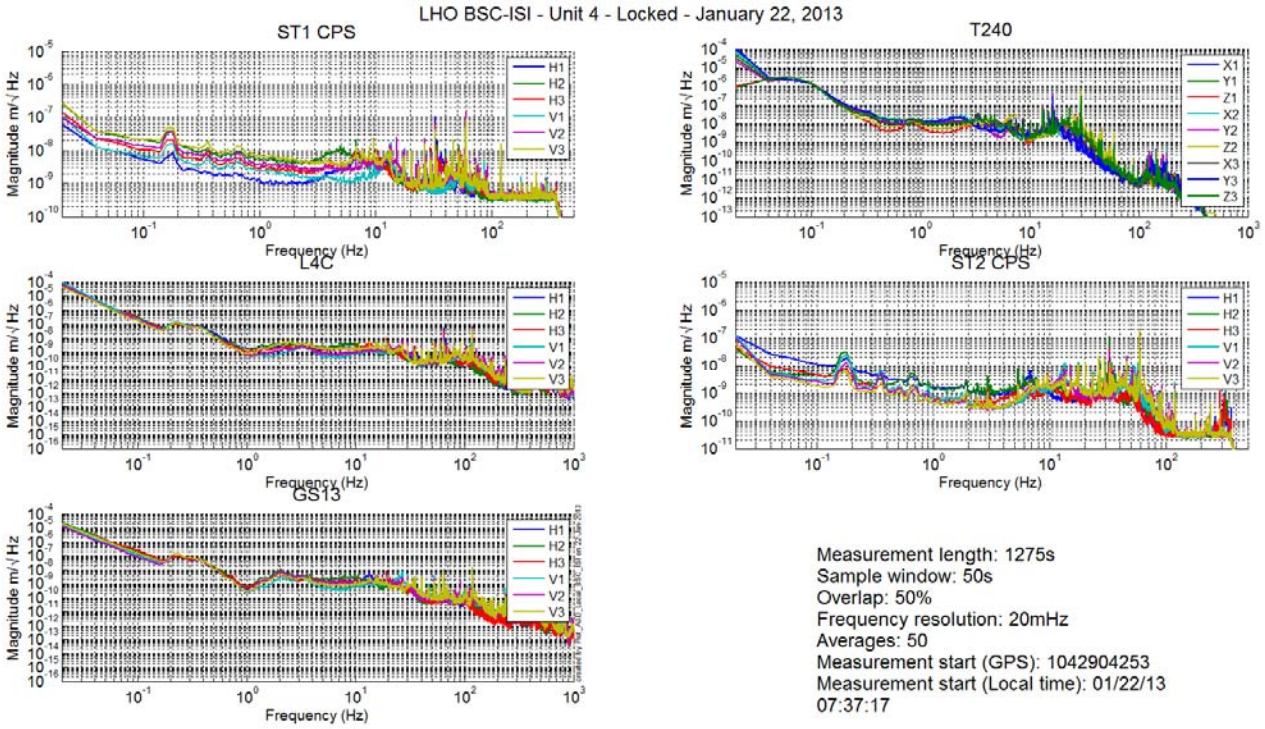

Figure 1: Spectra Stage 1 Locked Stage 2 Locked

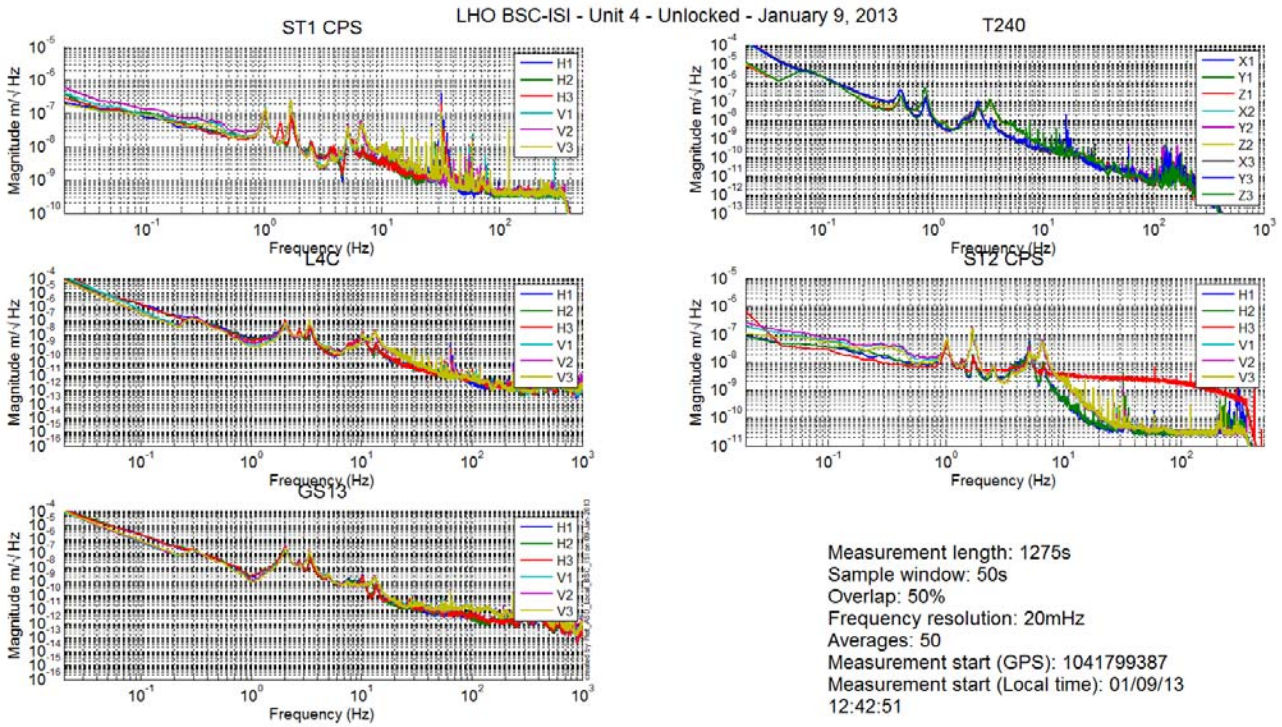

Figure 2: Spectra Stage 1 Unlocked Stage 2 Unlocked

Note: ST2 CPS-V3 was changed on January 10th 2013.

Stage Tilted

The powerspectra 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_4/Data/Spectra/Undamped/

- X1_ISI_ITMX_ASD_m_L4C_GS13_Stage_Tilted_2013_01_09.mat

seismic/BSC-ISI/X1/UNIT_4/Data/Figures/Spectra/Undamped/

- X1_ISI_ITMX_Tilted_ASD_m_LOC_ST1_L4C_2013_01_09.fig
- X1_ISI_ITMX_Tilted_ASD_m_LOC_ST2_GS13_2013_01_09.fig

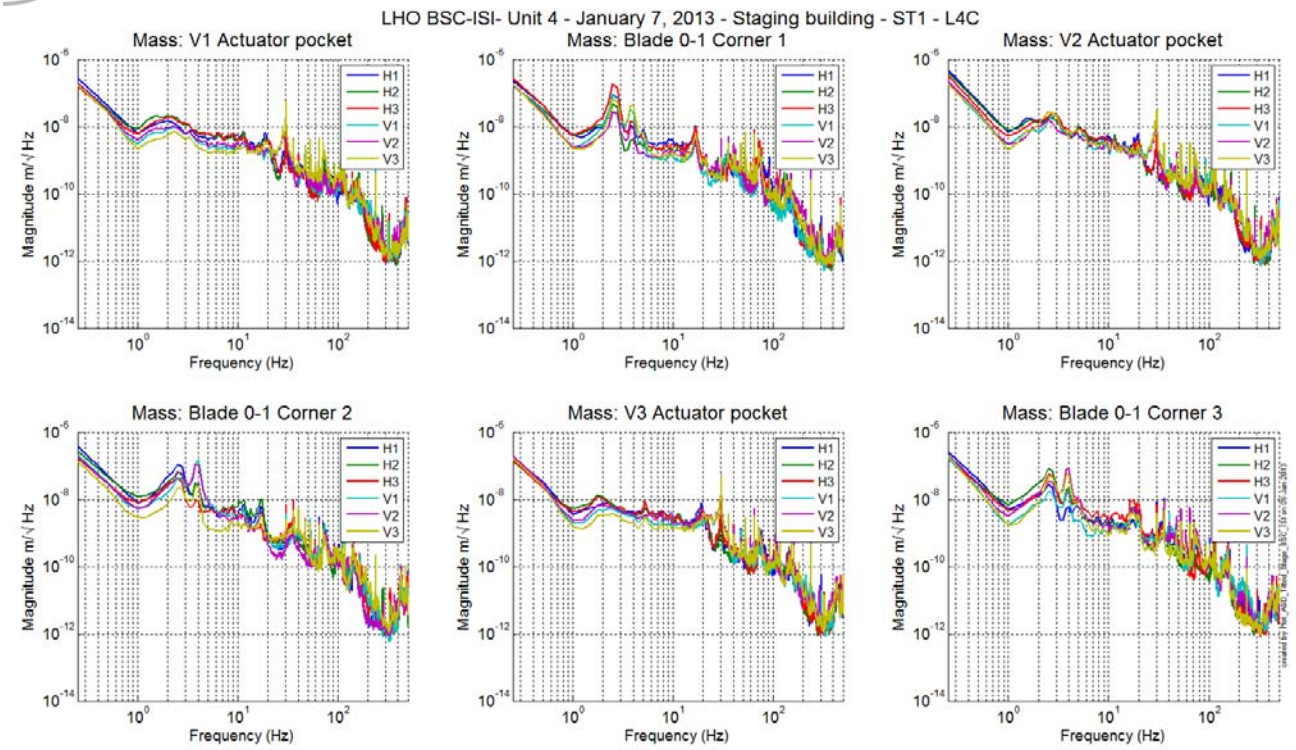

Figure 3 - ST1 L4C – Tilted

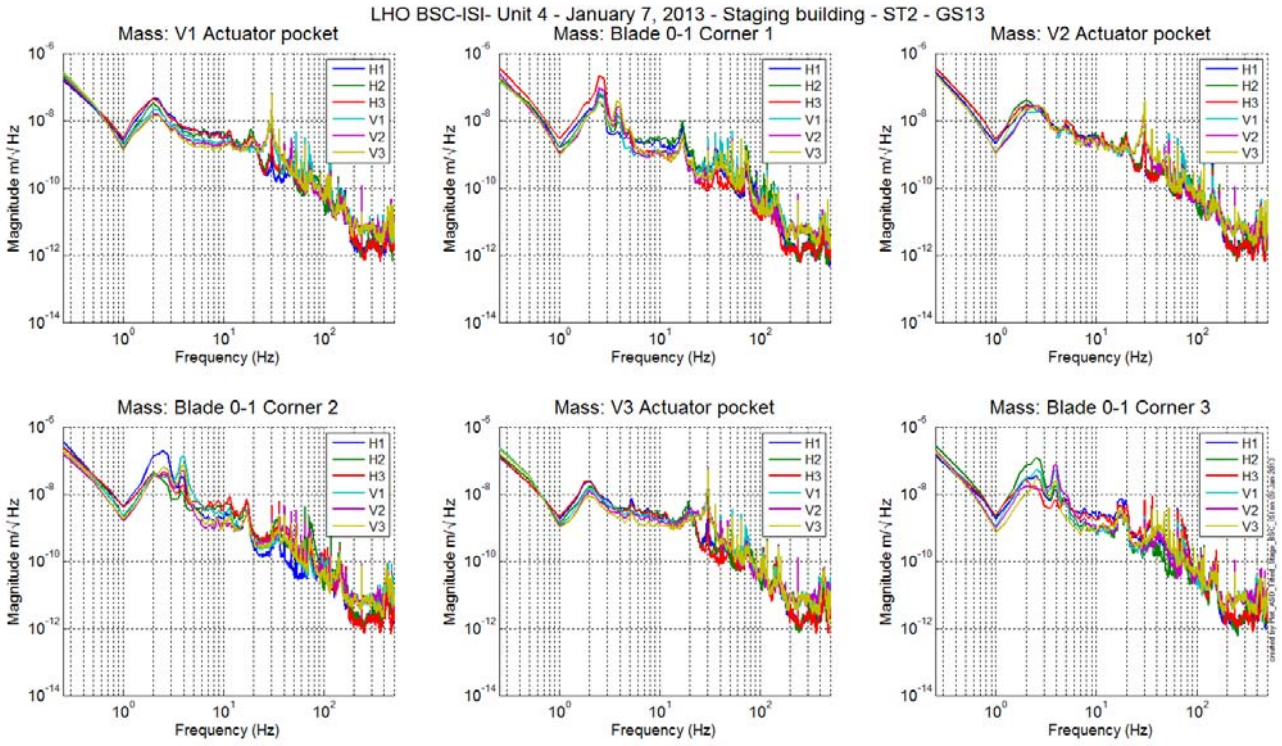

Figure 4 - ST1 GS13 – Tilted

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

- ***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	Coil driver name	Resistance (Ω)
ST1 H1	Coil1 Coarse 1	6.4
ST2 H1	Coil 1 Fine 1	10.1
ST2 V1	Coil 1 Fine 2	10.1
ST1 V1	Coil 1 Coarse 2	6.3
ST1 H2	Coil 2 Coarse 2	6.4
ST2 H2	Coil 2 Fine 1	10.1
ST2 V2	Coil 2 Fine 2	10.1
ST1 V2	Coil 2 Coarse 2	6.4
ST1 H3	Coil 3 Coarse 1	6.4
ST2 H3	Coil 3 Fine 1	10.1
ST2 V3	Coil 3 Fine 2	10
ST1 V3	Coil 3 Coarse 2	6.3

Table 15 - 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_4/Data/Static_Tests/ :
- X1_ISI_ITMX_Range_Of_Motion_20130122.mat

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-16071	423	16158	32229	38
ST1 - H2	-16485	248	15918	32404	39
ST1 - H3	-16772	-136	15418	32190	38
ST1 - V1	-15172	-142	14976	30148	36
ST1 - V2	-14631	-79	14610	29241	35
ST1 - V3	-14048	746	15548	29596	35
ST2 - H1	-10631	-436	9755	20387	6.1
ST2 - H2	-10014	71	10172	20186	6.0
ST2 - H3	-9734	207	10157	19891	5.9
ST2 - V1	-12560	-187	12190	24750	7.4
ST2 - V2	-11800	491	12782	24582	7.3
ST2 - V3	-12892	-844	11208	24100	7.2

Table 16 - 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***

This test is inaccurate due to the important hysteresis introduced by the dial indicators. Moreover, the sensors calibrations have been checked at LASTI. This test has not been performed on LLO Unit 2.

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 15Kg	Mean Load 30Kg	Diff – Load 15Kg	Diff – Load 30Kg	
V1	-446.5	-8055	-15592	-7610	-15144	
V2	-261	-7886	-15707	-7622	-15449	
V3	231.5	-7476	-15082	-7713	-15308	
				-7648.89	-15300	count
				-9.19	-18.383	mil
				-1198.39	-1198.2	lb/in
				-3.43	-3.45	**%**

The blades from stage 0 to stage 1 are too soft by 3.5%.

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	
V1	-550	-26001	-25451	
V2	-4.5	-26472	-26467.5	
V3	-1160	-26673	-25513	
			-25811	count
			-7.75	mil
			-1408	lb/in
			-3.88	%

In this section we measured the blade stiffness:

- Stage 0-1 blades are softer by 3.5% than design
- Stage 1-2 blades are softer by 3.9% than design

Test mitigation: Blades are softer than design. The low stiffness measurement is in good agreements with the mass budget. The rigid body modes frequencies should be close from 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_4/Data/Static_Tests/

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	4287	1723	1736	-6	5	-1
	ST1 - H2	1691	4206	1706	5	20	3
	ST1 - H3	1673	1664	4161	-5	6	-6
	ST1 - V1	42	-177	90	3527	-650	-623
	ST1 - V2	98	36	-146	-606	3425	-626
	ST1 - V3	-157	98	40	-645	-597	3458

Table 17 - Static test - Local to local - Stage 1

		Sensors					
		ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
Actuators	ST2 - H1	2391	373	356	-2	-1	-6
	ST2 - H2	364	2387	368	13	20	-10
	ST2 - H3	359	357	2337	-12	22	23
	ST2 - V1	80	144	-211	2895	326	-51
	ST2 - V2	-199	87	118	-7	2901	327
	ST2 - V3	117	-189	89	275	14	2827

Table 18 - Static test - Local 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 : __**

- ***Step 11- Static Testing - In the general coordinate basis (Static test - CPS)***
  - ***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_4/Data/Static_Tests/

		Sensors					
		ST1 - H1	**ST1 - H2**	**ST1 - H3**	**ST1 - V1**	**ST1 - V2**	**ST1 - V3**
Actuators	**ST1 - X**	1740	-802	-797	0	0	7
	ST1 - Y	10	1491	-1419	-7	-1	3
	ST1 - Z	-14	0	-10	764	719	729
	ST1 - RX	16	168	-148	-2915	2418	444
	ST1 - RY	-179	115	74	-1171	-1895	3049
	ST1 - RZ	3113	3112	3088	-7	7	-10

		Sensors					
		ST2 - H1	**ST2 - H2**	**ST2 - H3**	**ST2 - V1**	**ST2 - V2**	**ST2 - V3**
Actuators	**ST2 - X**	668	-1325	645	-58	-27	7
	ST2 - Y	1179	35	-1150	-20	-42	-31
	ST2 - Z	-6	28	-2	1011	1055	1011
	ST2 - RX	-284	12	268	-2479	2452	1
	ST2 - RY	149	-301	181	-1619	-1418	2813
	ST2 - RZ	1776	1797	1745	-45	-54	-32

Table 19 - 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 : ___**

- ***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_4/Data/Static_Tests/

		Sensors					
		ST1 - X	ST1 - Y	ST1 - Z	ST1 - RY	ST1 - RY	ST1 - RZ
Actuators	ST1 - X	1715	-9	-5	-4	7	53
	ST1 - Y	3	1674	-3	4	0	32
	ST1 - Z	8	-4	731	-25	-1	-10
	ST1 - RX	-2	362	-17	3006	15	9
	ST1 - RY	-360	19	-7	26	2974	6
	ST1 - RZ	31	7	-8	8	-8	3236

Table 20 - 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	1349	12	-22	-7	21	-2
	ST2 - Y	5	1337	-43	-31	6	25
	ST2 - Z	7	-13	1028	10	-28	8
	ST2 - RX	1	-28	-25	4185	67	2
	ST2 - RY	19	-10	-77	62	4244	14
	ST2 - RZ	-7	27	-34	-16	3	2564

Table 21 - 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 : ___**

- ***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_4/Data/Linearity_Test/
X1_ISI_ITMX_Linearity_test_20130110.mat

The linearity test figures can be found in the SVN at:
/seismic/BSC-ISI/X1/UNIT_4/Data/Figures/Linearity_Test/
- X1_ISI_ITMX_Linearity_test_20130110.fig

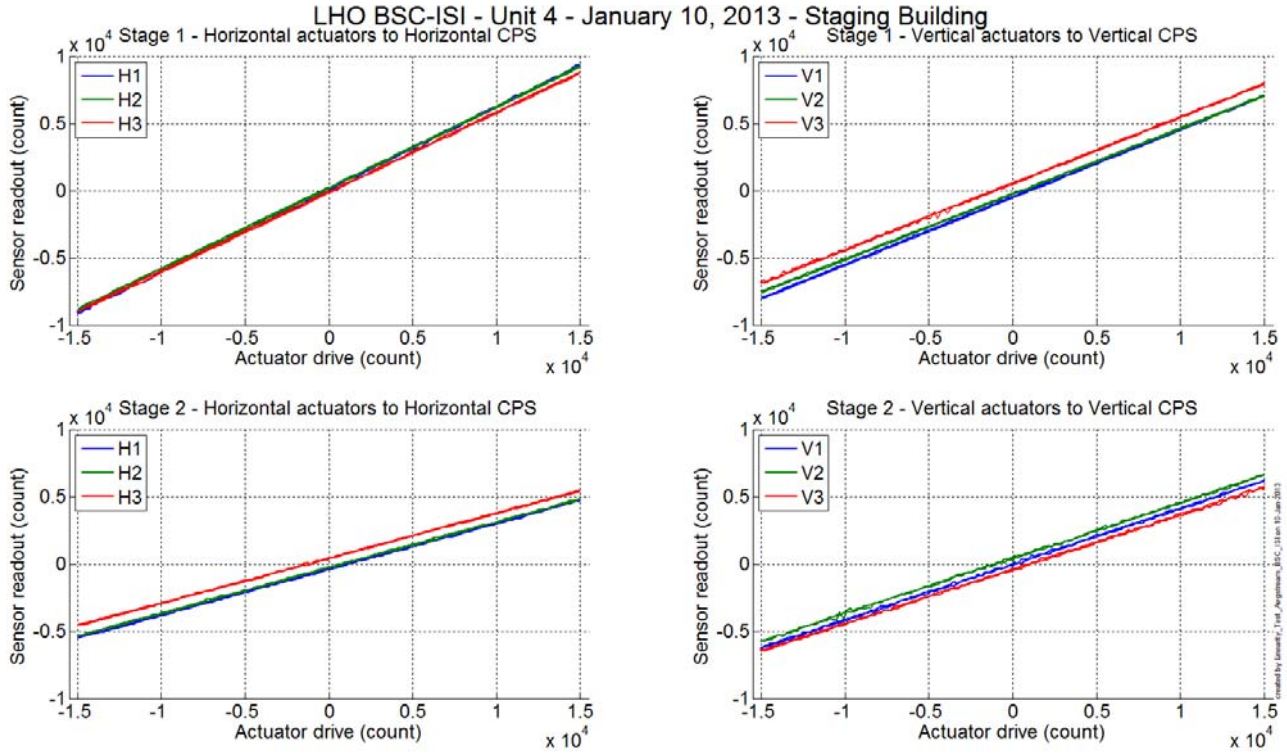

Figure 5 - Linearity Test

Slope – Offset:

		Slope	Offset	Average slope	Variation from average(%)
Stage 1	ST1 - H1	0.613	108	0.6034	1.67
	ST1 - H2	0.604	204		0.07
	ST1 - H3	0.593	-107		-1.74
	ST1 - V1	0.504	-487	0.4954	1.68
	ST1 - V2	0.488	-253		-1.53
	ST1 - V3	0.495	536		-0.15
Stage 2	ST2 - H1	0.341	-401	0.3380	0.87
	ST2 - H2	0.339	-281		0.33
	ST2 - H3	0.334	411		-1.20
	ST2 - V1	0.414	-32	0.4100	0.99
	ST2 - V2	0.412	413		0.41
	ST2 - V3	0.404	-410		-1.41

Table 22 - 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_4/Data/Transfer_Functions/Measurements/Undamped/

- X1_ISI_ITMX_Data_L2L_10mHz_100mHz_ST1_ST2_20130111-050023.mat
- X1_ISI_ITMX_Data_L2L_100mHz_700mHz_ST1_ST2_20130110-233712.mat
- X1_ISI_ITMX_Data_L2L_700mHz_10Hz_ST1_ST2_20130110-184619.mat
- X1_ISI_ITMX_Data_L2L_10Hz_100Hz_ST1_ST2_20130111-064353.mat
- X1_ISI_ITMX_Data_L2L_100Hz_500Hz_ST1_ST2_20130110-171116.mat
- X1_ISI_ITMX_Data_L2L_500Hz_1000Hz_ST1_ST2_20130110-155437.mat

Script file for processing and plotting local to local transfer functions in SVN at:
/seisvn/seismic/BSC-ISI/X1/UNIT_4/Scripts/Control_Scripts

- Step_1_TF_L2L_10mHz_1000Hz_X1_ISI_Unit_4.m

Figures of local to local transfer functions (Main couplings) in SVN at:
/seismic/BSC-ISI/X1/UNIT_4/Data/Figures/Transfer_Functions/Measurements/Undamped/

Measured of local to local transfer functions in the SVN at:
/svncommon/seisvn/seismic/BSC-ISI/X1/UNIT_4/Data/Transfer_Functions/Simulations/Undamped

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 3: The first resonance of the test stand can be seen at 33Hz on Stage 1 CPS.

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.

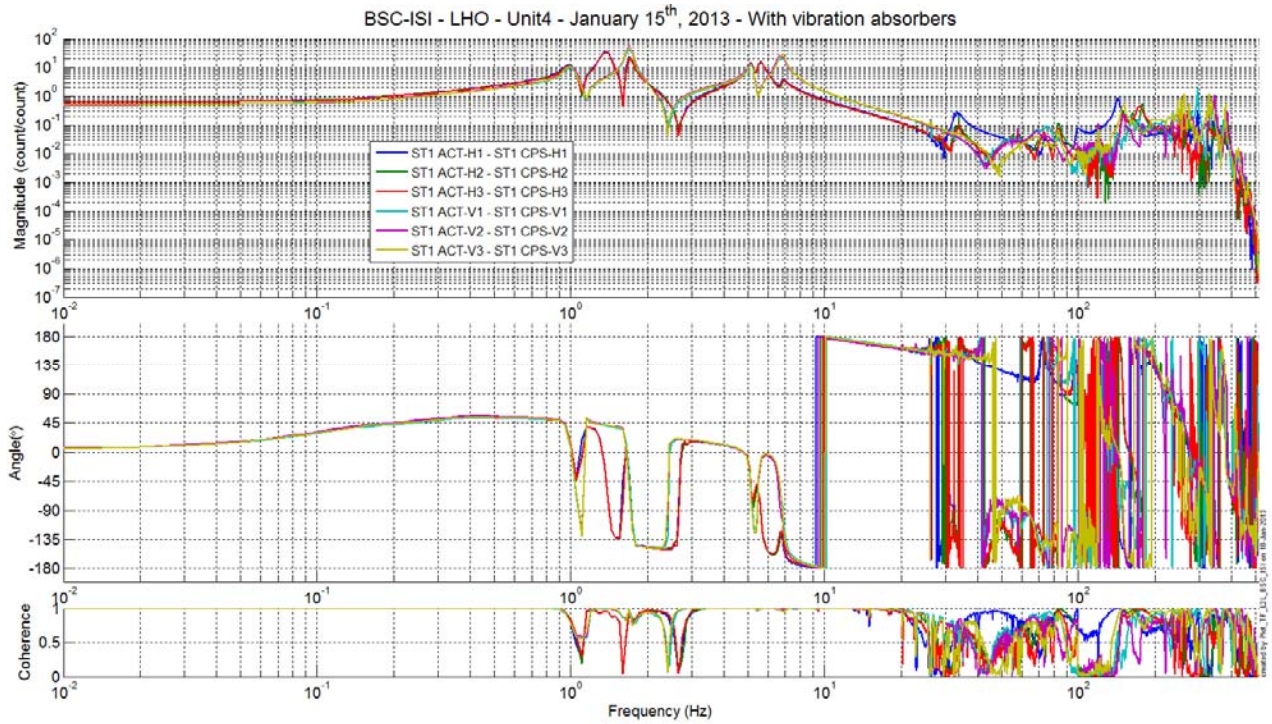

Figure 6: TF L2L Raw - ST1 Act to ST1 CPS

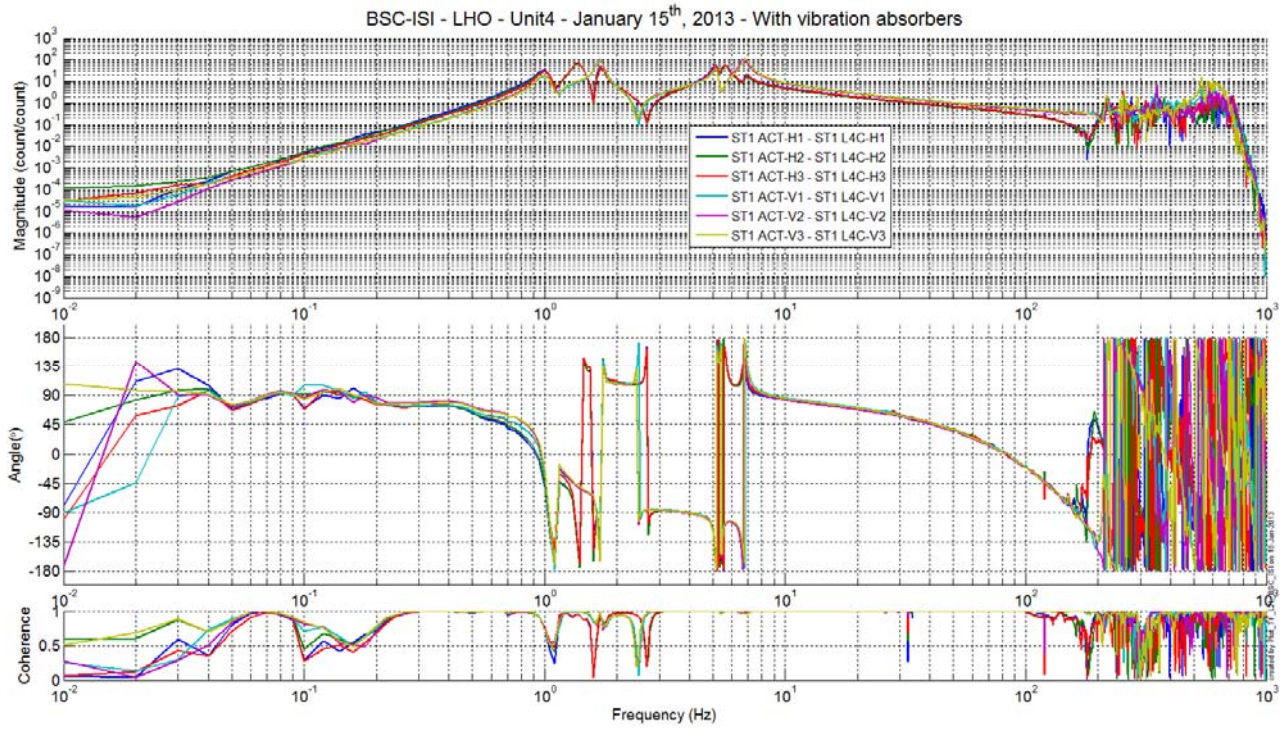

Figure 7: TF L2L Raw - ST1 Act to ST1 L4C

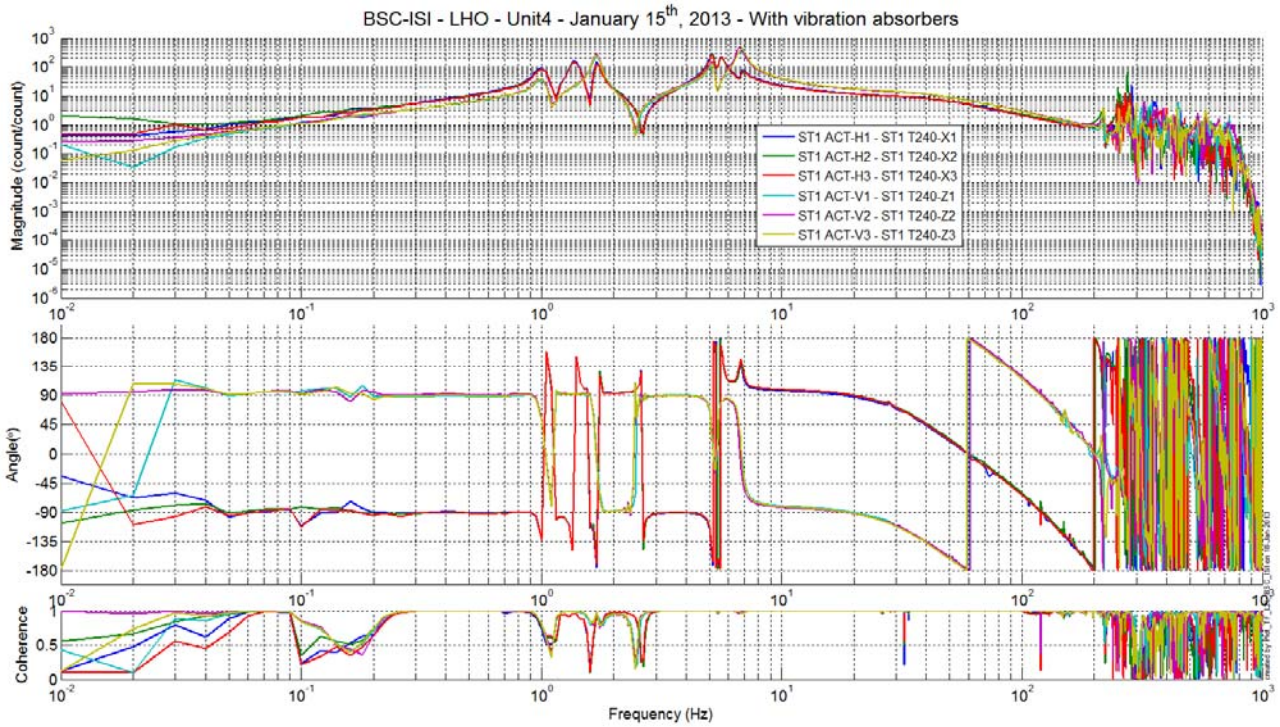

Figure 8 - TF L2L Raw - ST1 Act to ST1 T240

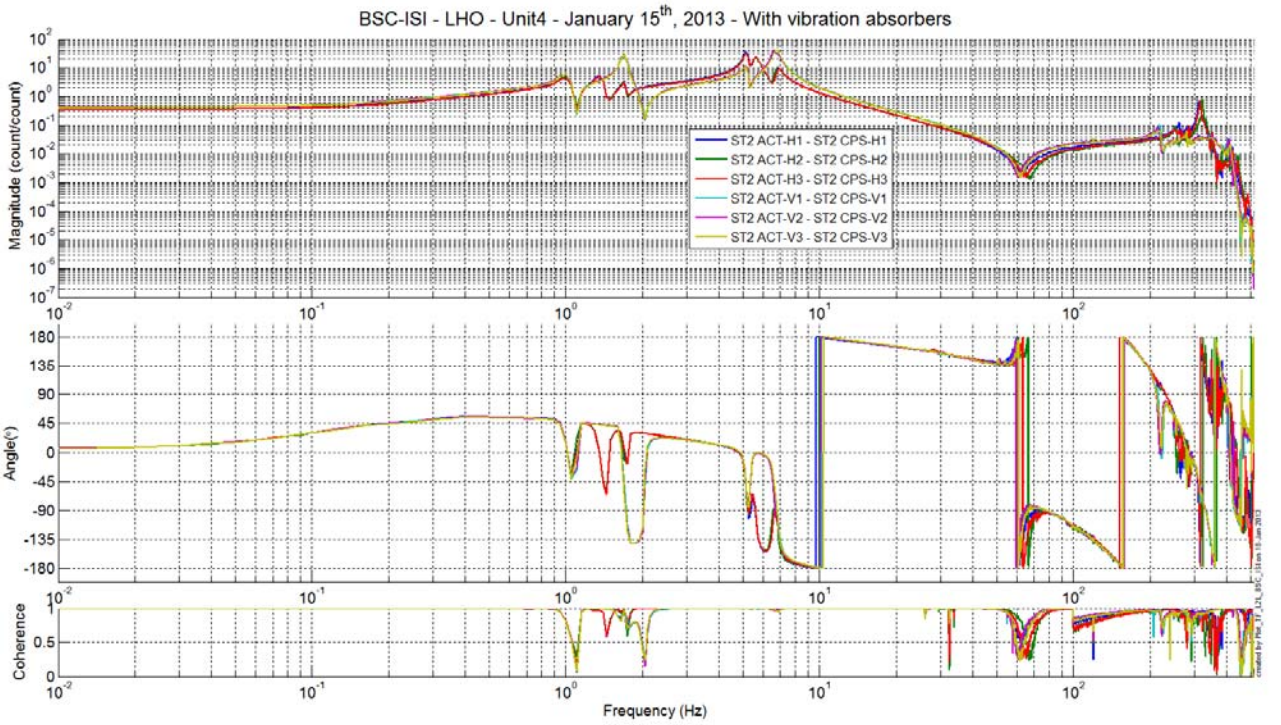

Figure 9: TF L2L Raw - ST2 Act to ST2 CPS

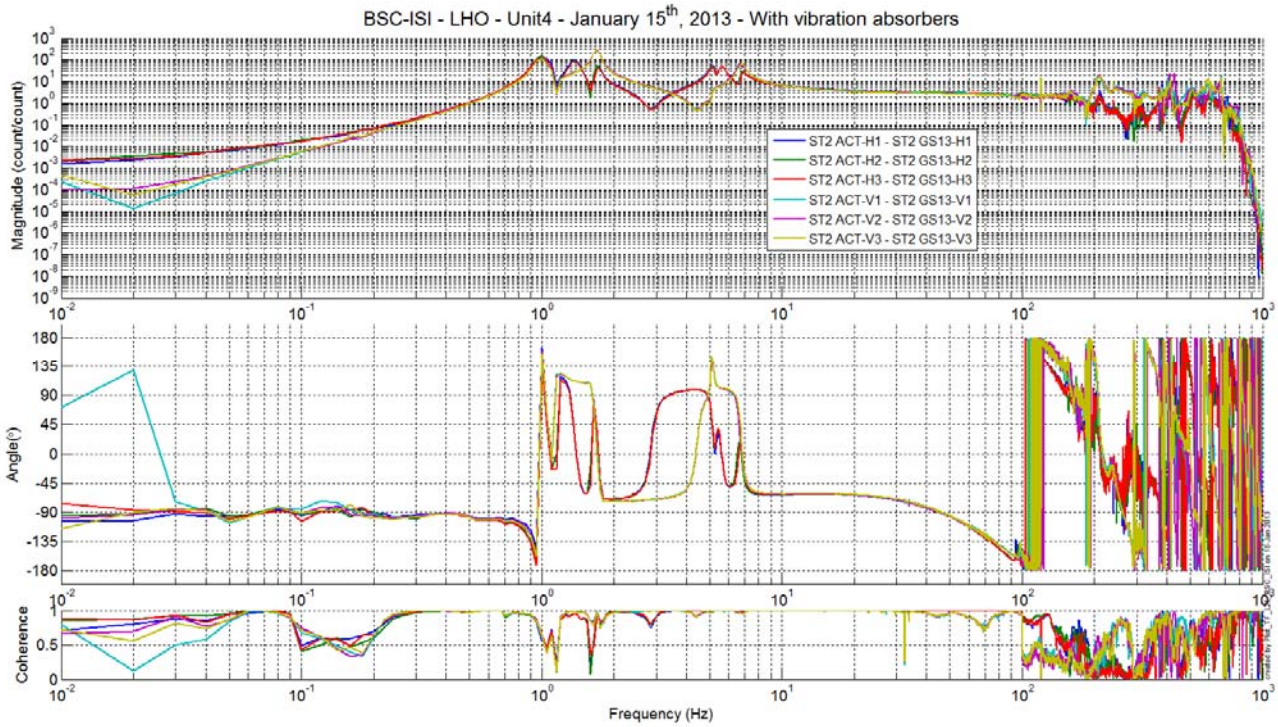

Figure 10: TF L2L Raw - ST2 Act to ST2 GS13

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_4/Data/Figures/Transfer_Functions/Simulations/Undamped/

- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST1_ACT_to_ST1_CPS_2013_01_15.fig
- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST1_ACT_to_ST1_L4C_2013_01_15.fig
- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST1_ACT_to_ST1_T240_2013_01_15.fig
- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST2_ACT_to_ST2_CPS_2013_01_15.fig
- X1_ISI_ITMX_TF_C2C_Symmetrized_from_ST2_ACT_to_ST2_GS13_2013_01_15.fig

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

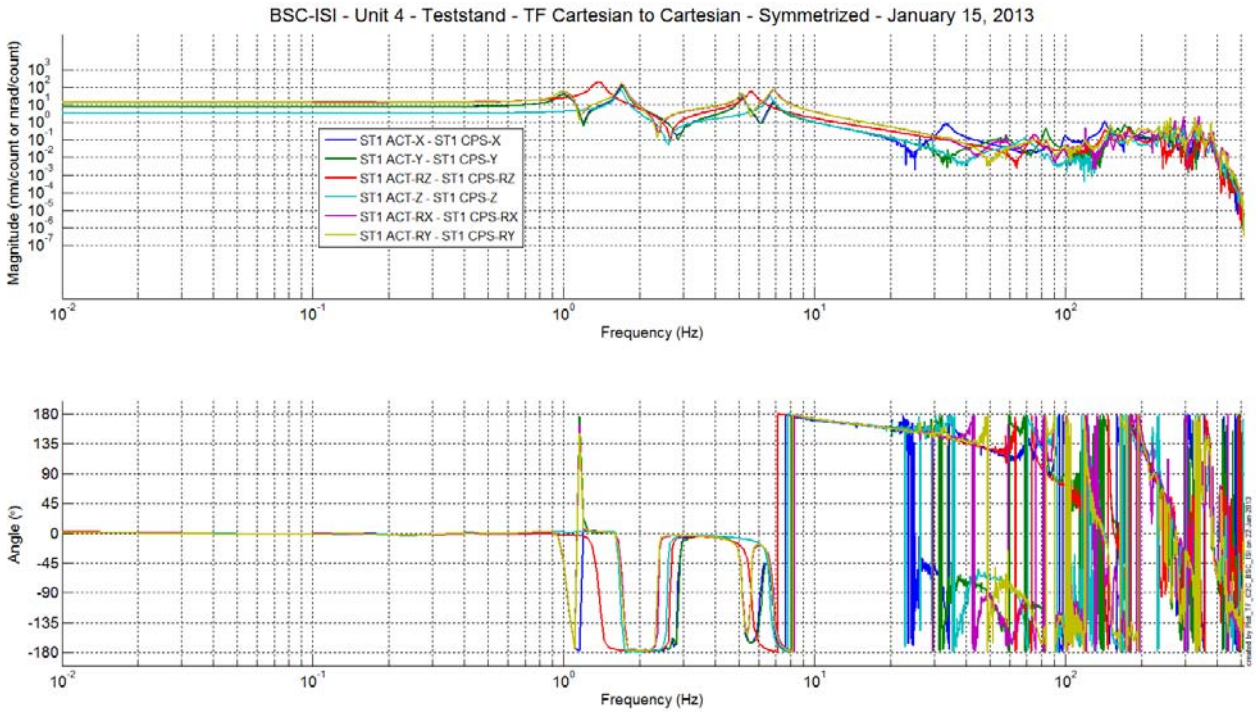

Figure 11 – Transfer functions in the Cartesian basis – ST1 CPS

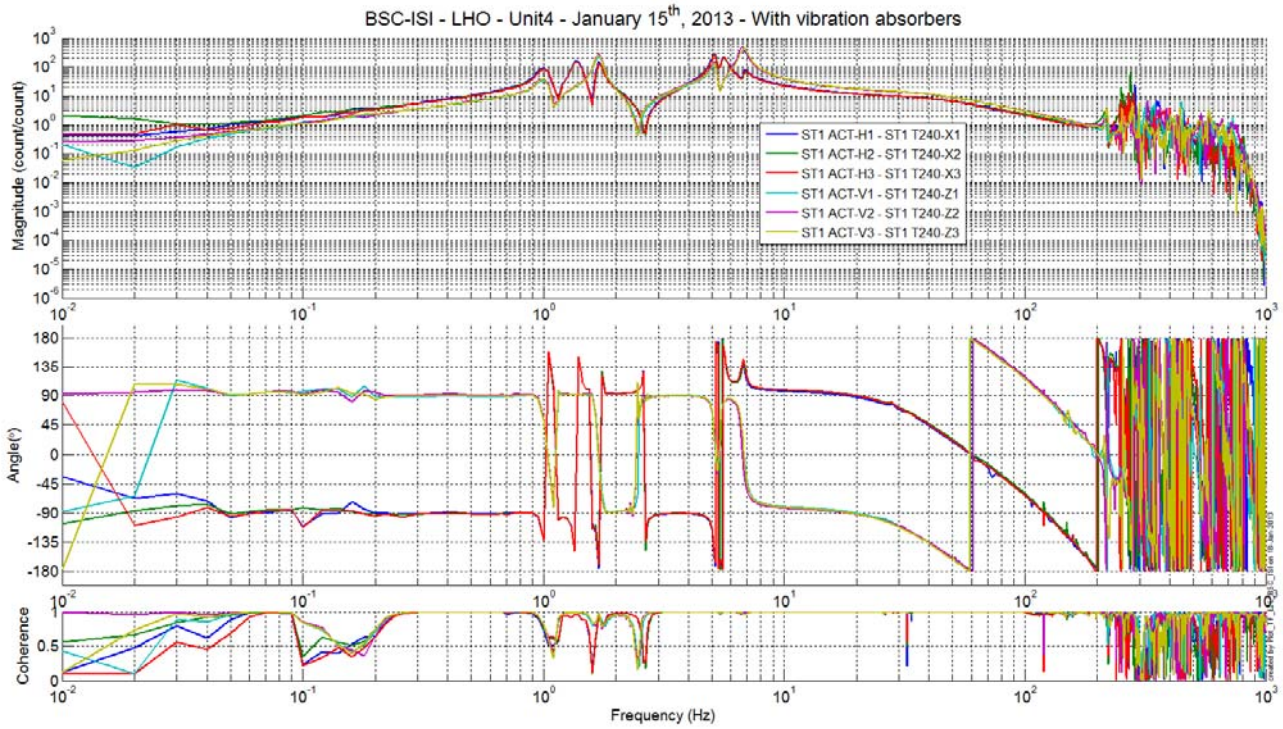

Figure 12 - Transfer functions in the Cartesian basis – ST1 T240

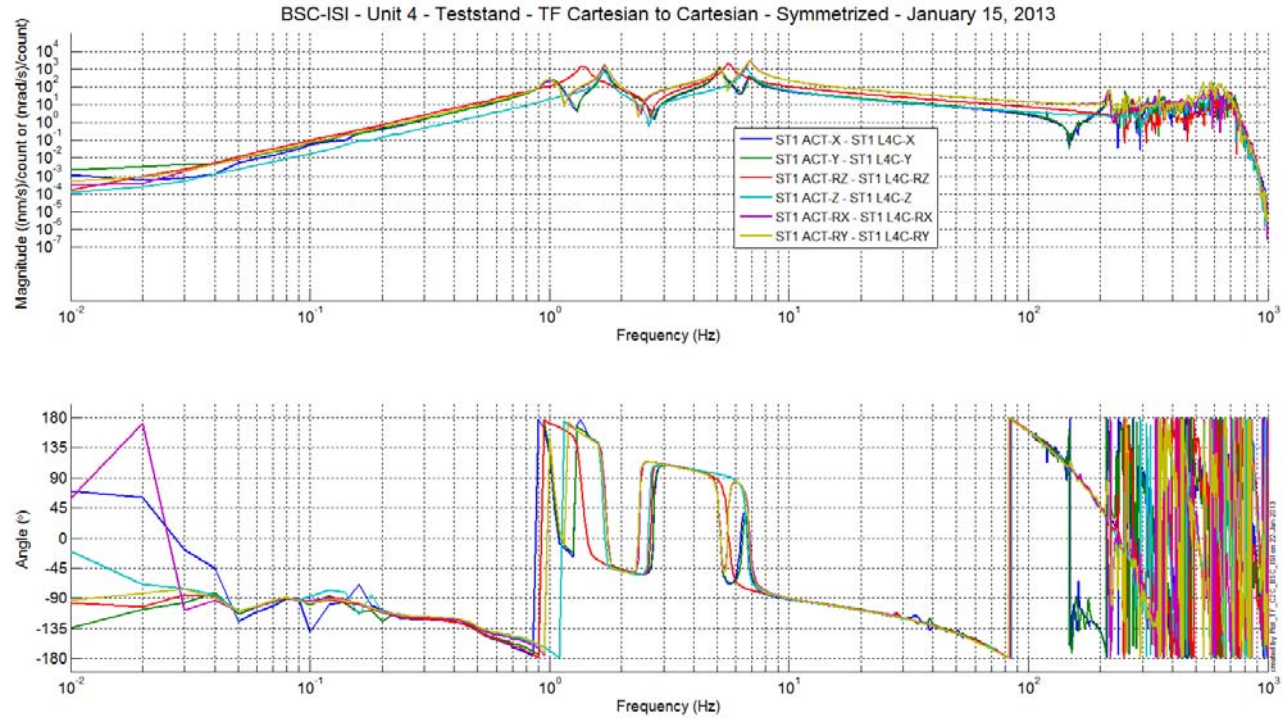

Figure 13 - Transfer functions in the Cartesian basis – ST1 L4C

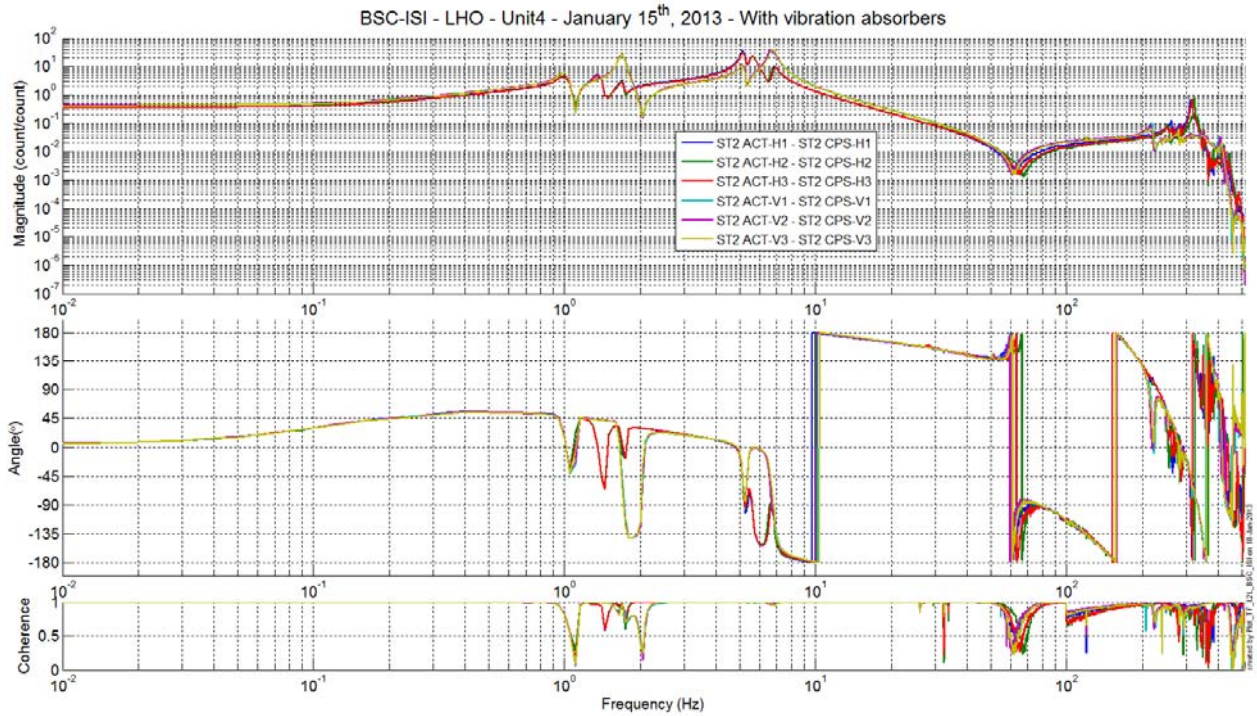

Figure 14 - Transfer functions in the Cartesian basis – ST2 CPS

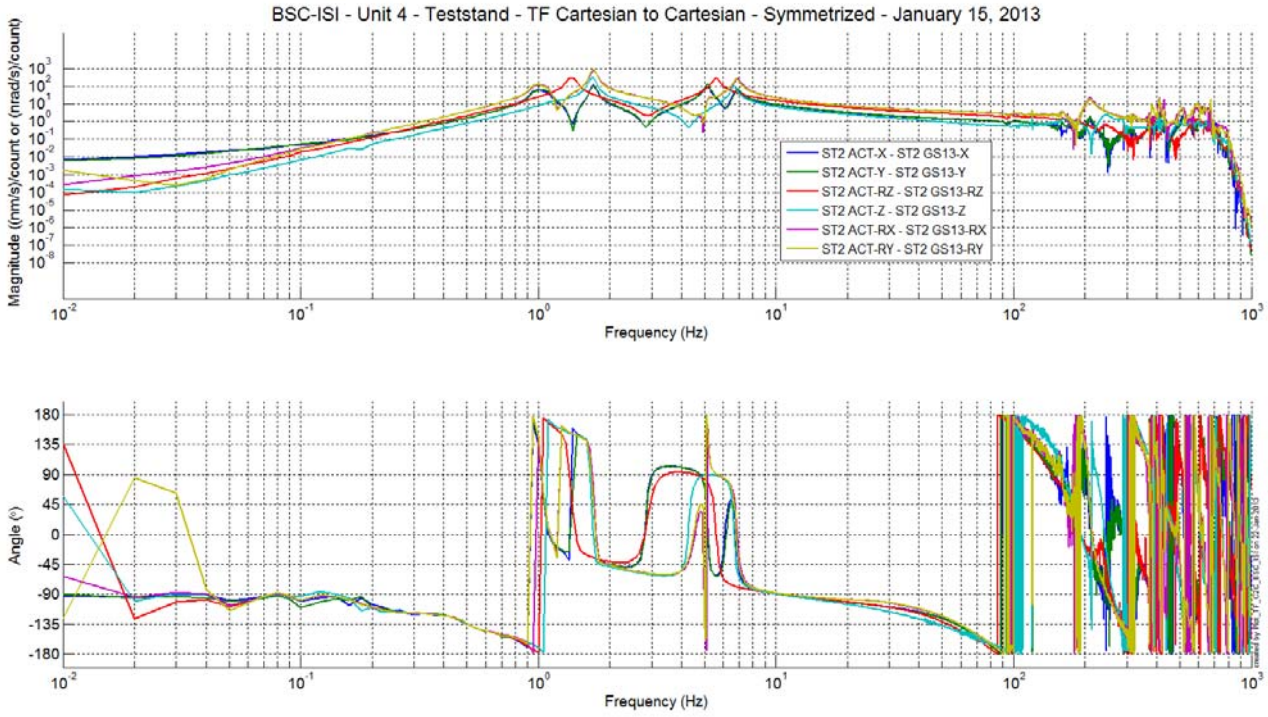

Figure 15 - Transfer functions in the Cartesian basis – ST2 GS13

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

- ***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 January 2013.

The LHO ISI-BSC2 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_4/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**