

LIGO Laboratory / LIGO Scientific Collaboration

LIGO- E1100855-V3

LIGO

October 18th, 2012

L1 BSC 2 BSC-ISI, Pre-integration Testing report,**Phase II**

E1100855-V3

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Introduction

The BSC-ISI testing is performed in three phases:

- 1) BSC-ISI, Pre-integration Testing, Phase I (post-assembly, in the staging building)
- 2) BSC-ISI, Pre-integration Testing, Phase II: Final tests done before insertion in the chamber
- 3) BSC-ISI, Integration Phase Testing: Procedure and results related to the commissioning in the chamber.

The ISI-BSC2 was moved from the Staging building to the LVEA test stand on May 17th, 2012.

This document presents results from the series of tests (Phase II) performed on the ISI-BSC2 (BS) in the corner station. The tests were done with the Beam Splitter suspension (BS) installed.

First tests started on August 6th, 2012. The first testing phase (II-a validation before cartridge installation) was completed on August 17th 2012.

All results are posted on the SVN at:

<https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/>

The following types of documents can be found in the SVN:

- Data location
- Figures location

1. Phase II-a

1. Hardware changes

1. CPS – E1100369

13579 CPS was replaced by 13523, because 13579 was constantly saturating regardless how close the sensor and the target was.

2. GS13 – E1100740

GS13 have not been replaced since phase I testing in the staging building.

3. L4C – E1100740

L4C have not been replaced since phase I testing in the staging building.

4. T240 – E1100740

The 3 T240s were replaced because their pressure sensors were not working at the time of Phase 1 testing. We know have:

- S/N 001 in corner 1
- S/N 028 in corner 2
- S/N 030 in corner 3

5. Cables – E1100822

Only 4 cables were changed in order to equilibrate the use of the different cables between BSC-ISIs.

- GS-13 Corner 1 D1100154 S11074260 was replaced by D1100155 S1107397
- Actuator 0-1 V Corner 2 D1100150 S1107076 was replaced by D1100151 S1107199
- Actuator 0-1 H Corner 2 D1100150 S1107074 was replaced by D1100151 S1107190
- Trillium Corner 1 D1100152 S1107223 was replaced by D1100153 S1107275

6. Misc

No hardware changes since phase I testing in the staging building.

2. Electronic Inventory

This table reports the electronic equipment used in the LVEA.

Hardware	Ligo reference	S/N
Interface Chassis Pod 1	D1002432	S1106357
Interface Chassis Pod 2	D1002432	S1200666
Interface Chassis Pod 3	D1002432	S1200665
Anti-aliasing Chassis Pod 1	D1002693	S1200947
Anti-aliasing Chassis Pod 2	D1002693	S1200946
Anti-aliasing Chassis Pod 3	D1002693	S1200948
Anti-image Chassis	<i>D070081</i>	S1200995
Binary Input Chassis 1	D1001726	S1101291
Binary Input Chassis 2	D1001726	S1101292
Binary Output Chassis	D1001728	S1101325
T240 Interface Pod 1	D1002694	S1104427
T240 Interface Pod 2	D1002694	S1104425
T240 Interface Pod 3	D1002694	S1104421
Anti-image Chassis	<i>D1000305</i>	<i>N/A</i>
Coil driver Pod 1	D0902744	S1103305
Coil driver Pod 2	D0902744	S1103337
Coil driver Pod 3	D0902744	S1103360
Expansion chassis	L1seib62	S1101148

Table 1 - Electronic inventory

3. Models Modifications

No model modifications were done between the beginning and the end of Phase 2a testing.



4. Mass distribution

This final mass distribution will be presented once all elements will be installed on the ISI (during phase II-b). These elements are the vibration absorbers on stage 1 and the QUAD structure.

1. Seismic

Stage 1

8/16/2012	D0902612	D0902613	D0902614	D0902615	D0902616					D0901075		lbs	kgs
					01	02	03	04	05	1	2		
	12	15	10	10	3.5	1	2	5	0.5	11	22		
C1-1	1											12	5.44
C1-2		0										0	0.00
C1-3							1	1				7	3.18
C2-1	1											12	5.44
C2-2		1										15	6.80
C2-3						1	1					3	1.36
C3-1	1											12	5.44
C3-2		1										15	6.80
C3-3							1		1			6	2.72
Stage 1	3	2	0	0	0	2	2	2	0	0	0	82	37.19

Stage 2

8/16/2012	D100313	D1003161					D071200						lbs	kgs	
		19.	20.	21.	22.	23.	0	1	2	3	4	5			6
	50	6	6	6	6	6	0.	1.	2.	4.	7.	15.	27.		
Keel	12						6	1	2	5	9	6	2	600	272.40
Optical		1	1	4	1	1								172.8	78.45
E-1									1	1		3		53.5	24.29
E-2							4	2		3				18.1	8.22
E-3							4					1	1	45.2	20.52
F1							4	5						35.1	15.94
F2													2	54.4	24.70
F3							1						2	55	24.97
Stage 2	12	1	12	1	1	1	13	7	1	4	0	4	6	1034. 1	469.48

8/16/2012	D972213	D972214	D0901075	D071200					
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			5 kg	10 kg	01	02	03	04	05	06		
	610	376	11	22	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
A	1								1	1	652.8	296.10
B		1								4	338.8	153.68
C	1										610	276.69
D											0	0.00
E-1											0	0.00
E-2											0	0.00
E-3											0	0.00
F1						1			1		17.8	8.07
F2						1				4	111	50.35
F3					1	1				2	57.7	26.17
Stage 2	2	1	0	0	1	3	0	0	2	11	1788.1	811.07

2. Suspension

The BS weight was estimated to be 204.70 kgs. (E1000337)

3. Miscellaneous

The added cables were estimated to weigh 5.86 kgs. (E1000337)

4. 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

	Plan	3/9/2012	LVEA
Stage 1 (kg)	108.86	36.29	37.19
Stage 2 (kg)	1183.42	1096.83	811.07
Suspension (kg)			204.7
Miscellaneous (kg)			5.86
Total (kg)	1292.28	1133.12	1058.82

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

5. Basic functionalities just after installing the BSC-ISI on the test stand

1. Pressure sensors

All pressure sensors are working.

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Static_Tests/

LLO_ISI_BS_Pressure_Sensors_Check_Calibrated_2012_08_06_163846.mat

Pressure (KPa)



Sensors	Corner 1	Corner 2	Corner 3
ST1-L4C-P	66.93	99.11	98.97
ST1-L4C-D	1.68	1.21	1.48
ST1-GS13-P	99.92	100.14	99.92
ST1-GS13-D	-0.93	-1.12	-0.91
ST1-T240-P	153.48	153.00	153.57

Table 2 - Geophones Pressure sensors

Note/comment about this test: The direct pressure of the corner 1 L4-C was identified to be a problem with the BSC-ISI interface and not with the L4-C itself.

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

2. Spectra

Spectra of the instrument can be found in the SVN at:

seismic/BSC-ISI/L1/BS/Data/Spectra/Undamped/

LLO_ISI_BS_ASD_m_LOC_CPS_T240_L4C_GS13_2012_08_06_200624.mat

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Figures/Spectra/Undamped/LLO_ISI_BS_ASD_m_LOC_CPS_T240_L4C_GS13_2012_08_06_200624.fig

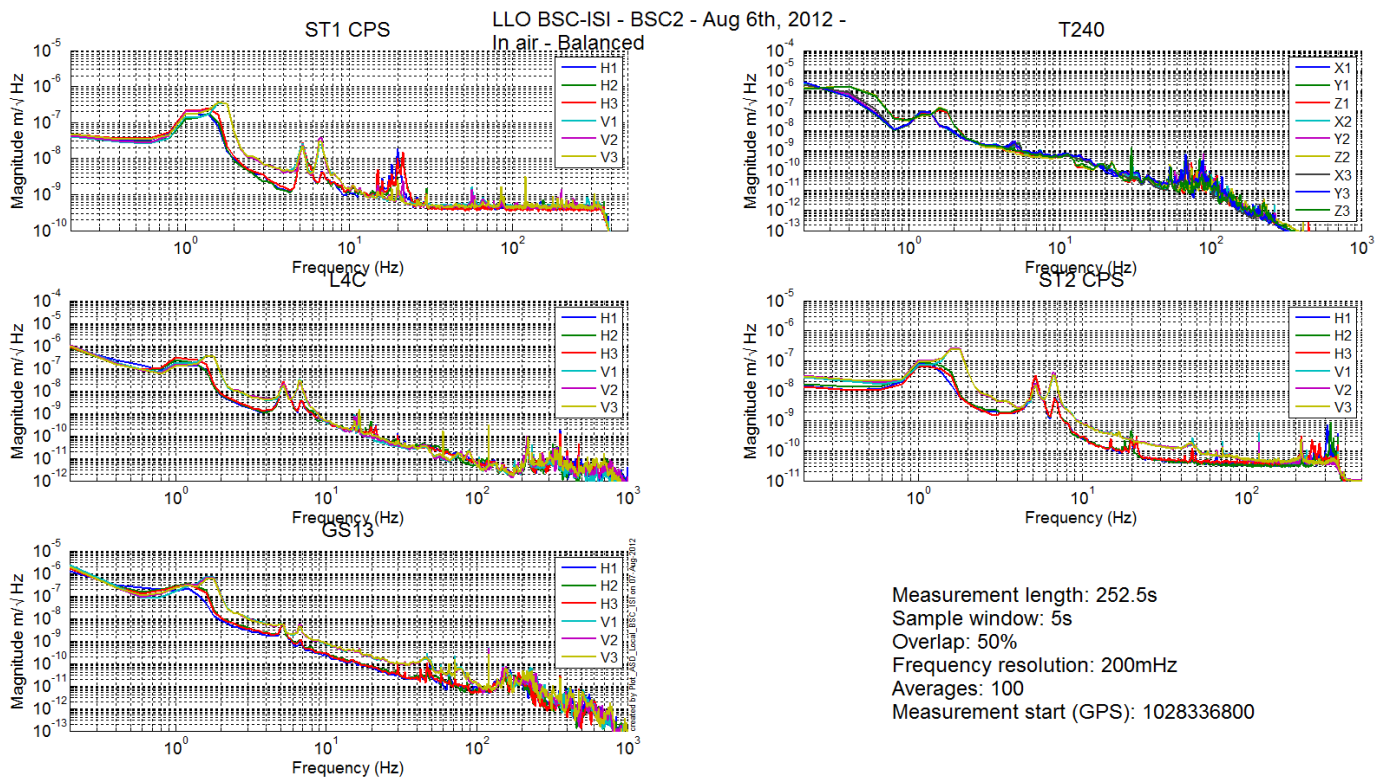


Figure 1 - Spectra inboard instruments - ISI Unlocked

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



3. Actuators-cables resistance

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Static_Tests/
 - L1_ISI_BSC2_Actuators_Resistance_20120817.mat

	Stage 1						Stage 2					
	H1	H2	H3	V1	V2	V3	H1	H2	H3	V1	V2	V3
Script	7.39	7.38	7.49	7.30	7.41	7.23	11.31	11.75	11.59	11.32	11.78	11.19
Hand	7.3	7.4	7.5	7.3	7.4	7.5	11.5	11.5	11.5	11.3	11.6	11.3

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

4. Offsets CPS Unlocked vs locked

The table is not perfectly balanced but it is considered sufficiently good to perform the series of test before the cartridge installation. Working conditions at the end station are difficult. A fine balancing will be done during phase II-b.

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Static_Tests/
 - LLO_ISI_BS_CPS_Read_Back_ISI_Locked_2012_08_06_155728.mat
 - LLO_ISI_BS_CPS_Read_Back_ISI_Unlocked_2012_08_06_163846.mat

Sensors	Table locked		Table unlocked		Difference locked - unlocked	
	Offset (Mean)	Std deviation	Offset (Mean)	Std deviation	Offset (Mean)	mil
ST1 - H1	-13.85	3.94	60.30	33.00	-74.14	-0.09
ST1 - H2	159.97	3.65	-1631.67	24.41	1791.64	2.13
ST1 - H3	31.39	4.03	-1860.89	33.13	1892.28	2.25
ST1 - V1	-149.63	6.23	492.39	42.35	-642.02	-0.76
ST1 - V2	-43.47	3.88	4010.50	47.66	-4053.97	-4.83
ST1 - V3	-128.72	4.93	1616.65	58.94	-1745.37	-2.08
ST2 - H1	56.46	9.44	-833.36	31.50	889.82	0.26
ST2 - H2	-214.09	11.24	-2306.60	52.65	2092.51	0.62
ST2 - H3	627.68	18.58	1860.72	43.70	-1233.05	-0.37
ST2 - V1	9.90	14.88	7394.22	120.64	-7384.31	-2.20
ST2 - V2	78.49	13.75	4126.33	129.11	-4047.84	-1.20
ST2 - V3	280.27	21.68	3503.18	146.70	-3222.91	-0.96

Table 3 - Locked vs Unlocked Position

Additionally note that during most of the testing, the balance was actually not as good as presented here. Indeed the testing was completed after alignment of the beam splitter and the balancing of this one was adjusted. They also added additional hardware onto the table for alignment purposes.

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



5. Offset local drive

Note: Due to longer cables, offsets measured by CPS for a 7000 count drive are slightly lower than offsets measured in the staging building.

Results of this test can be found in the SVN at:

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Static_Tests/

- LLO_ISI_BS_Offset_Local_Drive_20120814.mat

		Sensors					
		ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
Actuators	ST1 - H1	3743.11	1507.15	1507.14	8.52	-9.00	-7.16
	ST1 - H2	1495.88	3715.49	1494.25	-4.39	2.70	0.85
	ST1 - H3	1492.10	1485.77	3688.95	-16.73	-3.91	3.93
	ST1 - V1	34.40	-135.01	74.02	2853.91	-524.92	-496.35
	ST1 - V2	85.76	47.43	-120.90	-505.97	2946.74	-514.12
	ST1 - V3	-144.21	77.87	17.48	-531.26	-510.58	2916.33

Table 4 - Static Tests – Local to Local - Stage 1

		Sensors					
		ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
Actuators	ST2 - H1	2153.24	336.54	307.33	-18.60	-31.00	23.59
	ST2 - H2	347.74	2165.22	320.63	16.31	-39.44	13.02
	ST2 - H3	332.41	330.77	2155.23	18.07	-83.47	11.85
	ST2 - V1	66.54	97.52	-183.37	2563.58	308.05	-22.06
	ST2 - V2	-194.94	66.84	114.64	-9.30	2639.97	291.64
	ST2 - V3	114.60	-182.12	65.12	339.85	-4.82	2617.36

Table 5 - Static Tests – Local to Local - Stage 2

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

6. Offset Cartesian drive

The test was not performed because it only tests the matrices, which can be changed at any time.

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



7. Range of motion

The range of motion of the table is measured by pushing on the table in a direction collinear to the CPS. The Static tests results can be found on the SVN at:

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Static_Tests/LLO_ISI_BS_Range_Of_Motion_20120814.mat

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-15723.20	237.00	15708.62	31431.81	37.42
ST1 - H2	-15526.72	-1592.00	14300.75	29827.47	35.51
ST1 - H3	-16008.36	-2017.00	13769.04	29777.40	35.45
ST1 - V1	-11517.92	676.00	12886.89	24404.81	29.05
ST1 - V2	-7663.12	4922.00	17545.11	25208.23	30.01
ST1 - V3	-12405.74	115.00	12649.79	25055.53	29.83
ST2 - H1	-10453.53	-1296.00	7816.67	18270.20	5.44
ST2 - H2	-10705.45	-1452.00	7747.15	18452.60	5.49
ST2 - H3	-9038.56	228.00	9461.42	18499.98	5.51
ST2 - V1	-2806.55	8095.00	18990.87	21797.41	6.49
ST2 - V2	-5277.62	6051.00	17332.00	22609.62	6.73
ST2 - V3	-10869.26	335.00	11546.60	22415.86	6.67

Table 6 - Range of motion - Actuator drive in the LVEA

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

8. Linearity test

The data of the linearity test can be found on the SVN at:
seismic/BSC-ISI/L1/BS/Data/Linearity_Test/

- LLO_ISI_BSC2_Linearity_test_20120814.mat

The figures of the linearity test can be found on the SVN at:
seismic\BSC-ISI\H2\BS\Data\Figures\Linearity_Test\

- LLO_ISI_BSC2_Linearity_test_20120814.fig

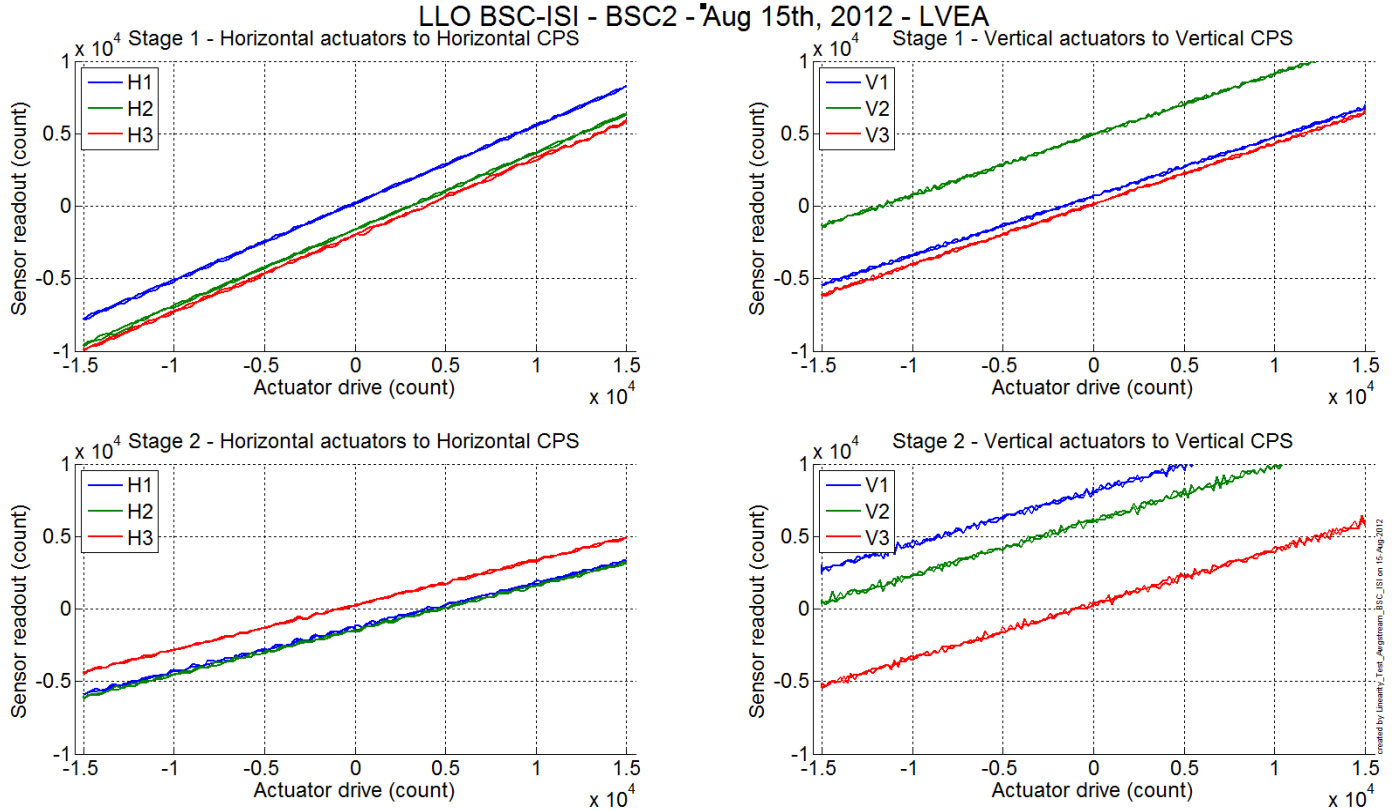


Figure 2 - Linearity test –L1 - BS – In LVEA

	Slope	Offset	Average slope	Variation from average(%)	
Stage 1	ST1 - H1	0.533697	226.1222	0.723451	
	ST1 - H2	0.530224	-1597.27	0.067976	
	ST1 - H3	0.52567	-2017.53	-0.79143	
Stage 1	ST1 - V1	0.407374	689.2569	-1.82241	
	ST1 - V2	0.419246	4942.302	1.038839	
	ST1 - V3	0.418187	152.1449	0.783571	
	Stage 2	ST2 - H1	0.305848	-1274.94	-0.56131
		ST2 - H2	0.308059	-1456.79	0.157416
		ST2 - H3	0.308817	269.3765	0.403897
Stage 2	ST2 - V1	0.362087	8128.792	-2.50818	
	ST2 - V2	0.377928	6102.843	1.757234	
	ST2 - V3	0.374191	330.0906	0.750941	

Table 7 - Slope – Offset Linearity test

Note: A few slopes are over 2% but nothing appears really bad.

Test result: Passed: Failed: Waived: X

6. Transfer functions and Comparison with measurements done in the staging building.

1. In the LVEA

The parameters for the measurements in the LVEA are slightly different from those in the staging building. We chose to have weaker excitation but longer averages in an effort to reduce risk of the attached suspension.

At this point, only the tuned mass dampers on the spring are installed (No vibration absorbers, no Viton under the keel masses, No vibration absorbers on the BS)

Measurements data can be found in the SVN at:

SeiSVN/seismic/BSC-ISI/L1/BS/Data/Transfer_Functions/Measurements/Undamped:

- LLO_ISI_BSC2_Data_L2L_10mHz_100mHz_ST1_ST2_20120816-171919.mat
- LLO_ISI_BSC2_Data_L2L_100mHz_700mHz_ST1_ST2_20120815-025159.mat
- LLO_ISI_BSC2_Data_L2L_700mHz_10Hz_ST1_ST2_20120816-194216.mat
- LLO_ISI_BSC2_Data_L2L_10Hz_100Hz_ST1_ST2_20120814-214508.mat
- LLO_ISI_BSC2_Data_L2L_100Hz_500Hz_ST1_ST2_20120814-191017.mat
- LLO_ISI_BSC2_Data_L2L_500Hz_1000Hz_ST1_ST2_20120814-170550.mat

Data after processing can be found in the SVN at:

SeiSVN/seismic/BSC-ISI/L1/BS/Data/Transfer_Functions/Simulations/Undamped

- LLO_ISI_BSC2_TF_L2L_Raw_10mHz_1000Hz_2012_08_17.mat

The transfer functions can be found in the SVN at:

seismic/BSC-ISI/L1/BS/Data/Figures/Transfer_Functions/Measurements/Undamped/

- LLO_ISI_BSC2_TF_L2L_Raw_from_ST1_ACT_to_ST1_CPS_2012_08_17.fig
- LLO_ISI_BSC2_TF_L2L_Raw_from_ST1_ACT_to_ST1_L4C_2012_08_17.fig
- LLO_ISI_BSC2_TF_L2L_Raw_from_ST1_ACT_to_ST1_T240_2012_08_17.fig
- LLO_ISI_BSC2_TF_L2L_Raw_from_ST2_ACT_to_ST2_CPS_2012_08_17.fig
- LLO_ISI_BSC2_TF_L2L_Raw_from_ST2_ACT_to_ST2_GS13_2012_08_17.fig

Note 1: The transfer functions are measured from the Output filters bank excitation point to the input (IN1) of the input filters bank. The transfer functions presented below are raw transfer functions without any electronic compensation.

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: On the ST1-ACT-H to ST1-CPS-H transfer functions, we can see the first resonances of the LVEA test stand at 20 Hz, 21.5Hz and 28.8Hz (matches within 1 Hz with LHO's results).

Note 4: Even without vibration absorbers on the BS structure, the first resonance visible on Stage 2 is at 154 Hz.

Because we haven't done the comparison plot, we leave the H2 BSC 6 transfer functions for comparison.

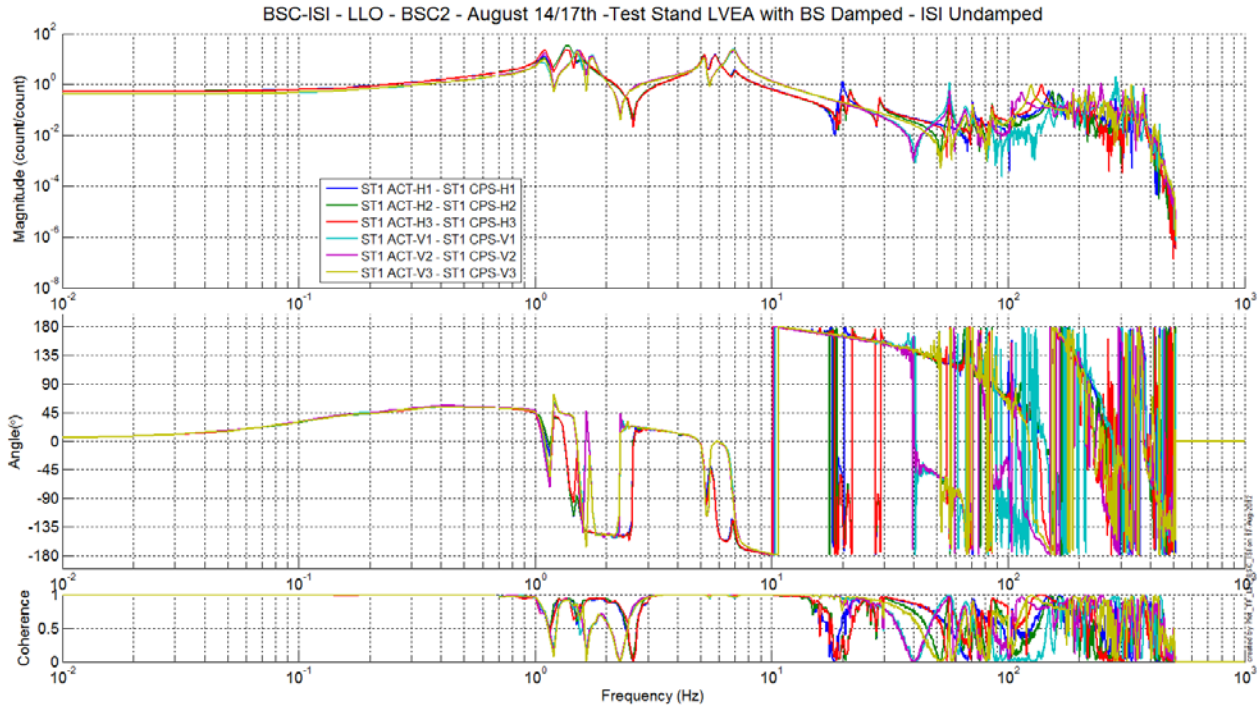


Figure 3 - TF ST1 ACT to ST1 CPS

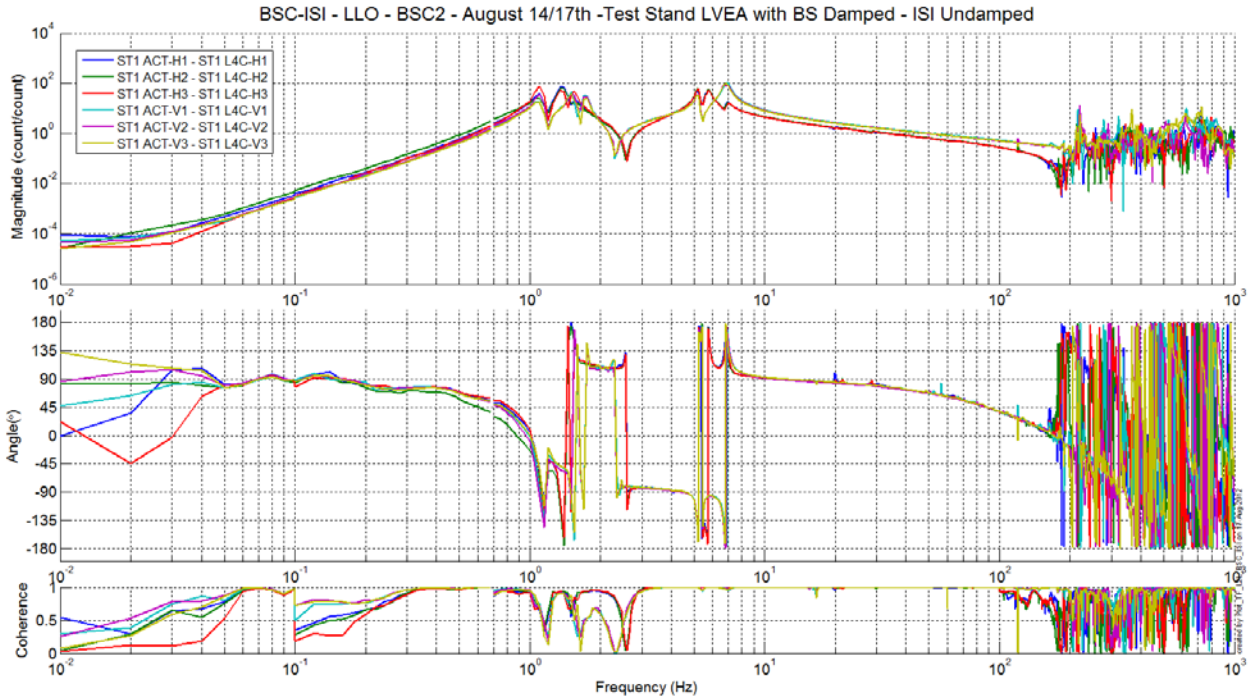


Figure 4 - TF ST1 ACT to ST1 L4C

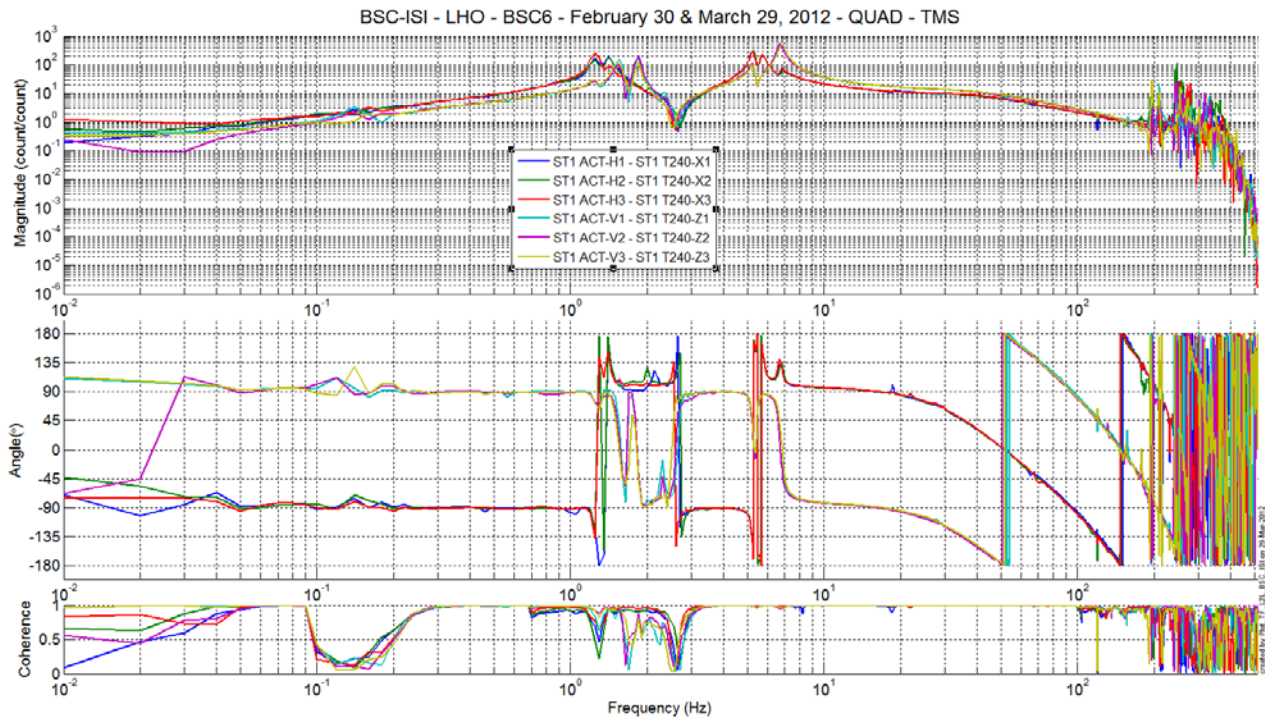


Figure 5 - TF ST1 ACT to ST1 T240

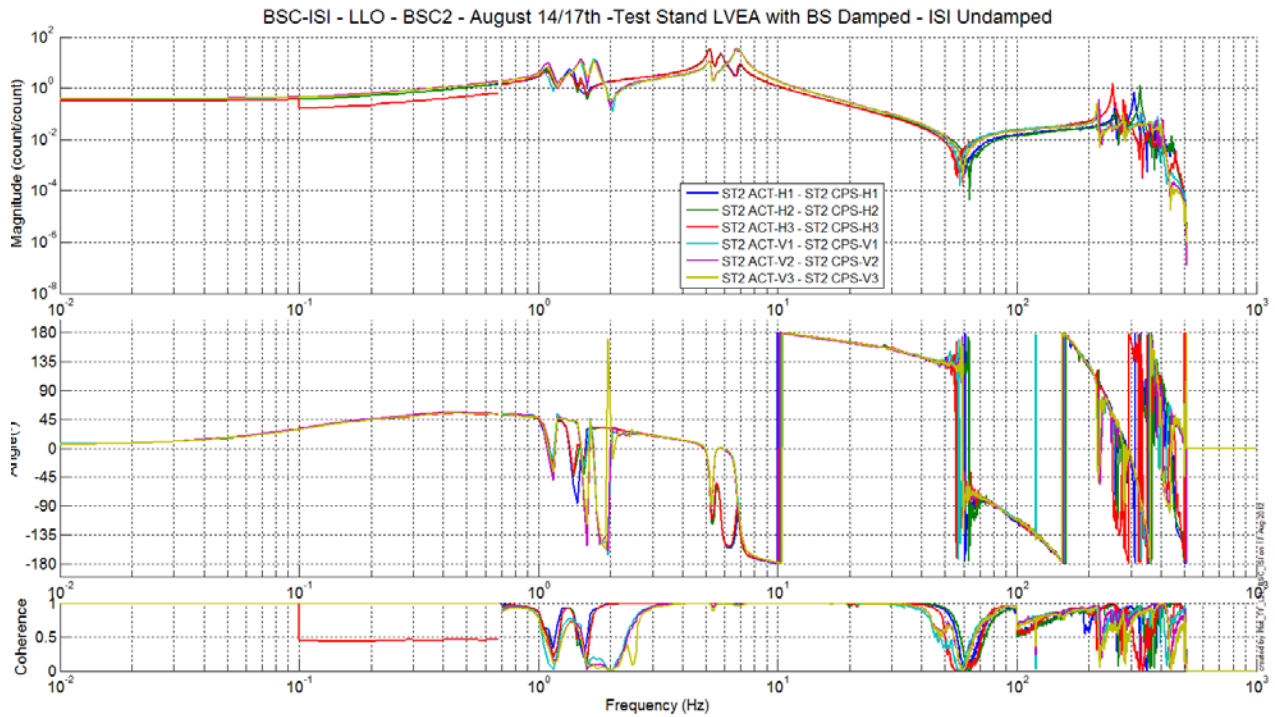


Figure 6 - TF ST2 ACT to ST2 CPS

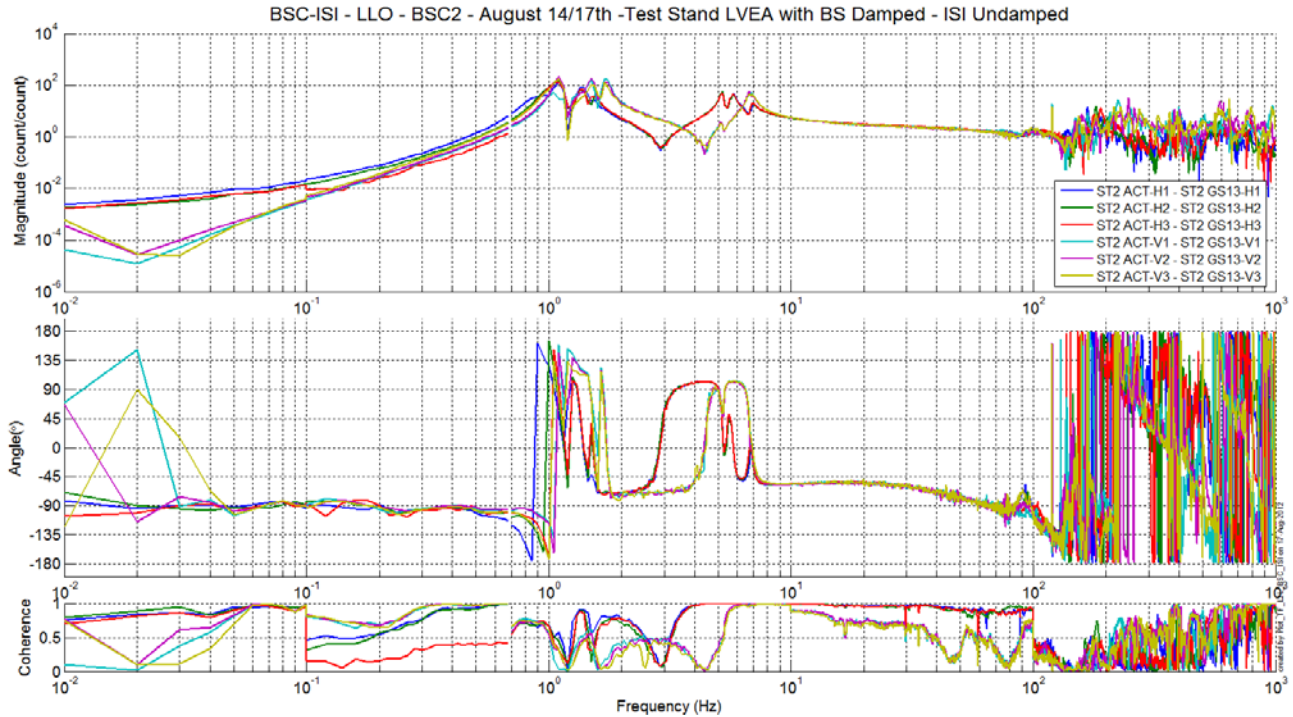


Figure 7 - TF ST2 ACT to ST2 GS13

2. Comparisons with measurements in the staging building

The script used to compare transfer function can be found in the SVN at:
 SeiSVN/seismic/BSC-ISI/Common/Plot_Functions_BSC_ISI/Version_0
 - Plot_Comparison_TF_L2L_BSC_ISI.m

The figure that shows the comparison between the transfer functions of the staging building and the LVEA are located in the SVN at:
 SeiSVN/seismic/BSC-ISI/L1/BS/Data/Figures/Transfer_Functions/Measurements/Comparison/L2L/

- COMP_LVEA_L1_ISI_BS_ST1_CPS_2012_10_11_.fig
- COMP_LVEA_L1_ISI_BS_ST2_CPS_2012_10_11_.fig
- COMP_LVEA_L1_ISI_BS_ST1_L4C_2012_10_11_.fig
- COMP_LVEA_L1_ISI_BS_ST2_GS13_2012_10_11_.fig

Main differences are:

- The DC gains (cables resistance)
- Resonances of the rigid body modes [1; 10]Hz (different payload)
- ST1-CPS resonances different in the staging building and the LVEA (Test stand short legs vs long legs). Resonance at 53Hz on ST1 CPS V1.
- Resonance at 78.5Hz on stage 2 sensors (Payload)
- Similar at high frequencies

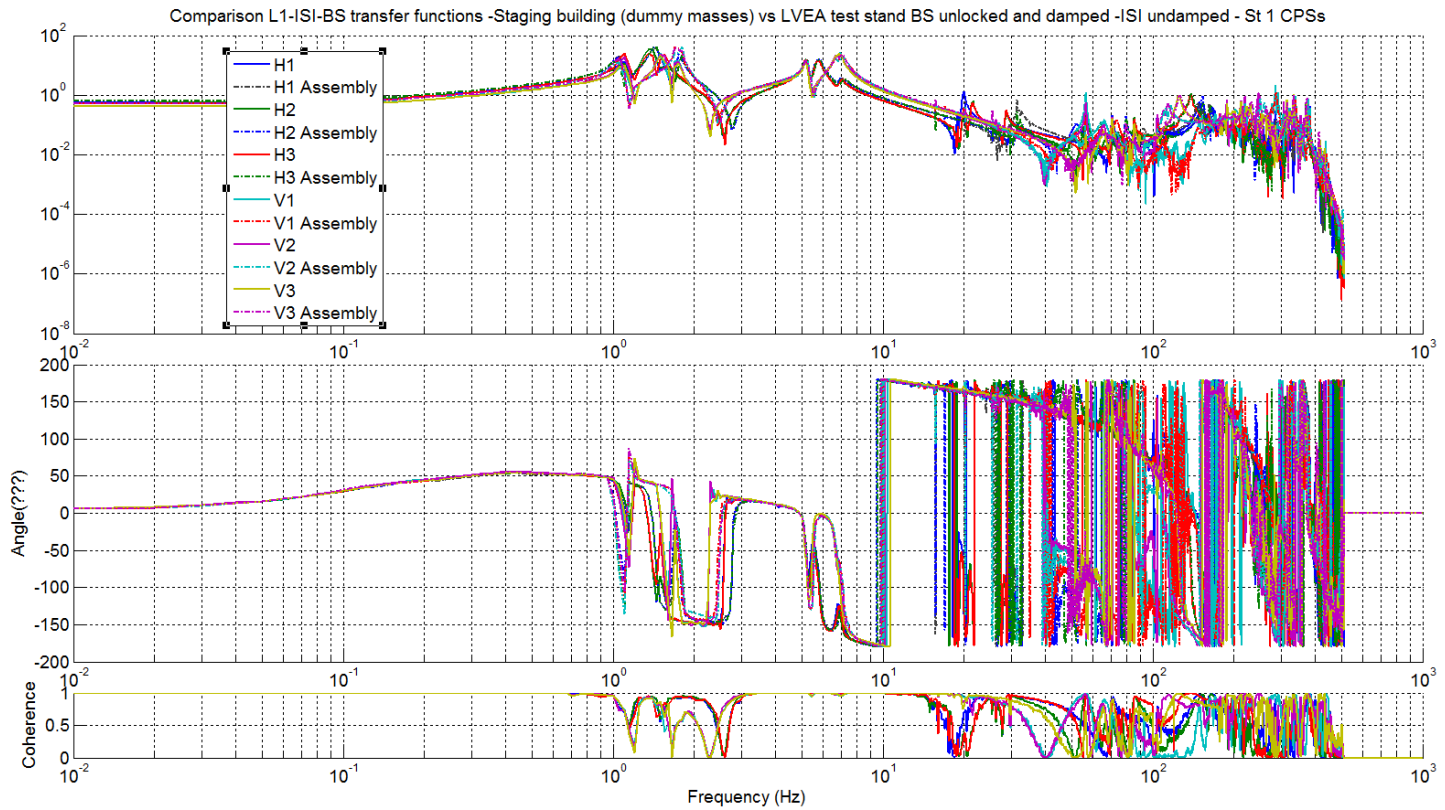


Figure 8 - Transfer functions comparison - ST1 ACT to ST1 CPS

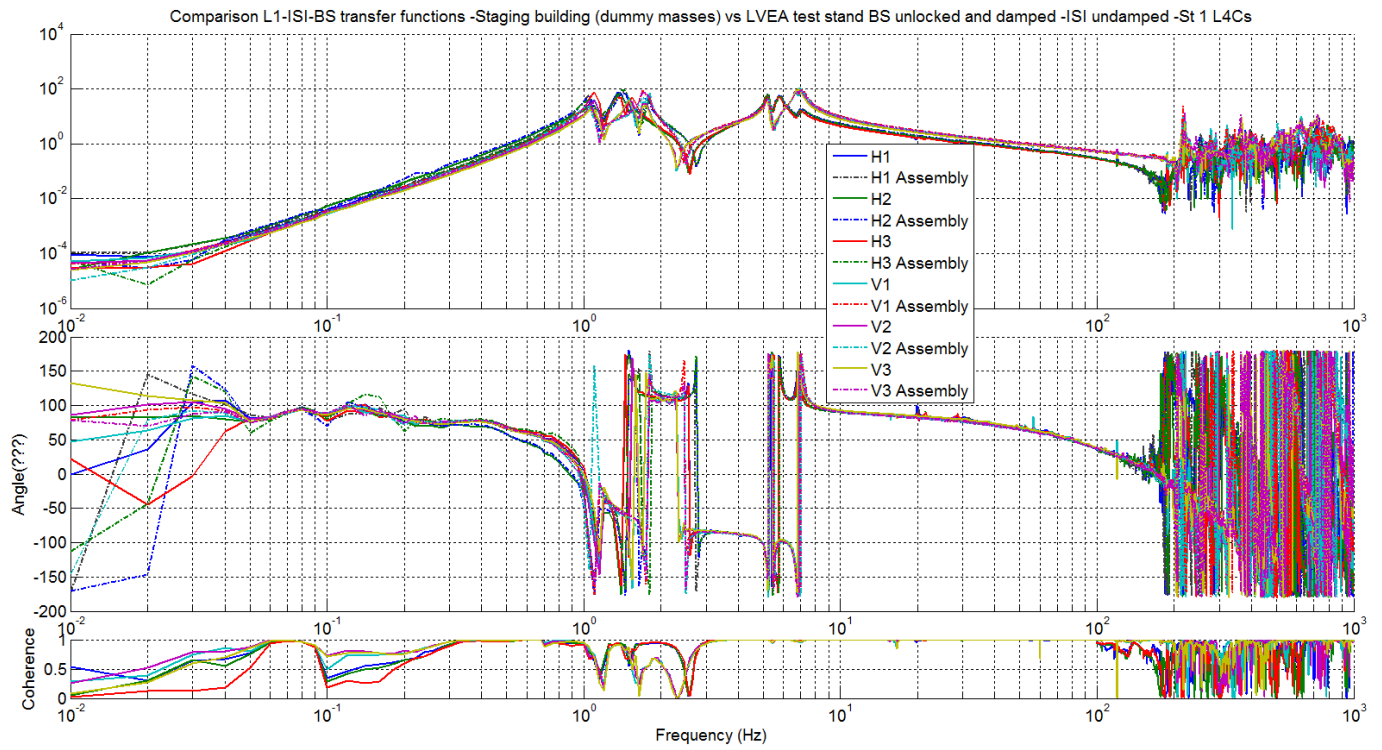


Figure 9 - Transfer functions comparison - ST1 L4C V to ST1 L4C V

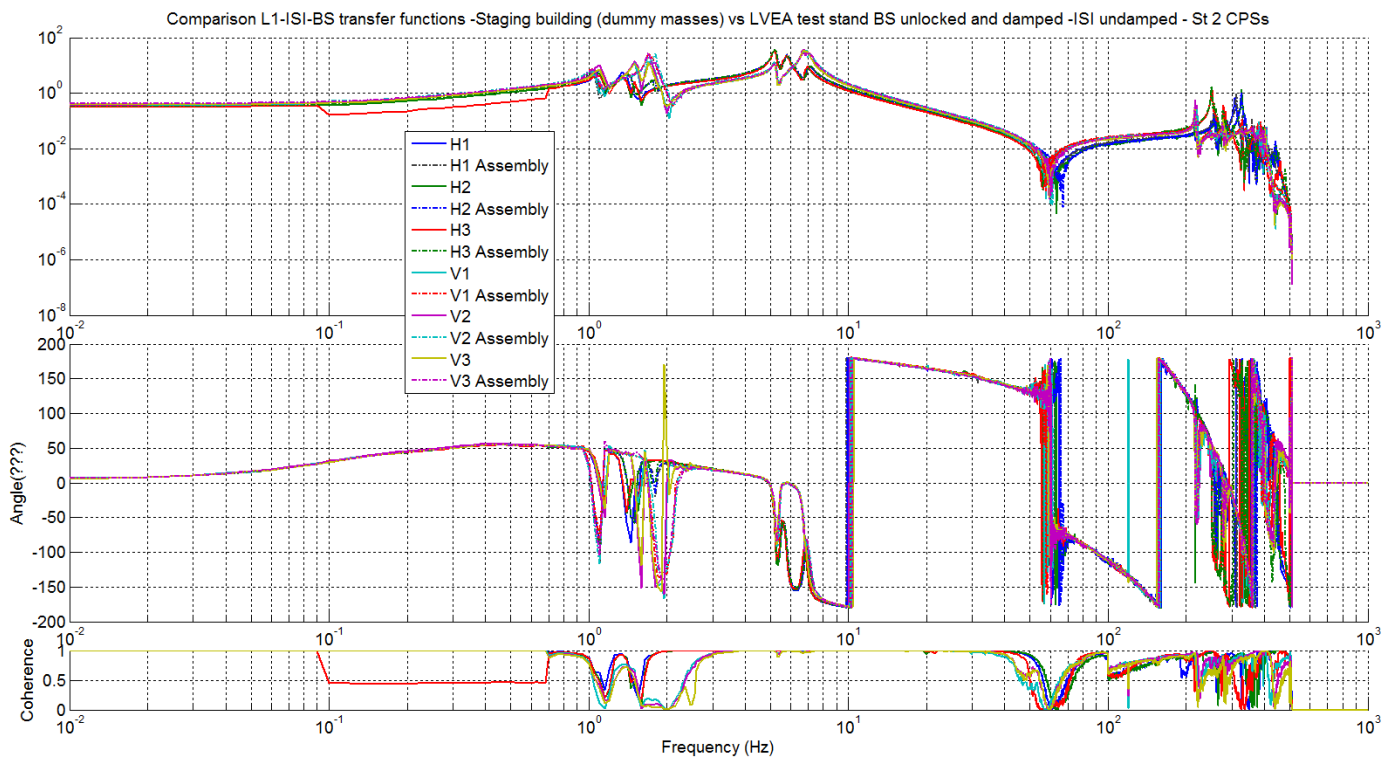


Figure 10 - Transfer functions comparison - ST2 ACT to ST2 CPS

Comparison L1-ISI-BS transfer functions -Staging building (dummy masses) vs LVEA test stand BS unlocked and damped -ISI undamped - St 2 CPSs

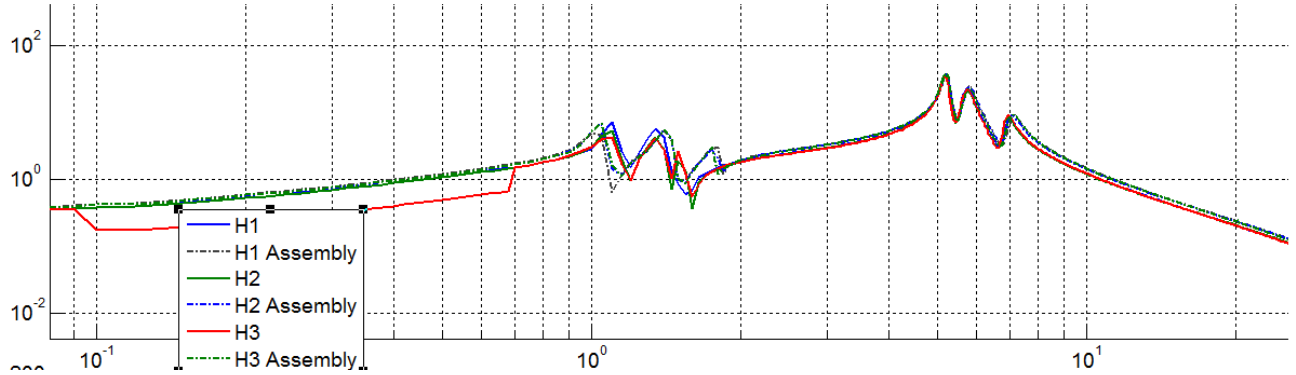


Figure 11 – Zoom in on transfer functions comparison - ST2 ACT H to ST2 CPS H

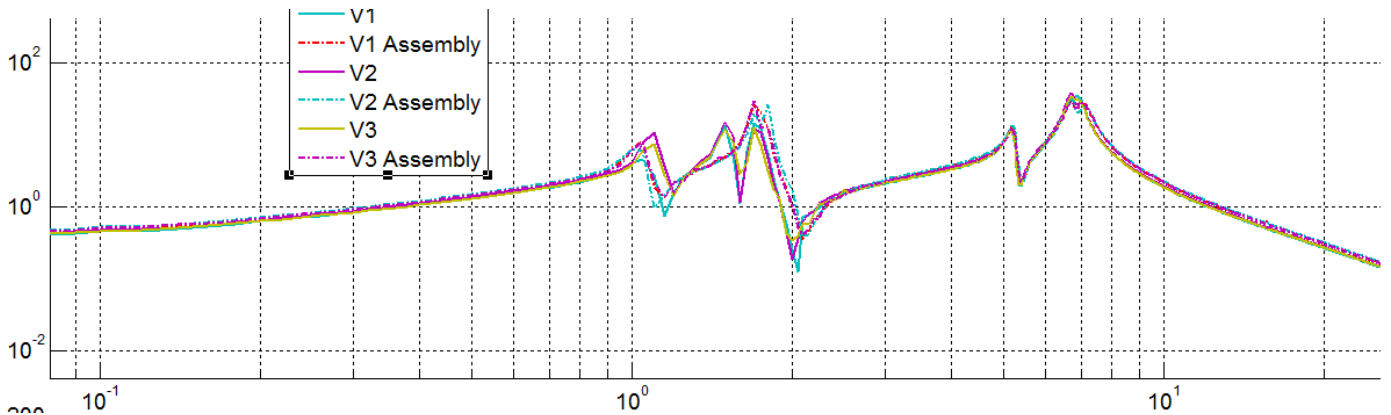


Figure 12 - Zoom in on transfer functions comparison - ST2 ACT V to ST2 CPS V

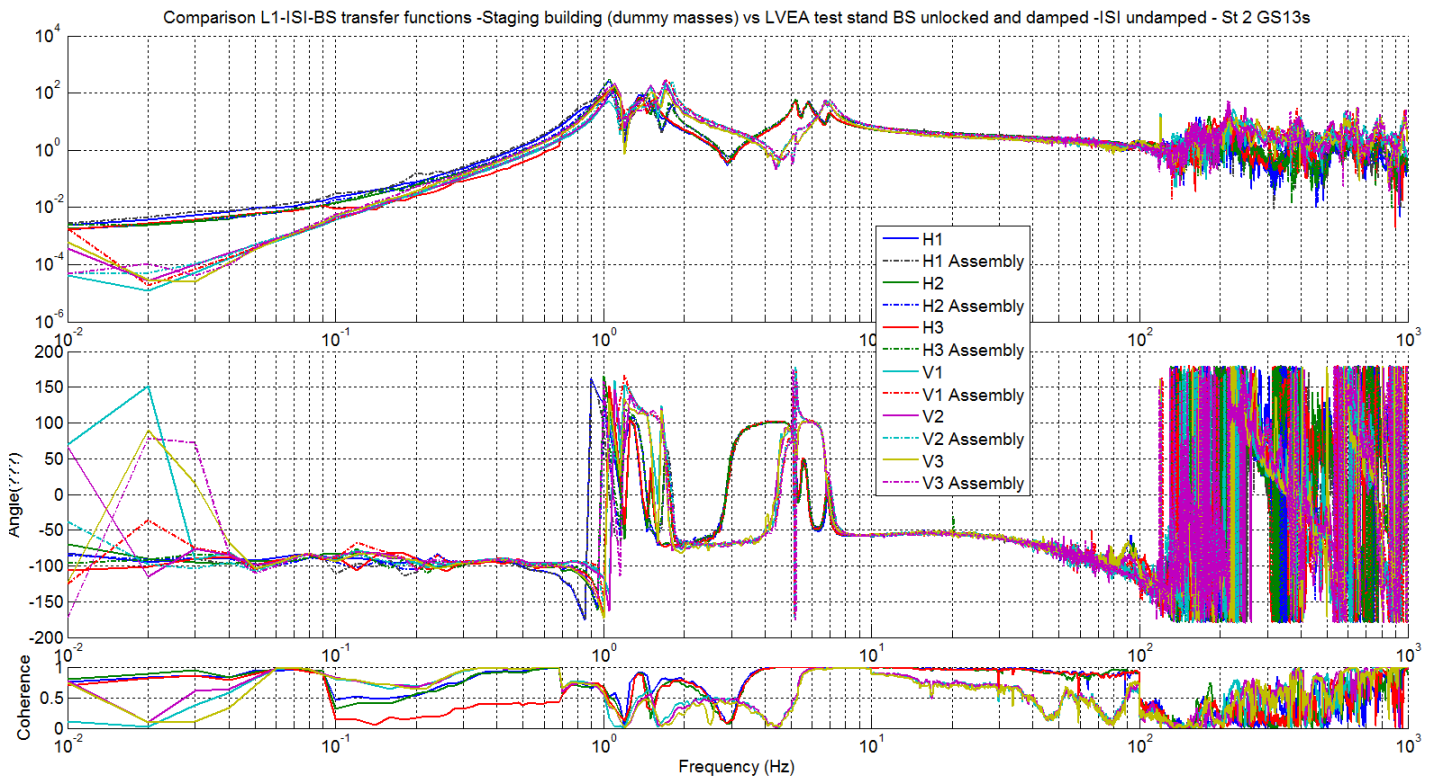


Figure 13 - Transfer functions comparison – ST2 ACT V to ST2 GS13 V

Comparison L1-ISI-BS transfer functions -Staging building (dummy masses) vs LVEA test stand BS unlocked and damped -ISI undamped - St 2 GS13s

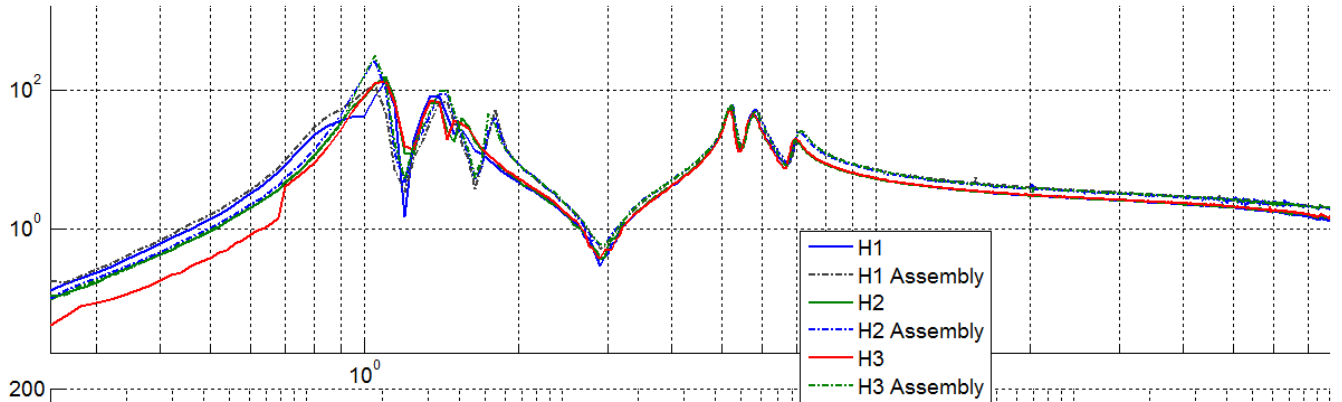


Figure 14 – Zoom in transfer functions comparison – ST2 ACT H to ST2 GS13 H

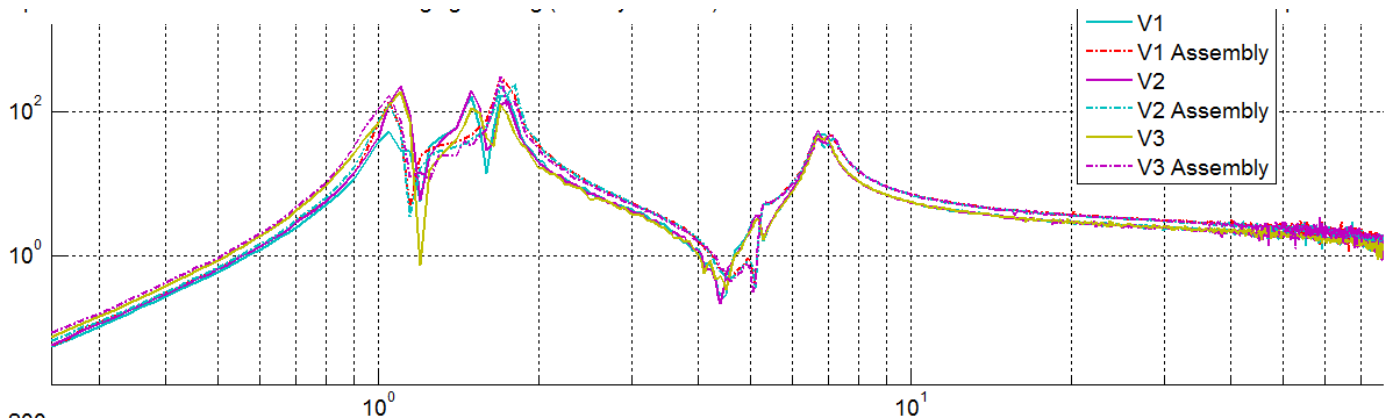


Figure 15 – Zoom in transfer functions comparison – ST2 ACT V to ST2 GS13 V

7. Conclusion Phase II-a

All results appear satisfying, apart from a few test waived (will be redone during phase II-b):

- Offset unlocked vs locked (Stage 1 is not perfectly balanced but it is sufficient for phase II-a testing)
- Static tests in the Cartesian basis (redundant with the static test in the local basis)
- Pressure sensor issue on L4C 1 (interface issue)
- Linearity test: some corners have slightly different slopes but nothing strikingly alarming. We have seen in the past (HAM-ISI phase 2 testing) stronger slopes different, blamed on different cable lengths inside the LVEA.
- Balancing on the test stand revealed a 75 kgs difference between the expected and the actual payload. This may be due to mistakes in the mass budget reporting, or poor weight estimation of the payload !?!

Test result:

Passed: X

Failed:

Waived:



2. Phase II-b- After cartridge install

The cartridge install was done on September 7th 201. The mass distribution was finalized, while vibration absorbers were installed. Also cable brackets were installed and the cabling was improved. Phase II-b testing was completed on October 10th and the dome was close on October 11th.

1. Mass distribution

This is the final mass distribution after cartridge install. We followed D1101852-v7 for the optical table and ballast masses and then balanced the ISI using the side masses. Please note that between Phase II a and Phase II b the vibration absorbers were installed on Stage 1 of the ISI.

1. Seismic

Stage 1

10/10/2012	D0902612	D0902613	D0902616					D1001760	lbs	kgs
			1	2	3	4	5			
	12	15	3.5	1	2	5	0.5	15.86		
C1-1									0	0
C1-2									0	0
C1-3				2		1		1	22.86	10.37844
C2-1									0	0
C2-2									0	0
C2-3								2	31.72	14.40088
C3-1									0	0
C3-2		1							15	6.81
C3-3				1				1	16.86	7.65444
Stage 1	0	1	0	3	0	1	0	4	82	39.24376

Stage 2

10/9/2012	D1003136	D1003161					D071200						lbs	kgs	
							0	1	2	3	4	5			6
	50	43.2	45.4	47.6	49.8	52	0.6	1.1	2.2	4.5	7.9	15.6	27.2		
Keel	12													600	272.40
Optical		1	1	19	1	1								1095.3	497.25
E-1									1	1		3		53.5	24.29
E-2							4	2		3				18.1	8.22
E-3							4					1	1	45.2	20.52
F1							4	5						35.1	15.94
F2													2	54.4	24.70
F3							1						2	55	24.97
Stage 2	12	1	12	1	1	1	13	7	1	4	0	4	6	1956.6	888.28



2. Suspension

The BS weight was estimated to be 204.70 kgs. (E1000337)

3. Miscellaneous

The added cables were estimated to weigh 5.86 kgs. (E1000337)

4. Total

	Plan	3/9/2012	LVEA (08/16/12)	Chamber (10/12/12)
Stage 1 (kg)	108.86	36.29	37.19	39.24
Stage 2 (kg)	1183.42	1096.83	811.1	888.28
Suspension (kg)			204.7	204.70
Miscellaneous (kg)			5.86	5.86
Total (kg)	1292.28	1133.12	1058.8	1138.08

This confirms that the BS weight was well estimated and that the difference in weight found in side chamber testing was due to a problem estimating the ISI masses.

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

2. Basic functionalities just after installing the BSC-ISI on the test stand

1. Pressure sensors

All pressure sensors are working.

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Static_Tests/L1_ISI_BS_Pressure_Sensors_Check_Calibrated_2012_10_14_163321.mat

Sensors	Pressure (KPa)		
	Corner 1	Corner 2	Corner 3
ST1-L4C-P	66.9776	98.96156	98.95647
ST1-L4C-D	1.223052	1.955529	1.801736
ST1-GS13-P	100.1601	100.3851	100.1741
ST1-GS13-D	-0.91096	-1.08985	-0.925
ST1-T240-P	153.6562	153.2118	153.8986

Table 8 - Geophones Pressure sensors

Note/comment about this test: The direct pressure of the corner 1 L4-C was identified to be a problem with the BSC-ISI interface and not with the L4-C itself.

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

2. Spectra

Spectra of the instrument can be found in the SVN at:

[seismic/BSC-ISI/L1/BS/Data/Spectra/Undamped/LLO_ISI_BS_ASD_m_LOC_CPS_T240_L4C_GS13_2012_10_01_202526.mat](https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Spectra/Undamped/LLO_ISI_BS_ASD_m_LOC_CPS_T240_L4C_GS13_2012_10_01_202526.mat)



<https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Figures/Spectra/Undamped/>

- LLO_ISI_BS_ASD_m_LOC_CPS_T240_L4C_GS13_2012_10_01_202526.fig

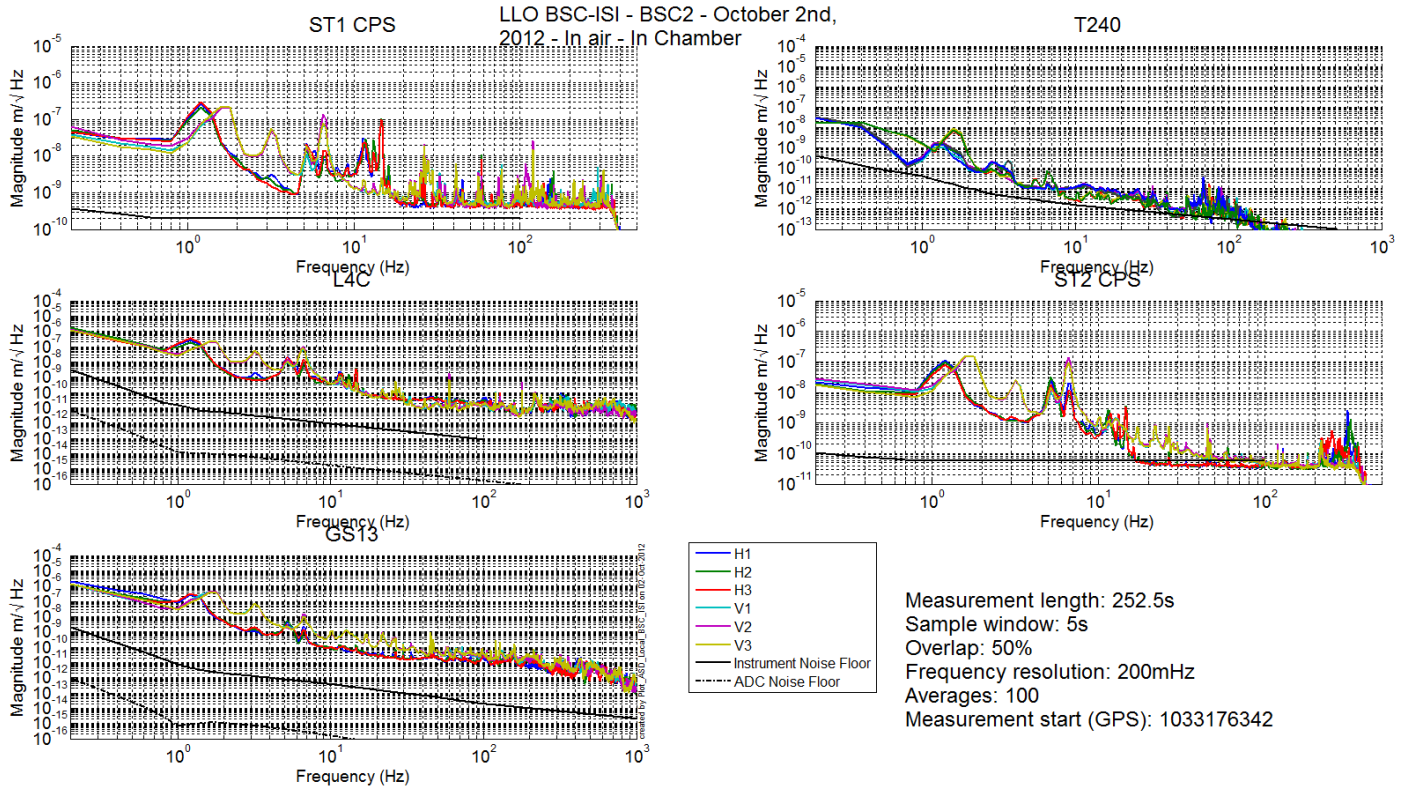


Figure 16 - Spectra inboard instruments - ISI Unlocked

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

3. Actuators-cables resistance

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Static_Tests/

- L1_ISI_BS_Actuators_Resistance_20121015.mat

	Stage 1						Stage 2					
	H1	H2	H3	V1	V2	V3	H1	H2	H3	V1	V2	V3
Script	7.02	6.95	6.90	6.90	7.02	6.94	11.01	11.40	10.78	10.96	11.41	11.17

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



		Sensors					
		ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
Actuators	ST1 - H1	3945.138	1589.714	1587.759	8.40346	11.05842	-4.06386
	ST1 - H2	1607.562	3968.233	1592.45	4.45278	-0.79596	-1.47768
	ST1 - H3	1594.809	1584.72	3920.97	-12.0188	18.85602	-1.92364
	ST1 - V1	24.4812	-141.38	74.46578	2940.304	-493.381	-486.627
	ST1 - V2	99.1584	46.283	-120.667	-480.811	3031.996	-508.308
	ST1 - V3	-132.198	73.04544	16.65176	-507.342	-471.681	2977.197

Table 10 - Static Tests – Local to Local - Stage 1

		Sensors					
		ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
Actuators	ST2 - H1	2213.337	354.623	322.746	-30.3301	-17.0111	-5.06274
	ST2 - H2	345.4151	2229.945	332.914	-13.6421	-56.5943	7.61952
	ST2 - H3	329.8847	339.9476	2211.603	-34.1825	-52.8874	5.0095
	ST2 - V1	75.46992	108.659	-167.07	2569.149	313.6153	12.25218
	ST2 - V2	-200.895	67.7532	104.3314	-7.05884	2643.61	301.7954
	ST2 - V3	102.7038	-144.555	65.5426	291.1055	-26.7397	2572.482

Table 11 - Static Tests – Local to Local - Stage 2

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

6. Offset Cartesian drive

The test was not performed because it only tests the matrices, which can be changed at any time.

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



7. Range of motion

The range of motion of the table is measured by pushing on the table in a direction collinear to the CPS. The Static tests results can be found on the SVN at:

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/BS/Data/Static_Tests/
 - L1_ISI_BS_Range_Of_Motion_20121015.mat

Sensor readout (counts)	Negative drive	Positive drive	Amplitude count	mil
ST1 - H1	-16264.6	15353.09	31617.68	37.6401
ST1 - H2	-15814.7	16021.22	31835.91	37.89989
ST1 - H3	-16690.3	15373.55	32063.83	38.17123
ST1 - V1	-15071.2	10145.66	25216.83	30.02003
ST1 - V2	-14914.3	11028.69	25943	30.88452
ST1 - V3	-13000	12586.91	25586.88	30.46057
ST2 - H1	-8648.96	10188.87	18837.84	5.606499
ST2 - H2	-8217.55	10750.42	18967.97	5.645228
ST2 - H3	-7054.84	11710.8	18765.64	5.585011
ST2 - V1	-15541.9	6716.805	22258.66	6.624602
ST2 - V2	-13600.9	9285.09	22886.03	6.811319
ST2 - V3	-12871.7	9495.85	22367.52	6.656999

Table 12 - Range of motion - Actuator drive in the LVEA

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

8. Linearity test

The data of the linearity test can be found on the SVN at:
 seismic/BSC-ISI/L1/BS/Data/Linearity_Test/

- LLO_ISI_BSC2_Linearity_test_20121009.mat

The figures of the linearity test can be found on the SVN at:
 seismic\BSC-ISI\H2\BS\Data\Figures\Linearity_Test\

- LLO_ISI_BSC2_Linearity_test_20121009.fig



LLO BSC ISI - BSC2 - Oct 9th, 2012 - In Chamber

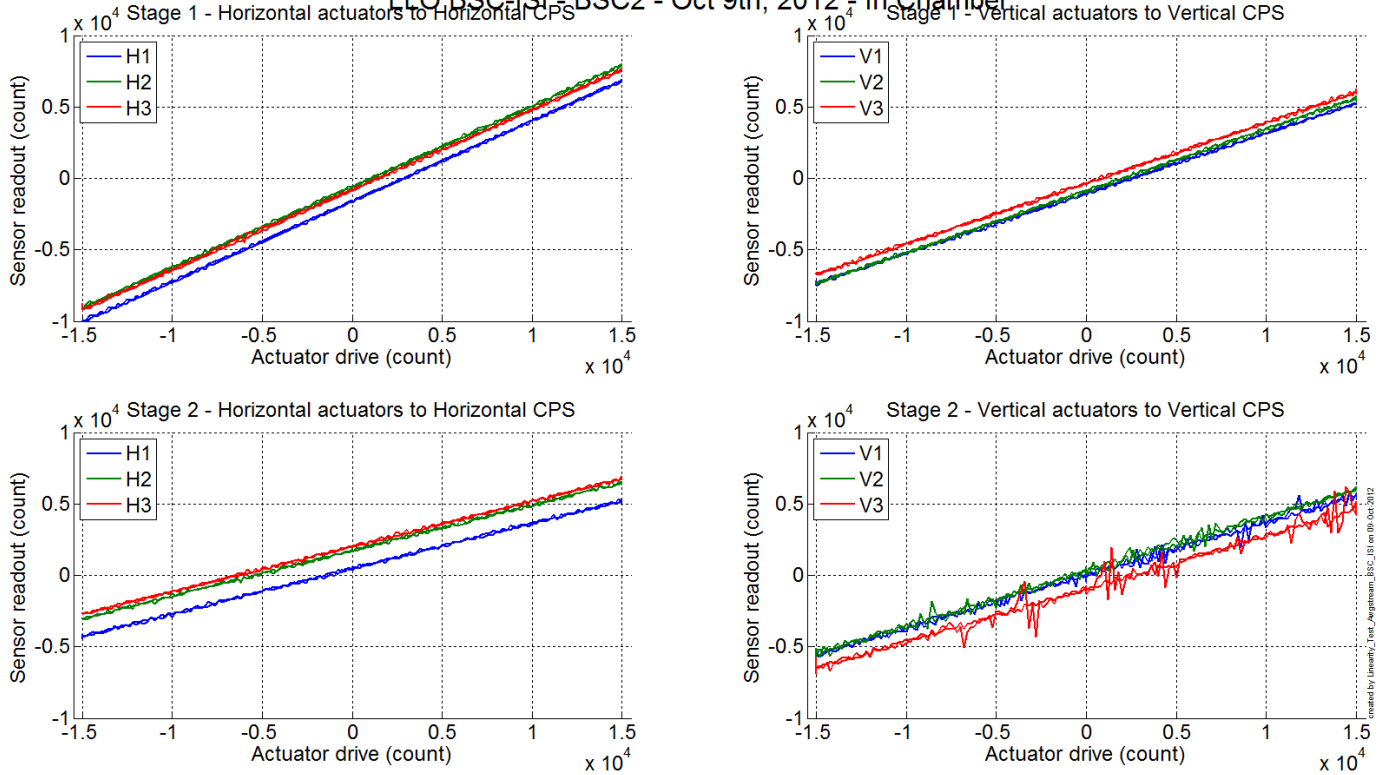


Figure 17 - Linearity test –L1 - BS – In Chamber

	Slope	Offset	Average slope	Variation from average(%)
Stage 1	ST1 - H1	0.562152	-1601.38	0.001176
	ST1 - H2	0.565076	-584.167	0.521231
	ST1 - H3	0.559209	-801.554	-0.52241
	ST1 - V1	0.420188	-1049.65	-1.34037
	ST1 - V2	0.432098	-873.607	1.456235
	ST1 - V3	0.425403	-343.901	-0.11587
Stage 2	ST2 - H1	0.31708	469.5074	-0.01015
	ST2 - H2	0.318163	1728.48	0.331479
	ST2 - H3	0.316093	2019.604	-0.32132
	ST2 - V1	0.371271	5.412806	-1.14717
	ST2 - V2	0.383337	275.1606	2.065527
	ST2 - V3	0.37213	-951.599	-0.91836

Table 13 - Slope – Offset Linearity test

Note: One slope is slightly over 2% but nothing dramatic.

Test result: Passed: Failed: Waived: X



3. Transfer functions and comparison with measurements done before the cartridge install

1. In the LVEA

We kept the excitations identical to what was used on the LVEA test stand before the cartridge install.

At this point, only the tuned mass dampers on the spring are installed (No vibration absorbers, no Viton under the keel masses, no vibration absorbers on the BS)

Measurements data can be found in the SVN at:

SeiSVN/seismic/BSC-ISI/L1/BS/Data/Transfer_Functions/Measurements/Undamped:

- LLO_ISI_BSC2_Data_L2L_10mHz_100mHz_ST1_ST2_20121010-224952.mat
- LLO_ISI_BSC2_Data_L2L_100mHz_700mHz_ST1_ST2_20121010-172700.mat
- LLO_ISI_BSC2_Data_L2L_700mHz_10Hz_ST1_ST2_20121011-180140.mat
- LLO_ISI_BSC2_Data_L2L_10Hz_100Hz_ST1_ST2_20121011-022506.mat
- LLO_ISI_BSC2_Data_L2L_100Hz_500Hz_ST1_ST2_20121011-011248.mat
- LLO_ISI_BSC2_Data_L2L_500Hz_1000Hz_ST1_ST2_20121011-015239.mat

Data after processing can be found in the SVN at:

SeiSVN/seismic/BSC-ISI/L1/BS/Data/Transfer_Functions/Simulations/Undamped

- LLO_ISI_BSC2_TF_L2L_Raw_10mHz_1000Hz_2012_10_11.mat

The transfer functions can be found in the SVN at:

seismic/BSC-ISI/L1/BS/Data/Figures/Transfer_Functions/Measurements/Undamped/

- LLO_ISI_BSC2_TF_L2L_Raw_from_ST1_ACT_to_ST1_CPS_2012_10_11.fig
- LLO_ISI_BSC2_TF_L2L_Raw_from_ST1_ACT_to_ST1_L4C_2012_10_11.fig
- LLO_ISI_BSC2_TF_L2L_Raw_from_ST1_ACT_to_ST1_T240_2012_08_17.fig
- LLO_ISI_BSC2_TF_L2L_Raw_from_ST2_ACT_to_ST2_CPS_2012_10_11.fig
- LLO_ISI_BSC2_TF_L2L_Raw_from_ST2_ACT_to_ST2_GS13_2012_10_11.fig

Note 1: The transfer functions are measured from the Output filters bank excitation point to the input (IN1) of the input filters bank. The transfer functions presented below are raw transfer functions without any electronic compensation.

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: On the ST1-ACT-H to ST1-CPS-H transfer functions, we can see the first HEPI resonances at 11 Hz.

Note 4: With the installation of the vibration absorbers, the first resonance on Stage 1 is at 219 Hz (moved from 154 Hz).

Because we haven't done the comparison plot, we leave the H2 BSC 6 transfer functions for comparison.

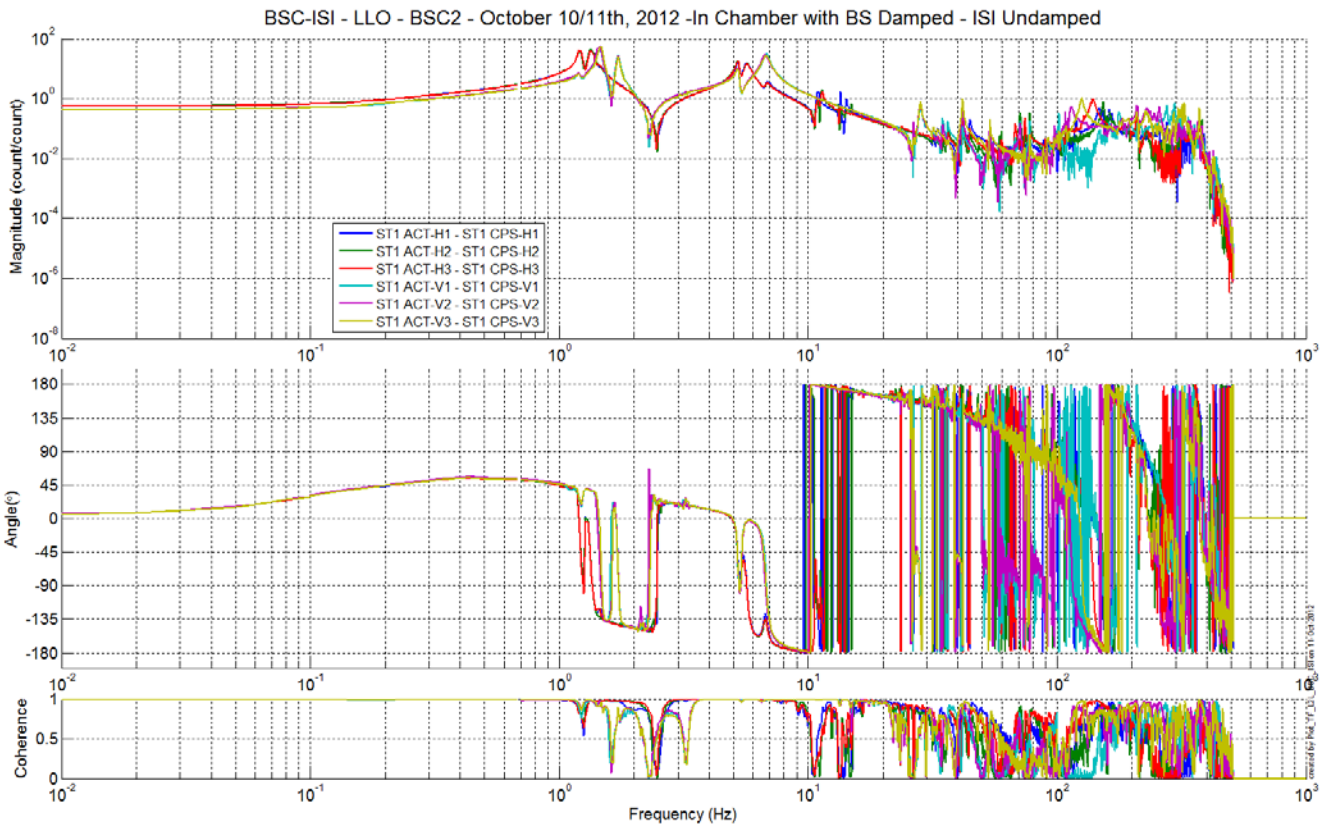


Figure 18 - TF ST1 ACT to ST1 CPS

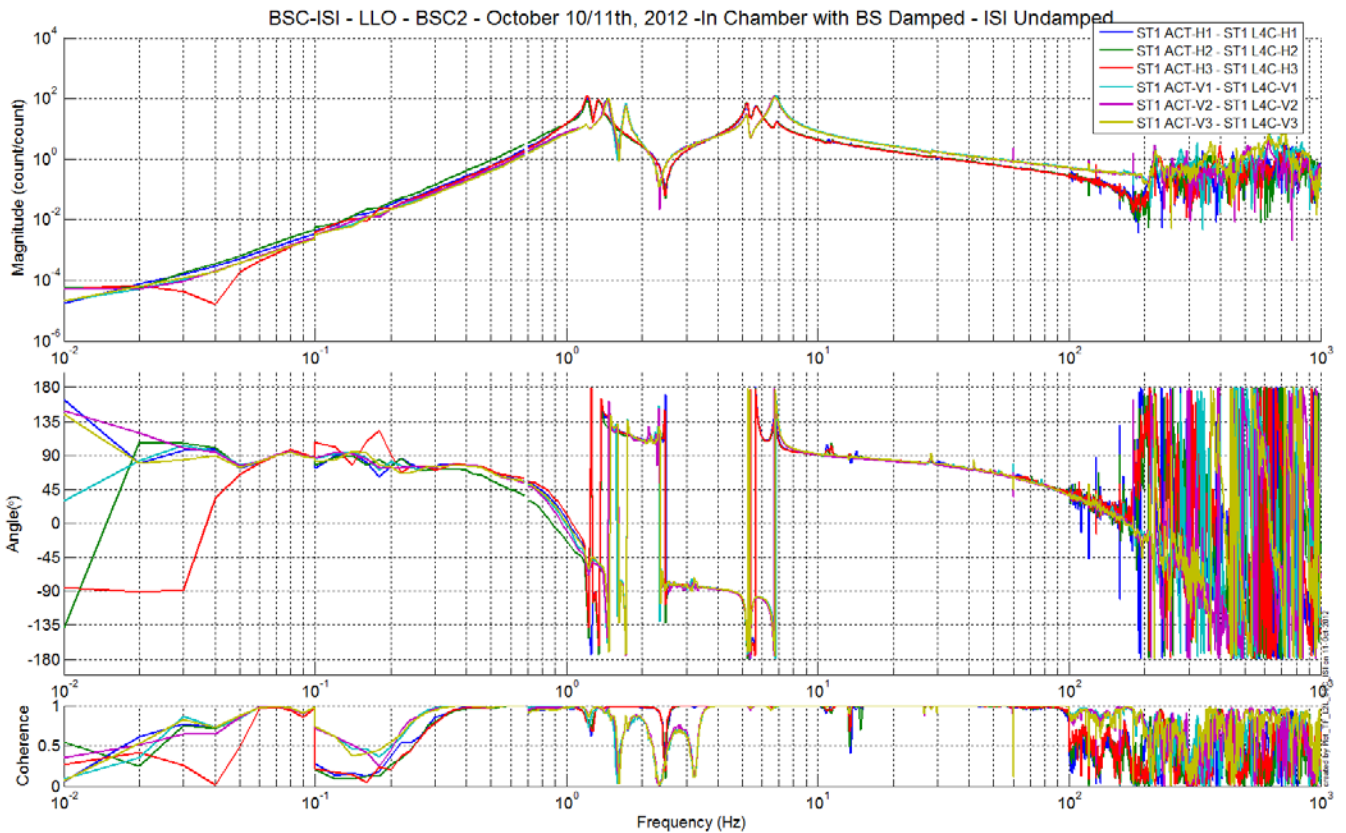


Figure 19 - TF ST1 ACT to ST1 L4C

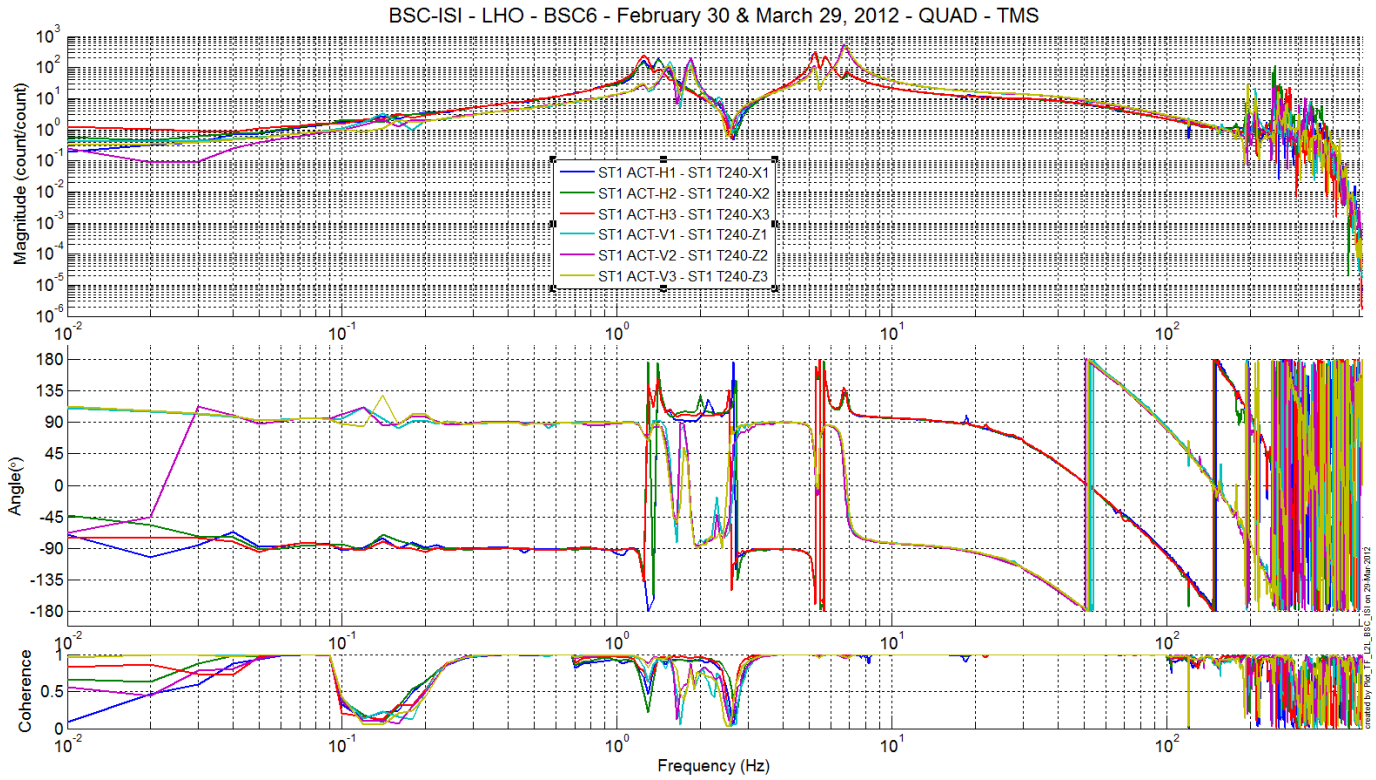


Figure 20 - TF ST1 ACT to ST1 T240

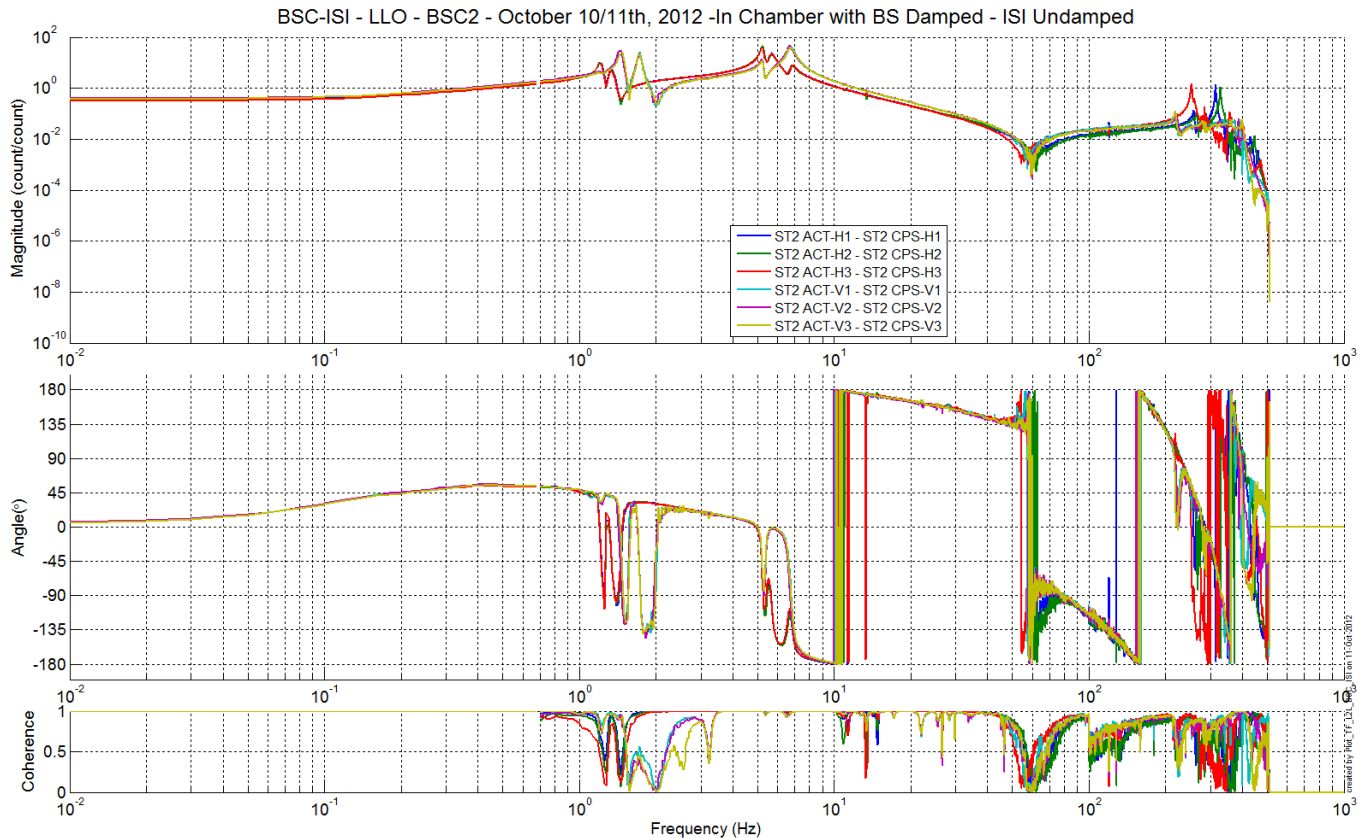


Figure 21 - TF ST2 ACT to ST2 CPS

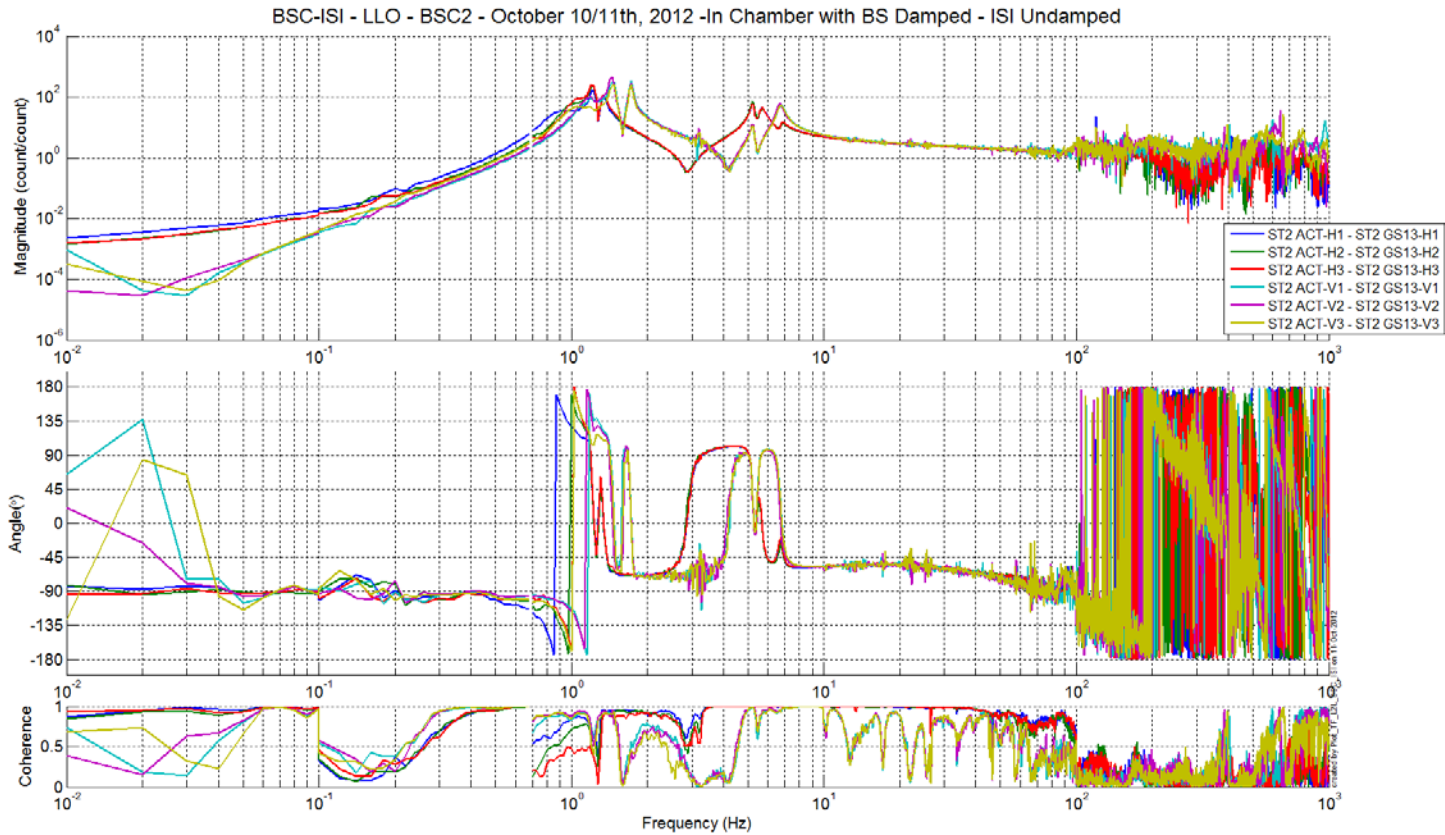


Figure 22 - TF ST2 ACT to ST2 GS13

2. Comparisons with measurements before cartridge install

The script used to compare transfer function can be found in the SVN at:
 SeiSVN/seismic/BSC-ISI/Common/Plot_Functions_BSC_ISI/Version_0/
 - Plot_Comparison_TF_L2L_BSC_ISI.m

The figure that shows the comparison between the transfer functions of the staging building and the LVEA are located in the SVN at:

SeiSVN/seismic/BSC-ISI/L1/BS/Data/Figures/Transfer_Functions/Measurements/Comparison/L2L/

- COMP_CARTRIDGE_L1_ISI_BS_ST1_CPS_2012_10_11_.fig
- COMP_CARTRIDGE_L1_ISI_BS_ST2_CPS_2012_10_11_.fig
- COMP_CARTRIDGE_L1_ISI_BS_ST1_L4C_2012_10_11_.fig
- COMP_CARTRIDGE_L1_ISI_BS_ST2_GS13_2012_10_11_.fig



Main differences are:

- Resonances of the rigid body modes [1; 10]Hz (different payload- with masses on optical table and on the keel)
- ST1-CPS resonances different between test stand and HEPI piers (visible between 10 and 70 Hz)
- Some noise around 3.2 Hz, especially visible on Stage 2 GS-13
- Transfer functions look similar at high frequencies with some improvement at 220 Hz on Stage 1 L4-Cs due to the installation of Stage 1 vibration absorbers.

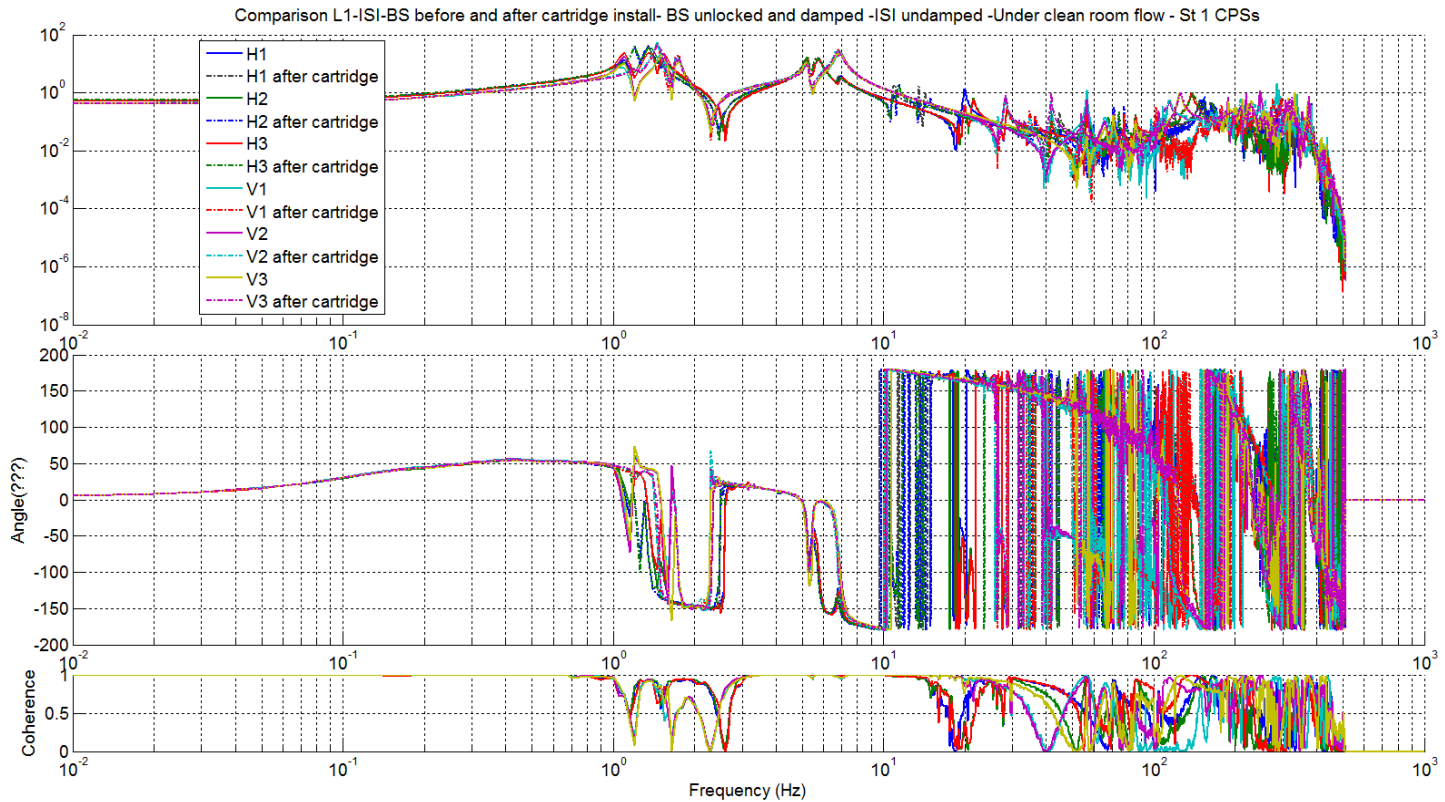


Figure 23 - Transfer functions comparison - ST1 ACT to ST1 CPS

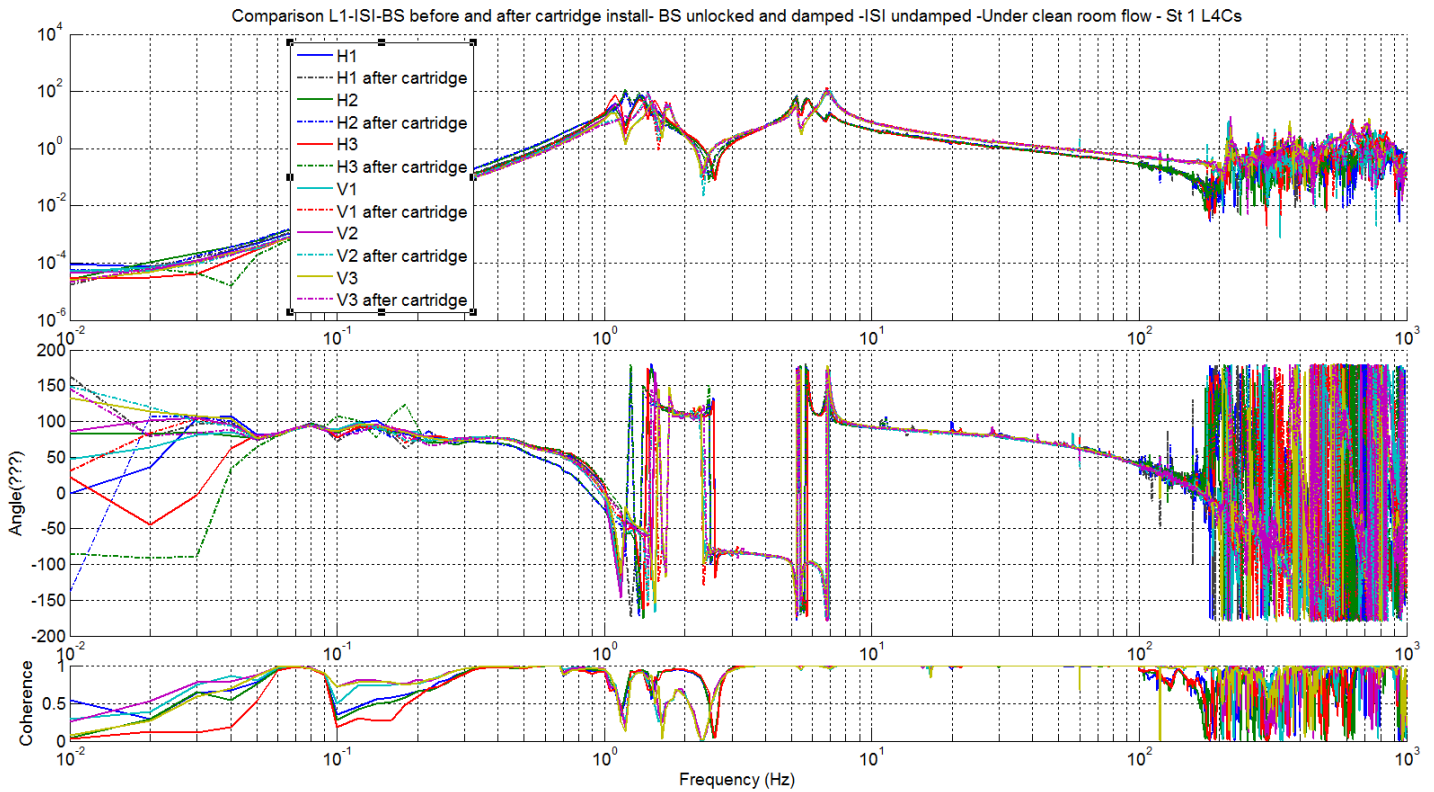


Figure 24 - Transfer functions comparison - ST1 L4C to ST1 L4C

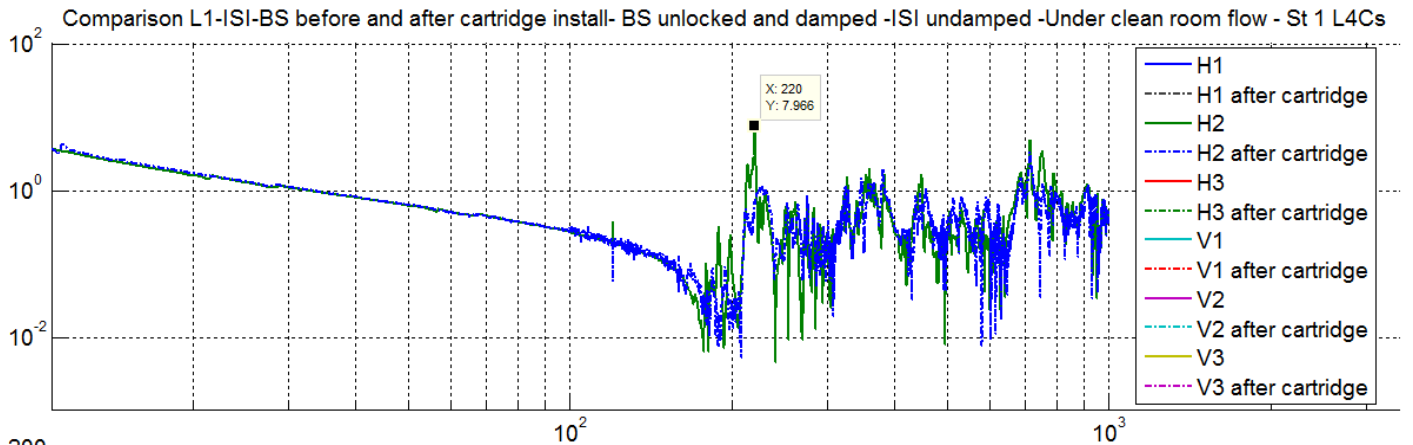


Figure 25 – Zoom in on transfer functions comparison – ST1 ACT to ST1 L4C –effect of ST 1 vibration absorbers

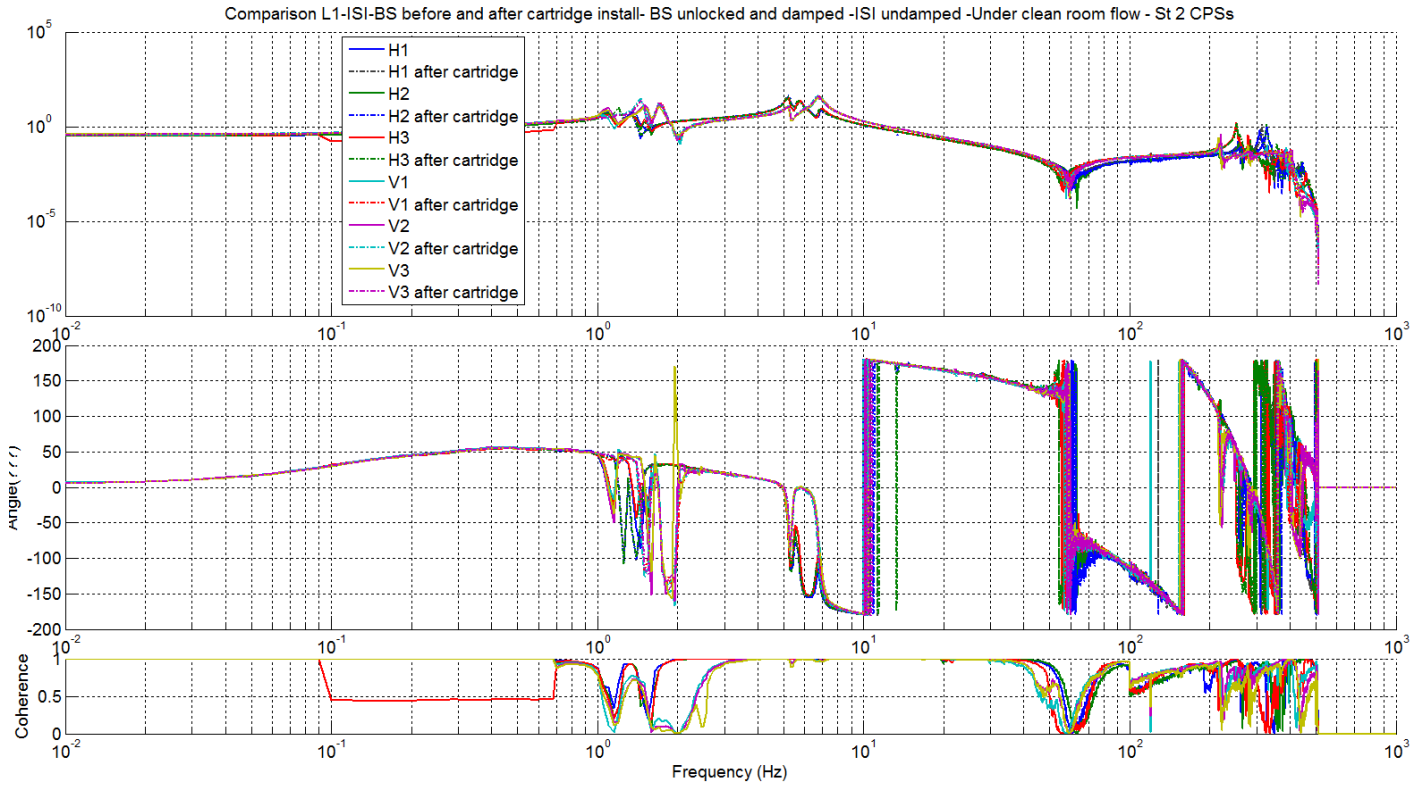


Figure 26 - Transfer functions comparison - ST2 ACT to ST2 CPS

Comparison L1-ISI-BS before and after cartridge install- BS unlocked and damped -ISI undamped -Under clean room flow - St 2 CPSs

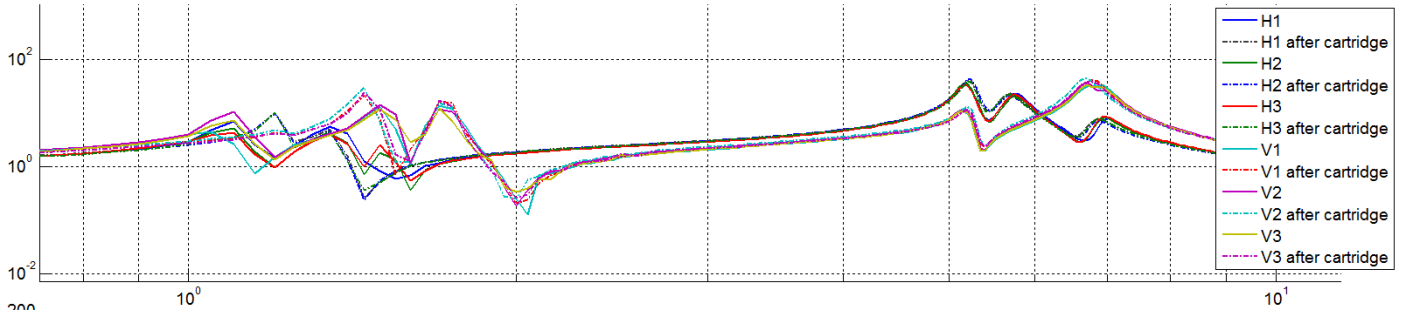


Figure 27 – Zoom in on transfer functions comparison - ST2 ACT to ST2 CPS

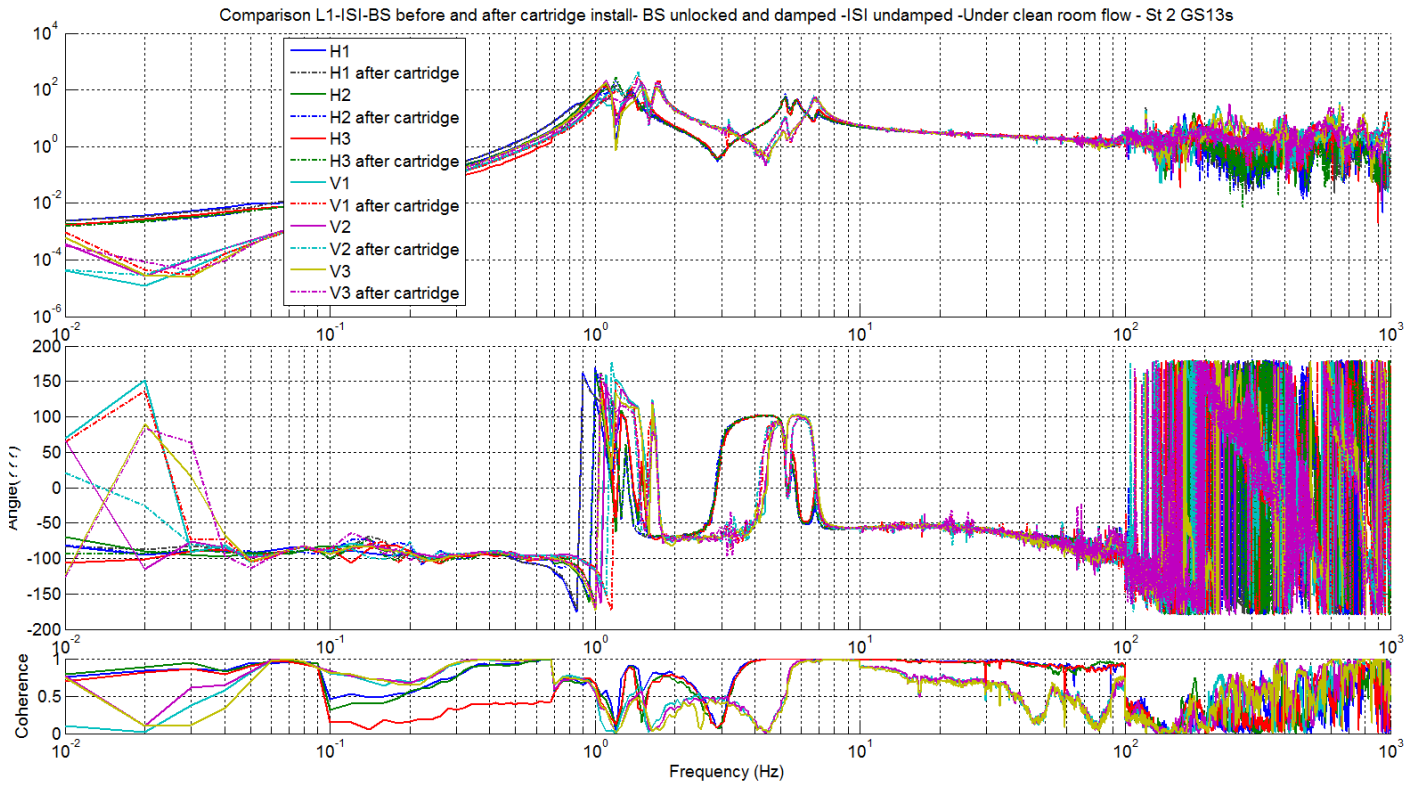


Figure 28 - Transfer functions comparison – ST2 ACT to ST2 GS13

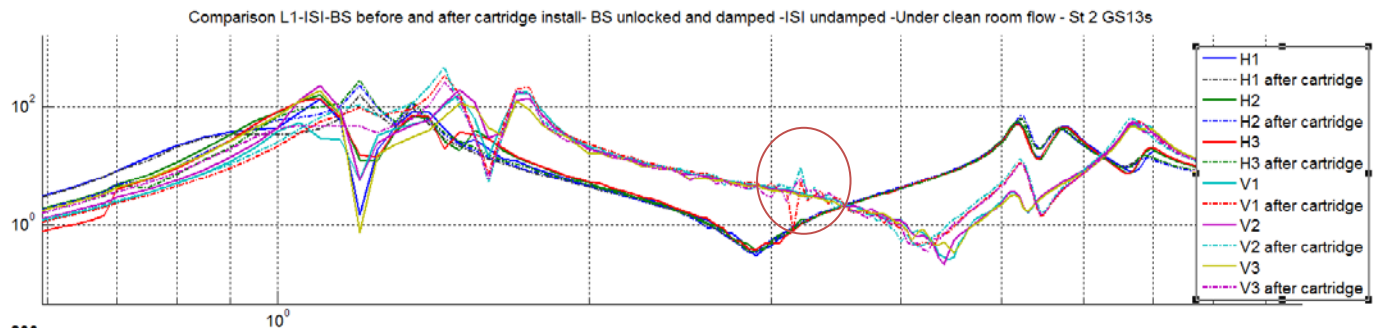


Figure 29 – Zoom in transfer functions comparison – ST2 ACT to ST2 GS13

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

3 -Comparisons with measurements after closing the dome

The script used to compare transfer function can be found in the SVN at:
SeiSVN/seismic/BSC-ISI/Common/Plot_Functions_BSC_ISI/Version_0/
- Plot_Comparison_TF_L2L_BSC_ISI.m

The figure that shows the comparison between the transfer functions of the staging building and the LVEA are located in the SVN at:

SeiSVN/seismic/BSC-ISI/L1/BS/Data/Figures/Transfer_Functions/Measurements/Comparison/L2L/

- COMP_DOME_L1_ISI_BS_ST1_CPS_2012_10_11_.fig
- COMP_DOME_L1_ISI_BS_ST2_CPS_2012_10_11_.fig



- COMP_DOME_L1_ISI_BS_ST1_L4C_2012_10_11_.fig
- COMP_DOME_L1_ISI_BS_ST2_GS13_2012_10_11_.fig

Comments:

- There is logically great agreement between those measurements as the only difference was the closing of the dome on October 11th. The main difference is that the noise previously visible around 3.2 Hz disappeared on those measurements.

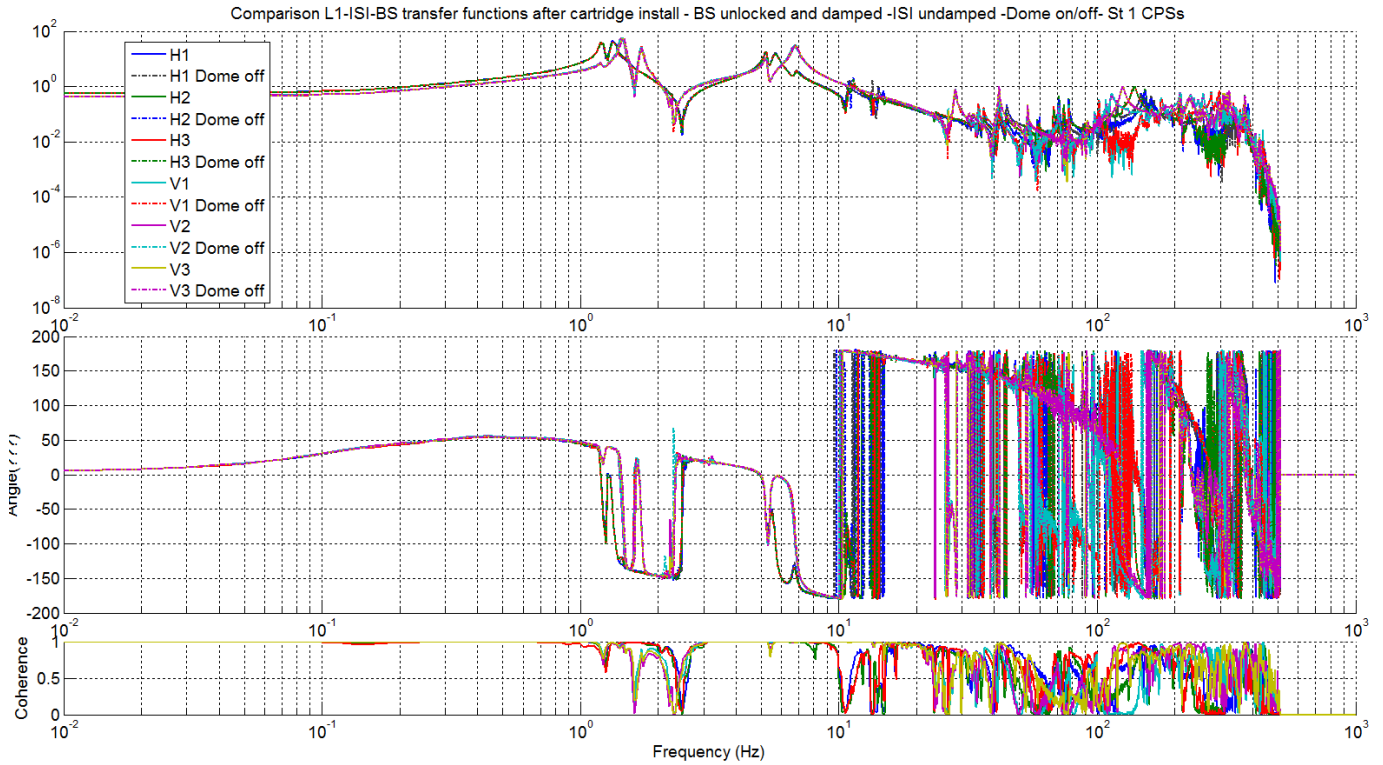


Figure 30 - Transfer functions comparison - ST1 ACT to ST1 CPS

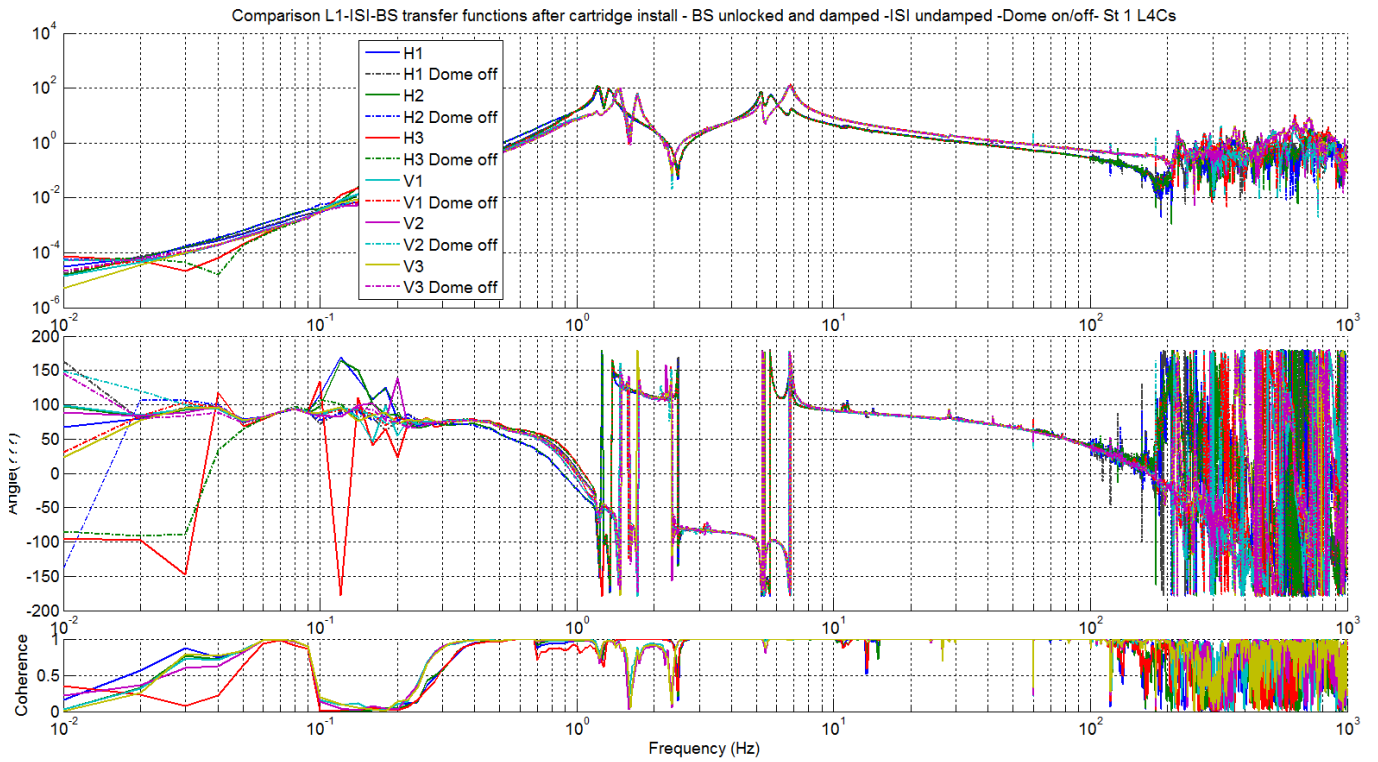


Figure 31 - Transfer functions comparison - ST1 L4C to ST1 L4C

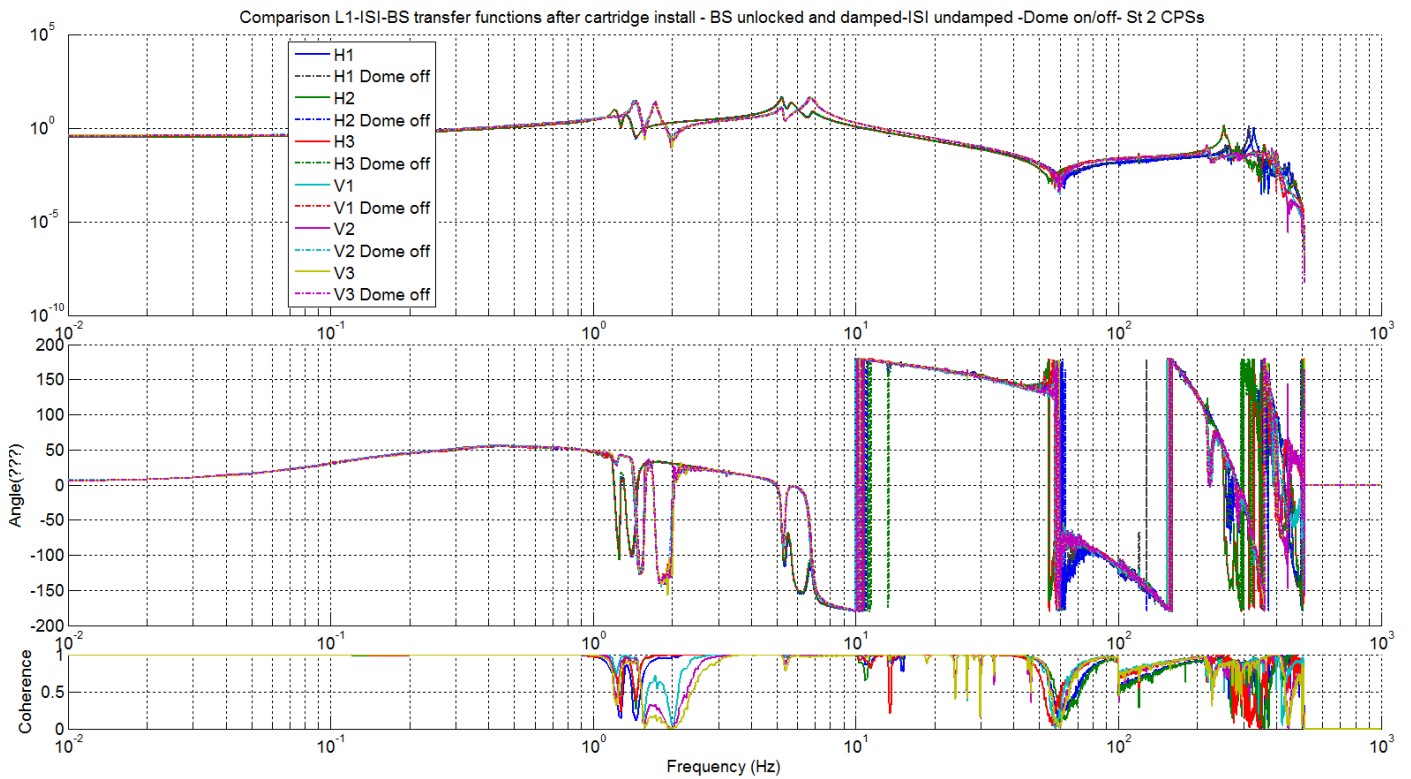


Figure 32 - Transfer functions comparison - ST2 ACT to ST2 CPS

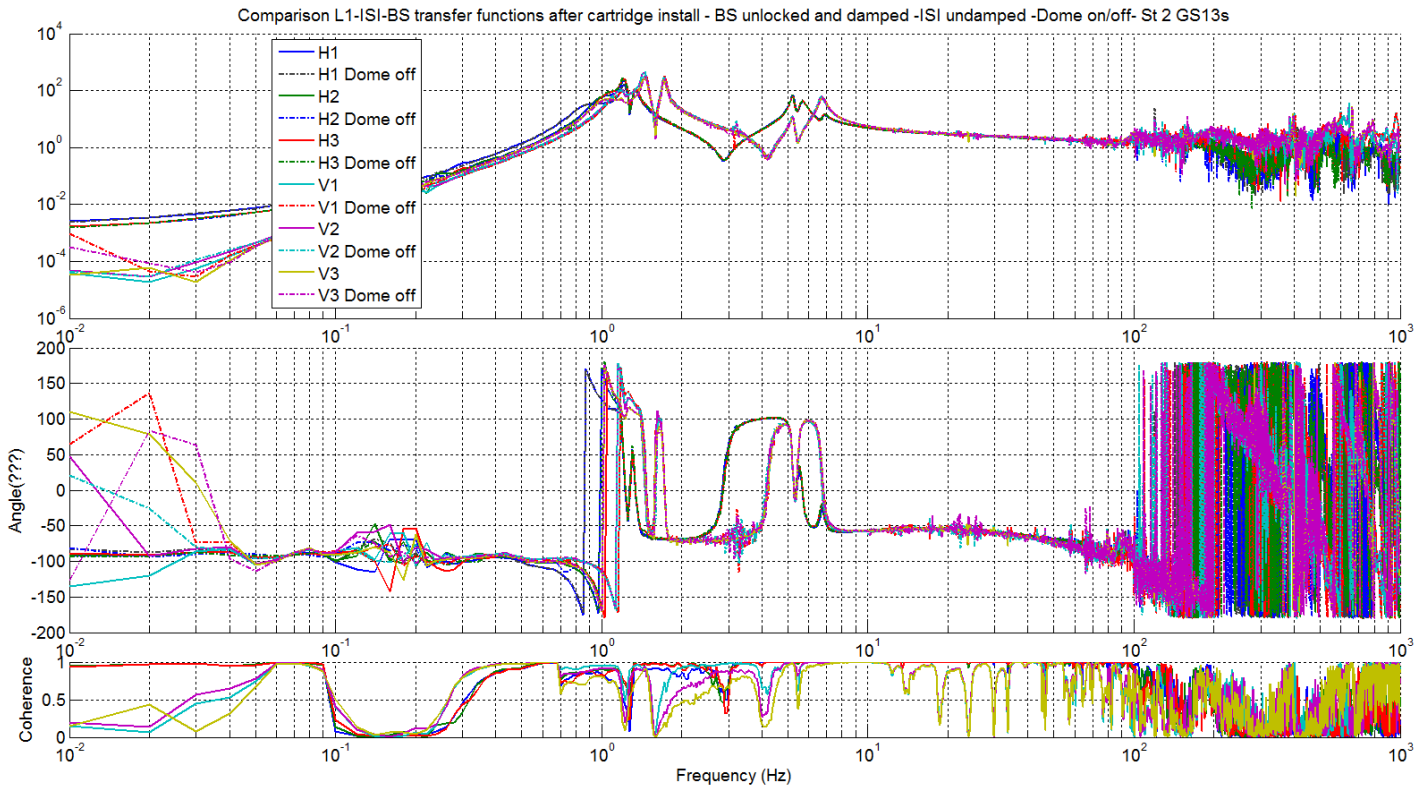


Figure 33 - Transfer functions comparison – ST2 ACT to ST2 GS13

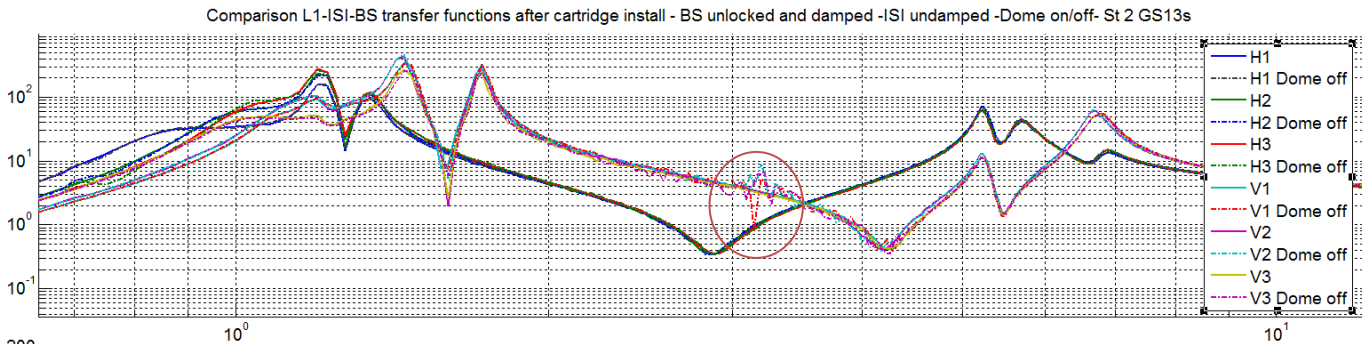


Figure 34 – Zoom in transfer functions comparison – ST2 ACT to ST2 GS13

Test result: Passed: X Failed: Waived:

4. Conclusion Phase II-b

All results appear satisfying, apart from a few tests waived:

- Static tests in the Cartesian basis (redundant with the static test in the local basis)
- Pressure sensor issue on L4C 1 (shown to be an interface issue)
- Linearity test: some corners have slightly different slopes but nothing strikingly alarming. We have seen in the past (HAM-ISI phase 2 testing) stronger slopes different, blamed on different cable lengths inside the LVEA.

The only worry we had after install was about the noise around 3.2 Hz and this noise disappeared right after the dome was closed.

Test result: Passed: X Failed: Waived:



Conclusion

The ISI-BSC2 was moved from the Staging building to the LVEA test stand in May 2012

This document presents series of tests (Phase II) performed on the ISI-BSC2 (BS).

First tests started in early August 2012, after BS installation and re-balancing of the ISI. Testing took 2 weeks (with breaks for Initial Alignment on the BS, the ISI was approved for Install on August 17th).

The cartridge install was done on September 7th 2012, after which payload was finalized and vibration absorbtion elements installed. Finally, Phase II-b testing was completed on October 10th and the dome was close on October 11th.