LIGO Laboratory / LIGO Scientific Collaboration

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L1 BSC 3 BSC-ISI, Pre-integration Testing report, Phase II

E1100857-v8

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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, 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-BSC3 was moved from the Staging building to the LVEA in December, 2012. Then the ISI was placed on the test stand a few days later.

This document presents results from the series of tests (Phase II) performed on the ISI-BSC3 (ITMX) in the corner station. The tests were done with the ITMX quadruple suspension installed in its final version.

First tests started on January 31th, 2012. The first testing phase (II-a validation before cartridge installation) was completed on February 4th 2012.

All results are posted on the SVN at:
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/ITMX/

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

Stage 1 H3 CPS SN 13466 has been changed with 13531, because it was giving a constant signal even when we were moving the probe.

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

T240s have not been replaced since phase I testing in the staging building.

5. Cables – E1100822

One cable has been replaced on this BSC since its Phase I Testing:

- D1100152 SN S1107246 extension cable for L4C V1 was giving a wrong pressure readout and has been replaced with SN S1107249. The issue is still there but we know it is not coming from the pod, but from the connection cable-feedthru. This won't prevent us from testing and this issue can be solved once the BSC-ISI is in chamber.

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	S1201323
Interface Chassis Pod 2	D1002432	S1201322
Interface Chassis Pod 3	D1002432	S1201327
Anti-aliasing Chassis Pod 1	D1002693	S1203102
Anti-aliasing Chassis Pod 2	D1002693	S1203101
Anti-aliasing Chassis Pod 3	D1002693	S1203100
Binary Input Chassis 1	D1001726	S1101299
Binary Input Chassis 2	D1001726	S1101298
Binary Output Chassis	D1001728	S1101328
T240 Interface Pod 1	D1002694	S1201892
T240 Interface Pod 2	D1002694	S1104429
T240 Interface Pod 3	D1002694	S1104428
Anti-image Chassis	***D1000305***	***S1203269***
Coil driver Pod 1	D0902744	S1103564
Coil driver Pod 2	D0902744	S1103315
Coil driver Pod 3	D092744	S1103329
Expansion chassis	L1seibsc3	S1100946

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

Stage 1	HighBay (lbs)	LVEA (lbs)	LVEA (kgs)
Corner 1	31.50	31.50	14.29
Corner 2	15	15	6.80
Corner 3	40.50	42.50	19.28
Total	87.0	89.0	40.37

Stage 2

The seismic masses on BSC 3 are;

- On the Keel Plate 1020.5 lbs (=462.9kgs)
- On the Optical Table 637.14 lbs (=289kgs)

The total of masses on Stage 2 is 1657.64 lbs (=751.9 kgs).

2. Suspension

The quad structure was weighed to be:

	Weight (lbs)	Weight (kgs)
Upper structure	266	120.66
Lower structure	531	240.86
Total	797	361.5128

3. Misc

- 44 lbs = quad sleeve [Betsy's alog 3621]
- 2 lbs = quad sleeve wedges [estimate]
- 5 lbs = cabling [estimate]
- 2 lbs cable brackets [estimate]
- 28 lbs = Vibration absorbers, quantity 4 [from E1000337-v2: 12.7 kg = 28 lbs]
- 3 lbs = Ring heater + brackets + cables [estimate]

Total Weight for Suspension: 906 lbs = 412 kg

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

			Staging Bldg	LVEA		
		Plan	10/01/2012	Detail	Overall	Difference
Stage 1 (kgs)		108.86	39.46	40.37	40.37	0.91
Stage 2 (kgs)	Masses	1183.42	1161.33	751.9	1164.29	2.96
	Suspension	N/A	N/A	361.51		
	Miscellaneous	N/A	N/A	50.88		
Total (kgs)		1292.28	1200.79	1204.66	1204.66	3.87

Both Stages difference in weight passes requirement (10 kgs) and are very similar to what we had in the Staging Building, our results are very consistent.

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

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

1. Pressure sensors

All pressure sensors are working except the L4C Corner 1. After trouble shooting the issue, it turns out that the pressure sensor in Corner 1 L4C is working and that the wrong value is coming from its extension cable D1100152 SN S1107246 that we replaced with SN S1107249. We also changed the fake feedthru part to connect this extension to a real feedthru; the pressure readout was good for a few minutes and went bad again. We're suspecting a bad connection of this cable extension and the feedthru. This problem is not holding the testing back though, we will change the extension again once BSC 4 is in chamber.
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/ITMX/Data/Static_Tests/
L1_ISI_ITMX_Pressure_Sensors_Check_Calibrated_2013_01_31_120446.mat

	Pressure (KPa)		
Sensors	**Corner 1**	**Corner 2**	**Corner 3**
ST1-L4C-P	99.5	100.1	99.5
ST1-L4C-D	-9.6	-1.2	-0.2
ST1-GS13-P	100.0	100.1	100.0
ST1-GS13-D	-0.7	0.6	-0.3
ST1-T240-P	154.1	153.3	153.8

Table 2 - Geophones Pressure sensors

Note/comment about this test: All the pressure sensors are good but we can see one value that doesn't meet the requirements (ST1 L4C D, which is L4C V1) but as it has been said earlier, after trouble shooting the problem, we now know it is not coming from the sensor itself but from the

connection to the feed through. This issue will be solved after the install and doesn't prevent us from testing this Unit.

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

2. Spectra

Spectra of the instrument can be found in the SVN at:
seismic/BSC-ISI/L1/ITMX/Data/Spectra/Undamped/
L1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2020_02_01_3 1:1:.mat

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/ITMY/Data/Figures/Spectra/Undamped/
L1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2020_02_01_3 1:1:.fig

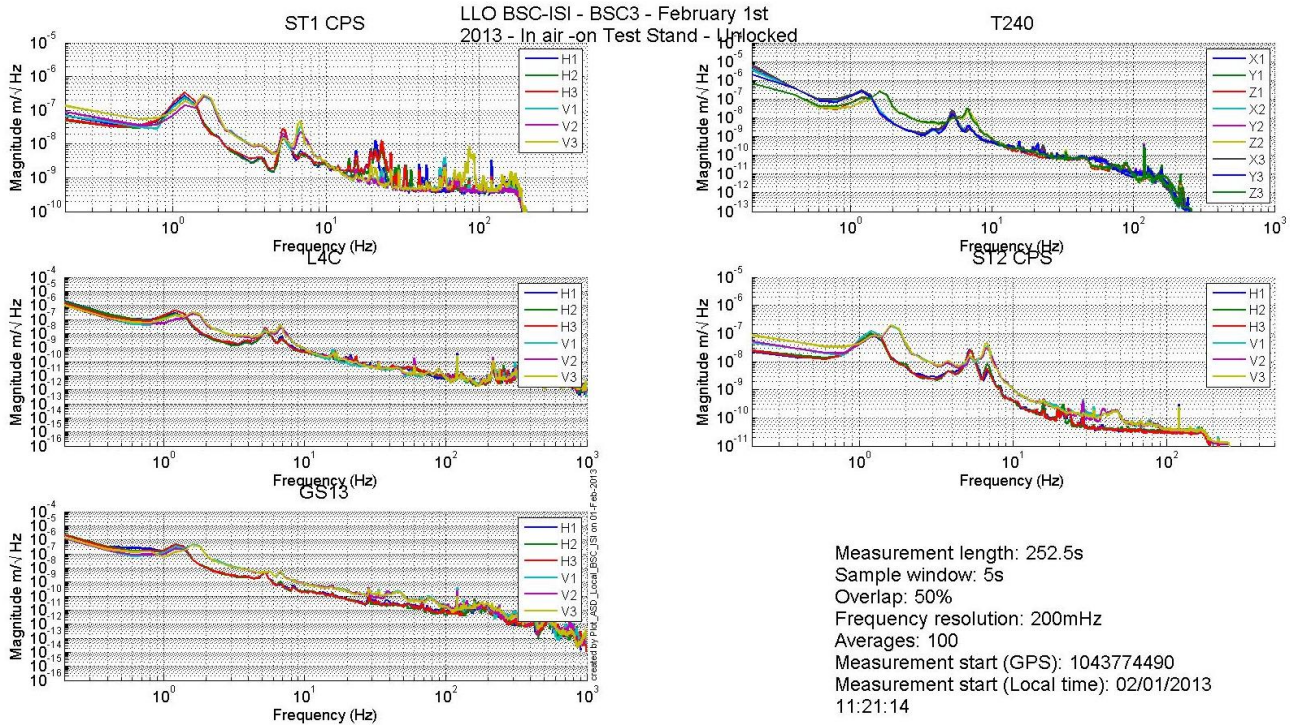


Figure 1 - Spectra inboard instruments - ISI Unlocked

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

3. Actuators-cables resistance

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

- L1_ISI_ITMX_Actuators_Resistance_20130201T115630.mat

	Stage 1						Stage 2					
	H1	**H2**	**H3**	**V1**	**V2**	**V3**	**H1**	**H2**	**H3**	**V1**	**V2**	**V3**
Script	7.9788	7.9443	7.7395	7.7443	7.8884	7.8606	11.672	11.561	11.877	11.481	12	11.941

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. A fine balancing will be done during phase II-b.
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/ITMX/Data/Static_Tests/

- L1_ISI_ITMX_CPS_Read_Back_ISI_Locked_2013_02_01_120424.mat
- L1_ISI_ITMX_CPS_Read_Back_ISI_Unlocked_2013_01_31_120424.mat

	Table locked		Table unlocked		Difference locked - unlocked	
Sensors	Offset (Mean)	Std deviation	Offset (Mean)	Std deviation	Offset (Mean)	mil
ST1 - H1	3.66	3.89	146.74	26.35	-143.08	-0.17
ST1 - H2	300.20	5.12	-1151.25	37.70	1451.45	1.73
ST1 - H3	649.07	3.61	-1670.27	61.84	2319.34	2.76
ST1 - V1	-133.38	5.10	43.61	46.30	-176.99	-0.21
ST1 - V2	-75.85	7.75	-298.18	39.55	222.33	0.26
ST1 - V3	-151.65	5.09	65.77	39.17	-217.42	-0.26
ST2 - H1	526.33	12.79	1785.12	65.38	-1258.79	-0.38
ST2 - H2	-680.52	7.65	-700.63	42.51	20.11	0.01
ST2 - H3	978.38	9.69	-58.97	89.19	1037.35	0.31
ST2 - V1	1244.30	8.56	2663.75	105.37	-1419.45	-0.42
ST2 - V2	-356.76	8.82	1190.84	95.83	-1547.60	-0.46
ST2 - V3	1574.90	8.00	2061.60	100.89	-486.70	-0.15

Table 3 - Locked vs Unlocked Position

Note: The two highlighted values don't meet the requirement by a few hundred counts. We're not too worried about it, since the final masses (vibration absorbers, all the Optical Table Masses and the Ballast masses) are not on yet and the CPS will have to be re-adjusted after the cartridge Install, so this will be an easy fix and doesn't prevent us from testing this Unit.

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/ITMX/Data/Static_Tests/

- L1_ISI_ITMX_Offset_Local_Drive_20130131.mat

Actuators \ Sensors	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - H1	3418.12	1385.70	1372.85	21.18	-2.03	1.68
ST1 - H2	1381.29	3450.95	1381.11	6.85	12.59	4.49
ST1 - H3	1366.62	1379.50	3407.40	-6.16	11.54	38.85
ST1 - V1	60.78	-108.18	81.39	2717.36	-447.05	-433.51
ST1 - V2	67.97	23.86	-113.63	-414.86	2653.26	-442.18
ST1 - V3	-122.85	80.11	54.03	-434.84	-417.44	2875.05

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

Actuators \ Sensors	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - H1	2069.686	333.1783	322.7549	-13.5116	-1.85548	22.3928
ST2 - H2	307.8634	2027.177	314.0907	-6.1246	-4.9305	-14.043
ST2 - H3	298.0452	318.4077	1995.944	-16.0376	-2.83834	33.9722
ST2 - V1	58.575	108.586	-160.55	2348.07	293.3302	29.8138
ST2 - V2	-151.905	54.3535	101.2956	19.5372	2318.535	343.1502
ST2 - V3	100.4344	-145.447	64.46388	286.7038	52.38362	2330.52

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:
seismic/BSC-ISI/L1/ITMX/Data/Static_Tests/

- L1_ISI_ITMX_Range_Of_Motion_20130131.mat

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-14425.16	NaN	14882.31	29307.48	34.89
ST1 - H2	-15814.71	-1040.00	13758.24	29572.95	35.21
ST1 - H3	-14264.10	-1638.00	12983.27	27247.37	32.44
ST1 - V1	-11631.68	16.00	11681.96	23313.64	27.75
ST1 - V2	-11736.11	-330.00	11052.50	22788.61	27.13
ST1 - V3	-12329.28	-22.00	12271.50	24600.78	29.29
ST2 - H1	-7057.95	1802.00	10638.40	17696.35	5.27
ST2 - H2	-9282.06	-646.00	7984.24	17266.30	5.14
ST2 - H3	-8586.21	-87.00	8388.57	16974.78	5.05
ST2 - V1	-7555.45	2540.00	12592.38	20147.83	6.00
ST2 - V2	-9040.98	963.00	10938.88	19979.86	5.95
ST2 - V3	-8041.29	1867.00	11736.88	19778.17	5.89

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/ITMX/Data/Linearity_Test/

- L1_ISI_ITMX_Linearity_test_20130201.mat

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

- L1_ISI_ITMX_Linearity_test_20130201.fig

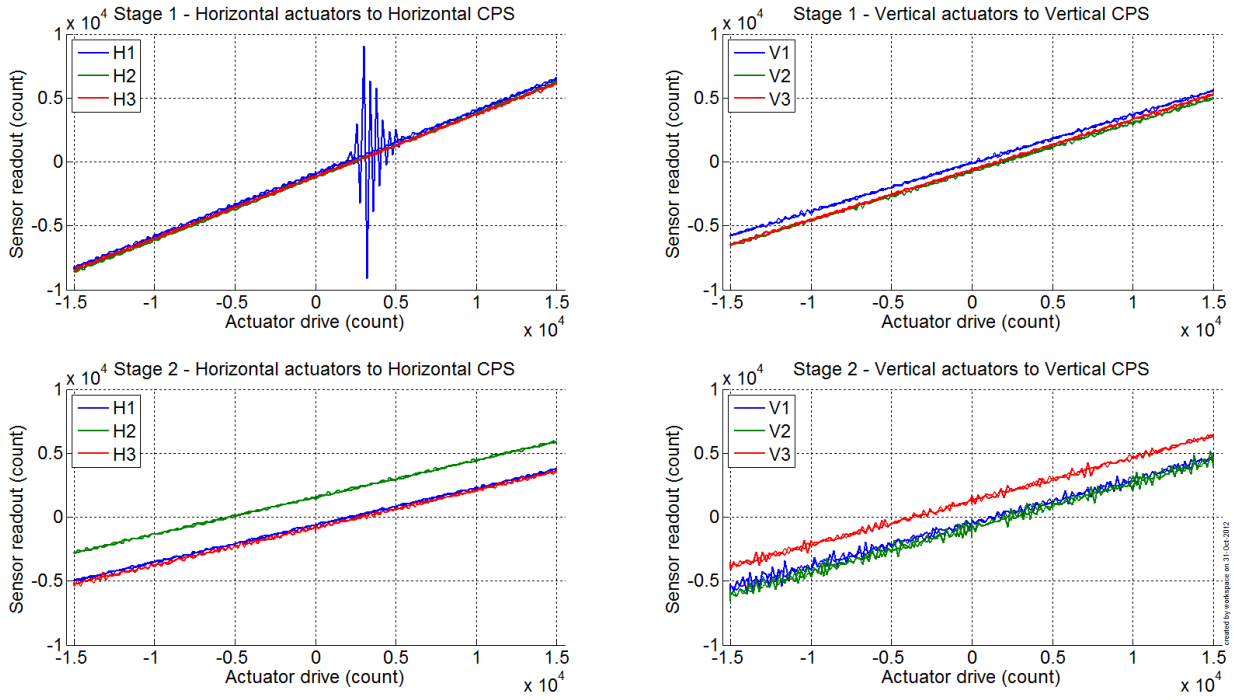


Figure 2 - Linearity test –L1 - BS – In LVEA

		Slope	Offset	Average slope	Variation from average(%)
Stage 1	ST1 - H1	0.4885	182.5163	0.4894	0.1907
	ST1 - H2	0.4935	-1113.6000		-0.8309
	ST1 - H3	0.4863	-1637.0000		0.6402
	ST1 - V1	0.3879	106.6968	0.3926	1.1971
	ST1 - V2	0.3795	-202.7173		3.3367
	ST1 - V3	0.4104	98.5823		-4.5339
Stage 2	ST2 - H1	0.2955	1779.0000	0.2899	-1.9317
	ST2 - H2	0.2891	-691.9026		0.2760
	ST2 - H3	0.2851	-59.7437		1.6557
	ST2 - V1	0.3372	2653.6000	0.3335	-1.0993
	ST2 - V2	0.3333	1185.9000		0.0700
	ST2 - V3	0.3301	2048.9000		1.0294

Table 7 - Slope – Offset Linearity test

Note all the results seem very coherent. On Stage 1 V2 and V3 actuators seem a little off compared to the average slope (we don't meet the requirement of 2.5%).

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

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

1. At the end station

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 for 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)

Measurements data can be found in the SVN at:
SeiSVN/seismic/BSC-ISI/L1/ITMX/Data/Transfer_Functions/Measurements/Undamped:

- LLO_ISI_BSC3_Data_L2L_10mHz_100mHz_ST1_ST2_20130204-105939.mat
- LLO_ISI_BSC3_Data_L2L_100mHz_700mHz_ST1_ST2_20130201-150630.mat
- LLO_ISI_BSC3_Data_L2L_700mHz_10Hz_ST1_ST2_20130203-003300.mat
- LLO_ISI_BSC3_Data_L2L_10Hz_100Hz_ST1_ST2_20130202-215607.mat
- LLO_ISI_BSC3_Data_L2L_100Hz_500Hz_ST1_ST2_20130202-203613.mat
- LLO_ISI_BSC3_Data_L2L_500Hz_1000Hz_ST1_ST2_20130202-193145.mat

Data after processing can be found in the SVN at:
SeiSVN/seismic/BSC-ISI/L1/ITMX/Data/Transfer_Functions/Simulations/Undamped

- LLO_ISI_BSC3_TF_L2L_Raw_10mHz_1000Hz_2013_02_04.mat

The transfer functions can be found in the SVN at:
seismic/BSC-ISI/L1/ITMX/Data/Figures/Transfer_Functions/Measurements/Undamped/

- LLO_ISI_BSC3_TF_L2L_Raw_from_ST1_ACT_to_ST1_CPS_2013_02_04.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST1_ACT_to_ST1_L4C_2013_02_04.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_CPS_2013_02_04.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_GS13_2013_02_04.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 21.1 Hz, 23.4Hz and 33.3Hz (matches within a few Hz our BSC 3 results).

Note 4: During the measurements, the Compensation filter for Stage 1 H1 Actuator was not turned on, that explains why its Magnitude is not as high as the others.

Note5: We had to retake both 10mHz to 100mHz and 100mHz to700mHz TF

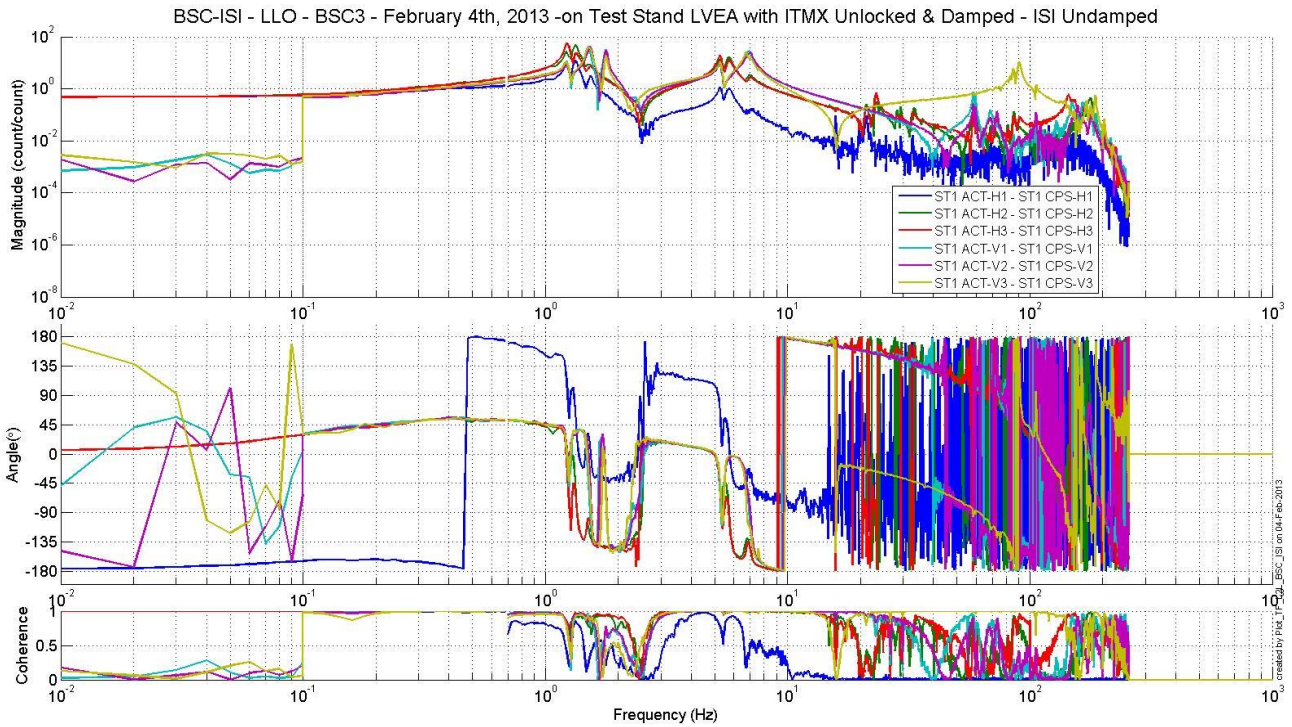


Figure 3 - TF ST1 ACT to ST1 CPS

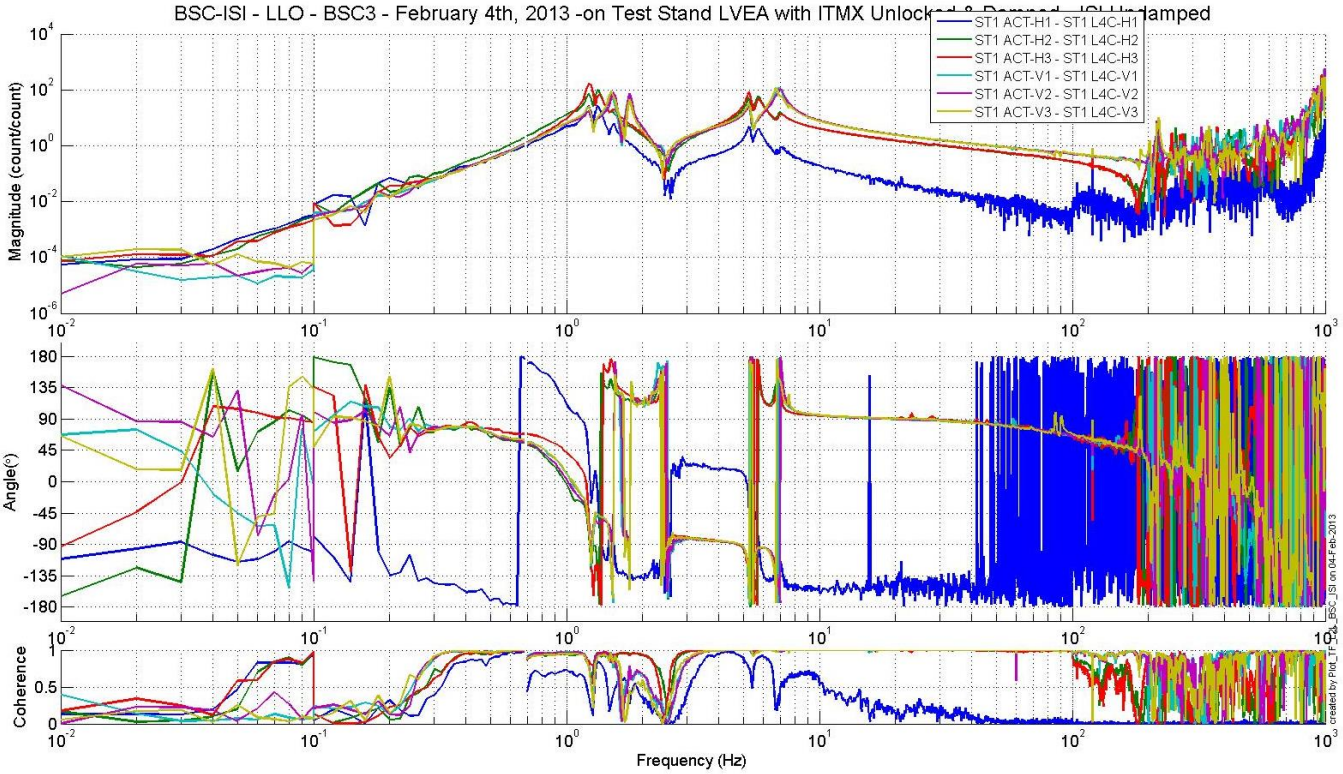


Figure 4 - TF ST1 ACT to ST1 L4C

Figure 5 - TF ST1 ACT to ST1 T240

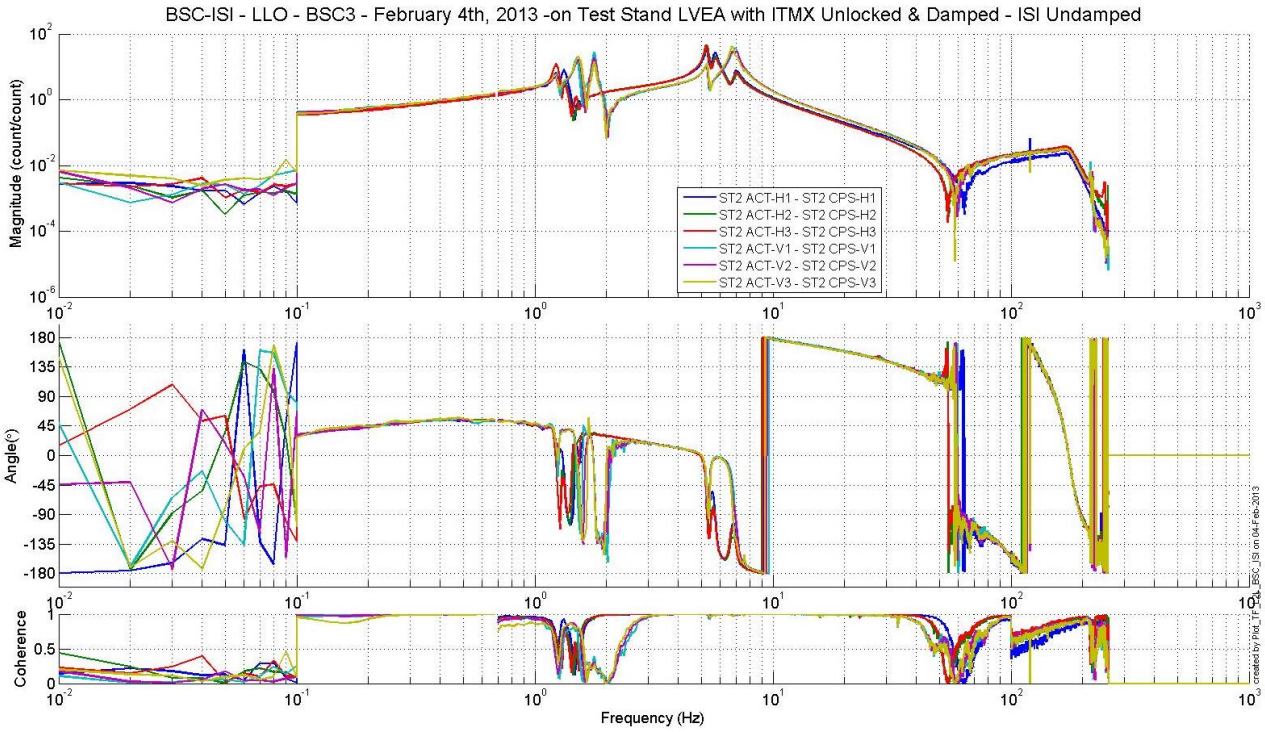


Figure 6 - TF ST2 ACT to ST2 CPS

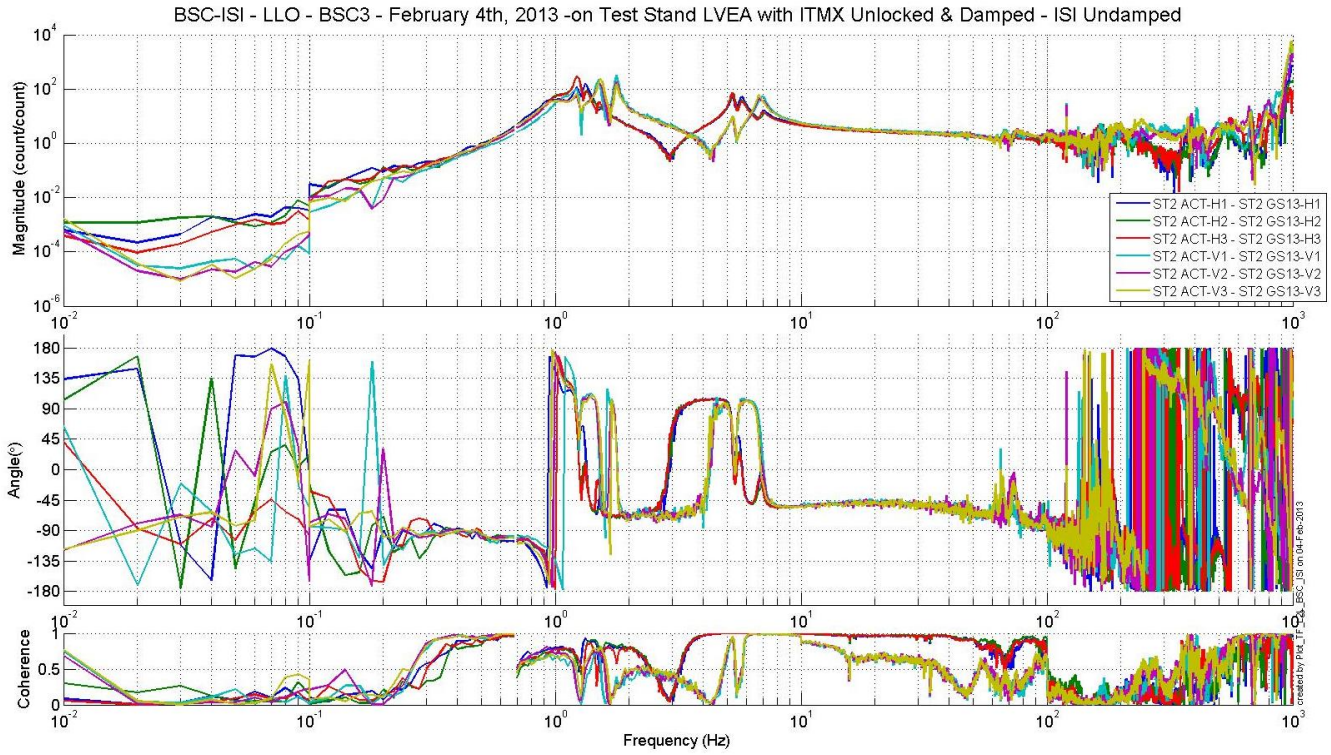


Figure 7 - TF ST2 ACT to ST2 GS13

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/L1/ITMX/Scripts/Control_Scripts

- Comparison_TF_C2C_LHO_ISI_BSC3.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/ITMY/Data/Figures/Transfer_Functions/Comparisons/L2L

- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST1_ACT_H_to_ST1_CPS_H_20130204_vs_20121216.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST1_ACT_V_to_ST1_CPS_V_20130204_vs_20121216.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST1_ACT_H_to_ST1_L4C_H_20130204_vs_20121216.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST1_ACT_V_to_ST1_L4C_V_20130204_vs_20121216.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST2_ACT_H_to_ST2_CPS_H_20130204_vs_20121216.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST2_ACT_V_to_ST2_CPS_V_20130204_vs_20121216.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST2_ACT_H_to_ST2_GS13_H_20130204_vs_20121216.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST2_ACT_V_to_ST2_GS13_V_20130204_vs_20121216.fig

Main differences are:

- The DC gains (cables resistance is different due to the length difference)

- Resonances of the rigid body modes [1; 10]Hz (different payload) It is especially visible from 1 to 2 Hz on all sensors.
- ST1-CPS resonances different in the staging building and EY (Test stand short legs vs long legs).
- Resonance at 20.5 Hz on stage 2 sensors (4^{th} vertical mode of the quad? –cf https://lhocds.ligo-wa.caltech.edu/wiki/Resonances)
- Similar at high frequencies

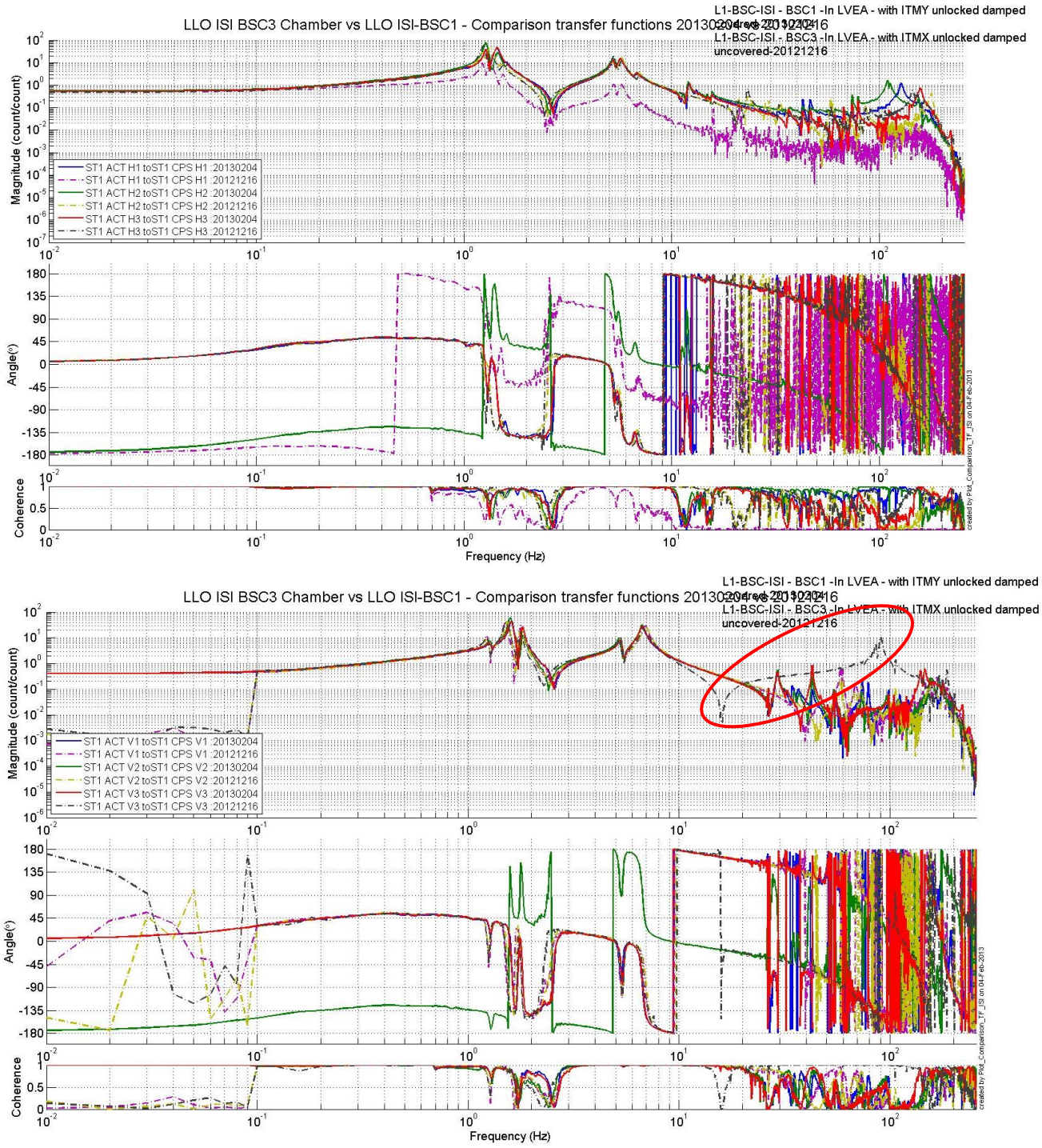


Figure 8 - Transfer functions comparison - ST1 ACT to ST1 CPS

Note: we can notice that Stage 1 ACT V3 to Stage CPS V3 resonances were at different frequencies on BSC 1 compared to BSC 3.

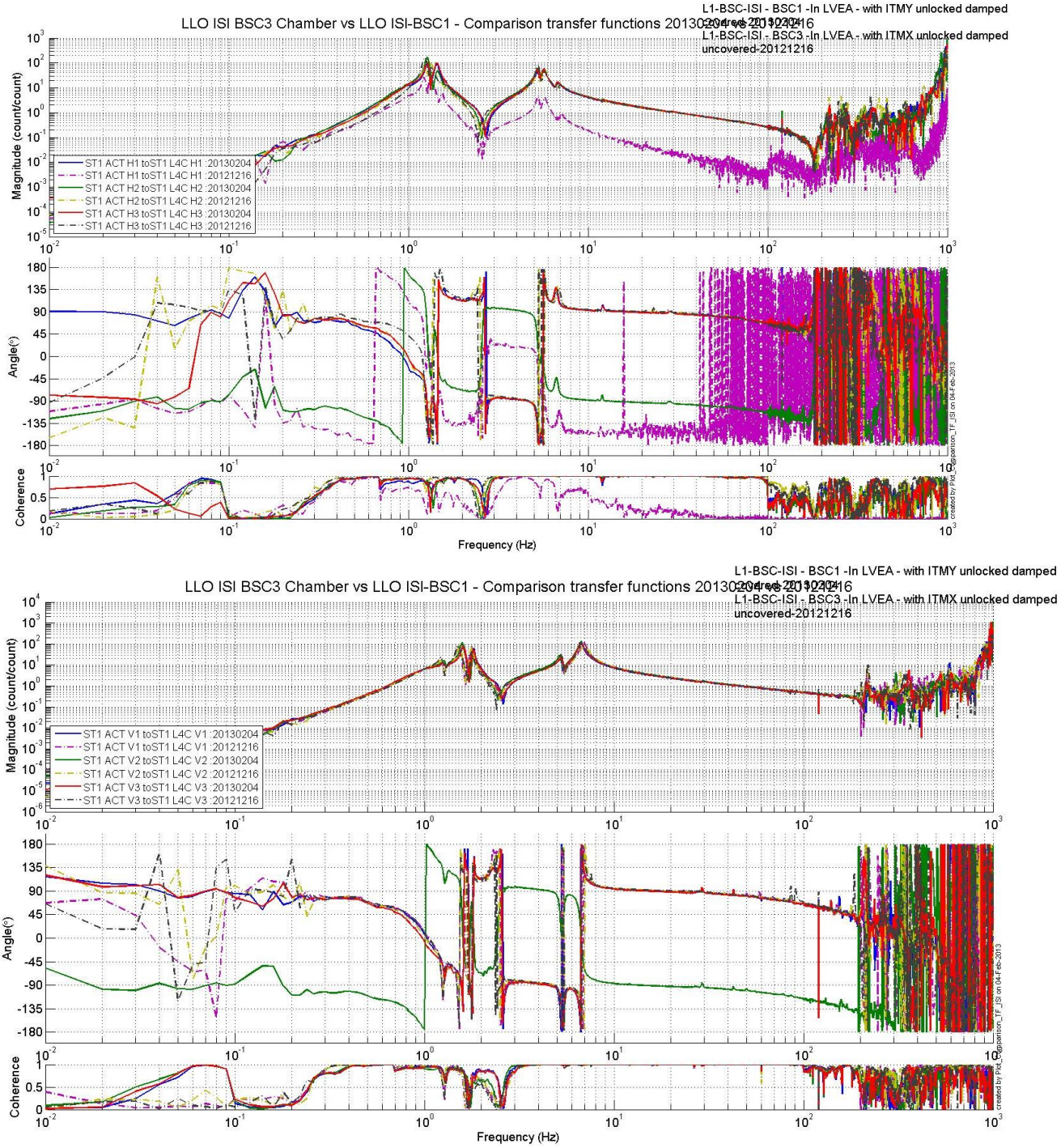


Figure 9 - Transfer functions comparison - ST1 ACT to ST1 L4C

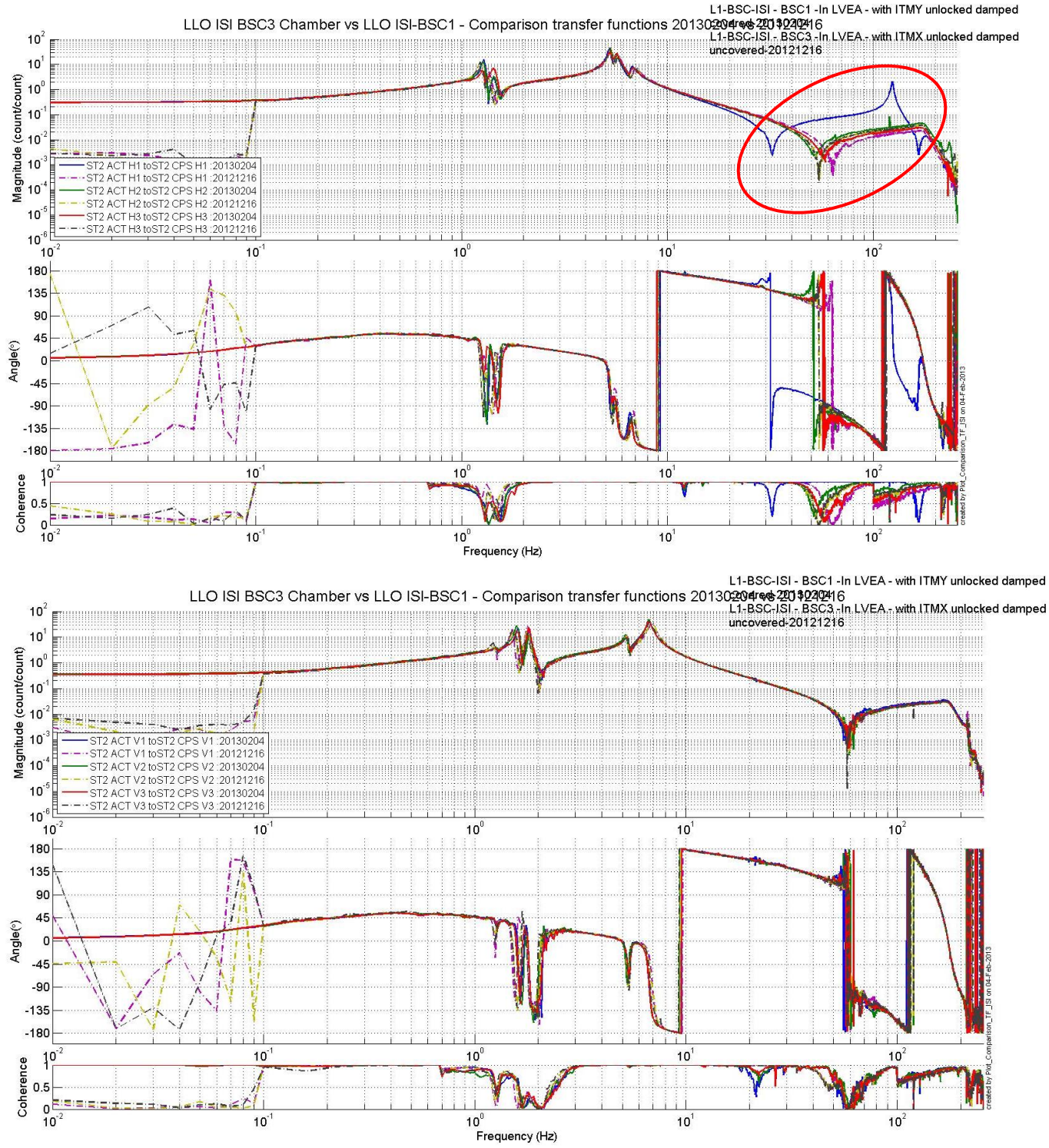


Figure 10 - Transfer functions comparison - ST2 ACT to ST2 CPS

Note: we can notice that Stage 1 ACT H1 to Stage CPS H1 resonances are at different frequencies on BSC 3 compared to BSC 1.

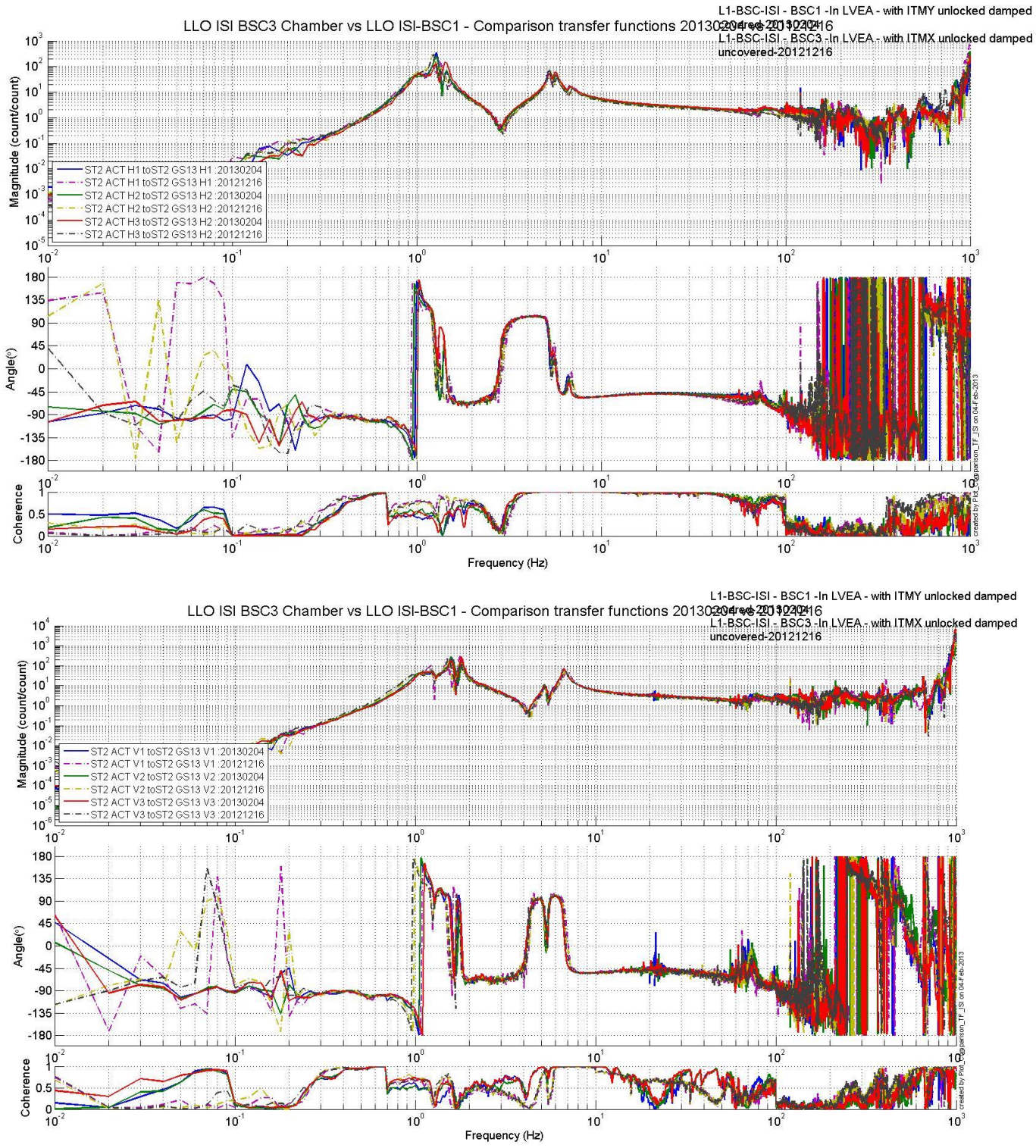


Figure 11 - Transfer functions comparison – ST2 ACT to ST2 GS13

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

7. Conclusion Phase II-a

All results appear satisfying; apart from a few tests waived (will be done during phase II-b):

- Pressure Sensor Test failed. This issue has been found, and we know it is not coming from the L4C V1 pressure sensor itself but from a bad connection at the feedthru or a bad extension cable, so we will solve this issue after the cartridge install.
- Offset CPS Unlocked vs Locked: the difference between the averages Locked-Unlocked on Stage 1 H3 is a little bit too big to meet the requirements but nothing alarming and the final weights are not on so the ISI will have to be rebalanced and the CPS re-centered anyway.
- Static tests in the Cartesian basis (redundant with the static test in the local basis)
- Linearity test: Stage 1 V2 and V3 actuators seem a little off compared to their average slope but nothing preventing us from Install.
- During the Transfer Functions, the Compensation filter for Stage 1 H1 Actuator was not turned on, but we will do another set of Transfer Functions after the Cartridge Install.

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

2. Phase II-a

1. Hardware changes

1. CPS – E1100369

No change.

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

T240s have not been replaced since phase I testing in the staging building.

5. Cables – E1100822

Cables have not been changed since the testing in the LVEA. The issue we were having during the testing on the Test stand in the LVEA, on the Vertical L4C pressure sensor in corner 1 has disappeared which confirms our hypothesis that it was coming from the connection at the fake feed through. We will keep an eye on it though.

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	S1201323
Interface Chassis Pod 2	D1002432	S1201322
Interface Chassis Pod 3	D1002432	S1201327
Anti-aliasing Chassis Pod 1	D1002693	S1203102
Anti-aliasing Chassis Pod 2	D1002693	S1203101
Anti-aliasing Chassis Pod 3	D1002693	S1203100
Binary Input Chassis 1	D1001726	S1101299
Binary Input Chassis 2	D1001726	S1101298
Binary Output Chassis	D1001728	S1101328
T240 Interface Pod 1	D1002694	S1201892
T240 Interface Pod 2	D1002694	S1104429
T240 Interface Pod 3	D1002694	S1104428
Anti-image Chassis	***D1000305***	***S1203269***
Coil driver Pod 1	D0902744	S1103564
Coil driver Pod 2	D0902744	S1103315
Coil driver Pod 3	D092744	S1103329
Expansion chassis	L1seibsc3	S1100946

Table 8 - 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.

7. Seismic

Stage 1

Stage 1	HighBay (lbs)	LVEA (lbs)	LVEA (kgs)	In Chamber (lbs)	In Chamber (kgs)
Corner 1	31.50	31.50	14.29	27.86	12.6
Corner 2	15	15	6.80	10	4.5
Corner 3	40.50	42.50	19.28	43.72	19.8
Total	87.0	89.0	40.37	81.58	37.0

Stage 2

The seismic masses on BSC 3 are;

- On the Keel Plate 650 lbs (=294.8kgs)
- On the Optical Table 714.3 lbs (=324kgs)
- On the Side 335.7 lbs (152.3 kgs)

The total of masses on Stage 2 is 1700.0 lbs (=771.1 kgs).

Note: We had to add 2 D071200 Type 01 and 1 D071200 Type 00 on Corner 1 to re-balance the ISI because after the Install, SUS removed a light part of the Quad, so we had to make up for it.

8. Suspension

The quad structure was weighed to be:

	Weight (lbs)	Weight (kgs)
Upper structure	266	120.66
Lower structure	531	240.86
Total	797	361.5128

9. Misc

- 44 lbs = quad sleeve [Betsy's alog 3621]
- 2 lbs = quad sleeve wedges [estimate]
- 5 lbs = cabling [estimate]
- 2 lbs cable brackets [estimate]
- 28 lbs = Vibration absorbers, quantity 4 [from E1000337-v2: 12.7 kg = 28 lbs]
- 3 lbs = Ring heater + brackets + cables [estimate]

Total Weight for Suspension: 906 lbs = 412 kg

10. 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

			Staging Bldg	LVEA		In chamber		
		Plan	10/1/2012	Detail	Overall	Detail	Overall	Difference
Stage 1 (kgs)		108.86	39.46	40.37	40.37	37	37	-2.5
Stage 2 (kgs)	Masses	1183.42	1161.33	751.9	1164.29	771.1	1183.49	22.2
	Suspension	N/A	N/A	361.51		361.51		
	Miscellaneous	N/A	N/A	50.88		50.88		
Total (kgs)		1292.28	1200.79	1204.66	1204.66	1220.49	1220.49	19.7

Even if Stage 2 doesn't meet the requirements in weight (10 kgs) we are very similar to what we had in the Staging Building overall, our results are very consistent (within 20kgs since the Staging building).

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

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

11. Pressure sensors

All pressure sensors are working.
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/ITMX/Data/Static_Tests/
L1_ISI_ITMX_Pressure_Sensors_Check_Calibrated_2020_03_11_3 3:0:.mat

	Pressure (KPa)		
Sensors	**Corner 1**	**Corner 2**	**Corner 3**
ST1-L4C-P	99.5	100.2	99.5
ST1-L4C-D	0.5	-1.2	-0.2
ST1-GS13-P	100.2	100.2	100.1
ST1-GS13-D	-0.7	0.5	-0.3
ST1-T240-P	154.1	153.3	153.8

Table 9 - Geophones Pressure sensors

Note/comment about this test: The issue we were having during the testing on the Test stand in the LVEA, on the Vertical L4C pressure sensor in corner 1 has disappeared which confirms our hypothesis that it was coming from the connection at the fake feed through. We will keep an eye on it though.

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

12. Spectra

Spectra of the instrument can be found in the SVN at:
seismic/BSC-ISI/L1/ITMX/Data/Spectra/Undamped/
L1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2020_02_14_3 3:9:.mat

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/ITMY/Data/Figures/Spectra/Undamped/
L1_ISI_ITMX_ASD_m_LOC_CPS_T240_L4C_GS13_2020_02_14_3 3:9:.fig

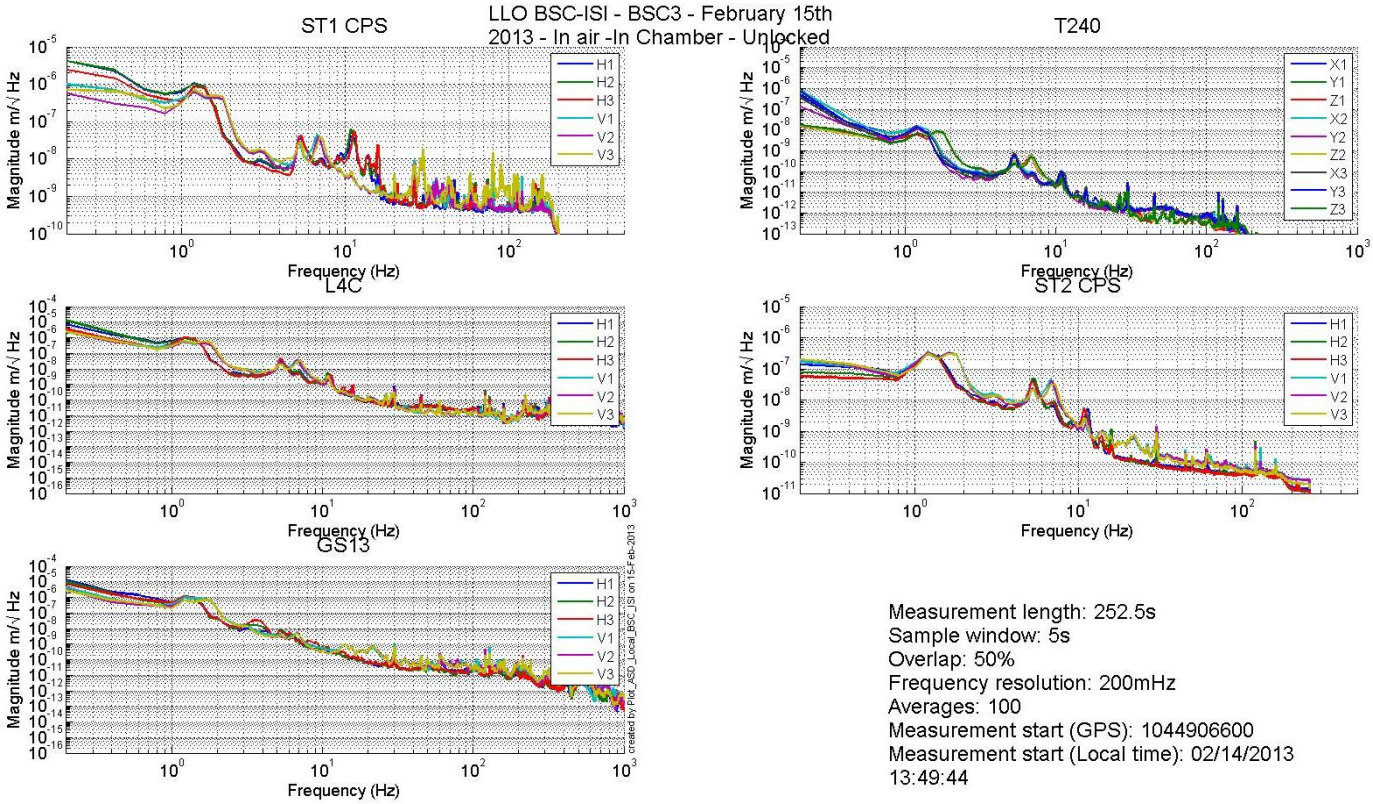


Figure 12 - Spectra inboard instruments - ISI Unlocked

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

13. Actuators-cables resistance

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

- L1_ISI_ITMX_Actuators_Resistance_20130214T151112.mat

	Stage 1						Stage 2					
	H1	**H2**	**H3**	**V1**	**V2**	**V3**	**H1**	**H2**	**H3**	**V1**	**V2**	**V3**
Script	7.9788	7.9443	7.7395	7.7443	7.8884	7.8606	11.6722	11.5613	11.8766	11.4809	12	11.9405

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

14. 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. A fine balancing will be done during phase II-b.
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/L1/ITMX/Data/Static_Tests/

- L1_ISI_ITMX_CPS_Read_Back_ISI_UnLocked_2020_03_08_3 1:0:.mat
- L1_ISI_ITMX_CPS_Read_Back_ISI_UnLocked_2020_03_08_3 0:4:.mat

	Table locked		Table unlocked		Difference locked - unlocked	
Sensors	Offset (Mean)	Std deviation	Offset (Mean)	Std deviation	Offset (Mean)	mil
ST1 - H1	140.88	20.99	326.45	29.79	185.57	0.22
ST1 - H2	50.88	14.90	486.32	36.96	435.44	0.52
ST1 - H3	-278.31	21.85	56.87	34.71	335.18	0.40
ST1 - V1	52.36	140.80	-680.13	54.88	-732.48	-0.87
ST1 - V2	134.45	47.42	811.29	47.08	676.84	0.81
ST1 - V3	-21.40	75.70	1093.31	48.72	1114.71	1.33
ST2 - H1	-493.17	18.99	2101.34	51.40	2594.51	0.77
ST2 - H2	-194.96	54.73	2339.62	62.17	2534.58	0.75
ST2 - H3	60.12	102.21	-357.82	50.16	-417.95	-0.12
ST2 - V1	227.21	48.02	2485.00	155.09	2257.79	0.67
ST2 - V2	9.09	228.98	-280.23	143.65	-289.32	-0.09
ST2 - V3	631.75	350.19	1472.40	145.34	840.66	0.25

Table 10 - Locked vs Unlocked Position

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

15. 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/ITMX/Data/Static_Tests/

- L1_ISI_ITMX_Offset_Local_Drive_20130214.mat

Actuators \ Sensors	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - H1	3754.76	1509.15	1503.04	-4.53	1.66	-0.25
ST1 - H2	1518.88	3820.09	1510.33	-0.46	-3.75	5.47
ST1 - H3	1506.59	1514.34	3759.80	-10.28	-0.42	29.26
ST1 - V1	51.97	-124.37	77.66	2912.47	-494.18	-470.74
ST1 - V2	86.60	23.43	-142.77	-466.15	2937.36	-488.69
ST1 - V3	-125.67	78.28	49.22	-485.40	-475.54	3169.11

Table 11 - Static Tests – Local to Local - Stage 1

Actuators \ Sensors	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - H1	2183.13	339.84	319.90	-22.40	20.98	-5.96
ST2 - H2	320.63	2160.34	346.04	23.05	-25.05	-118.62
ST2 - H3	319.41	341.88	2108.08	-24.62	27.88	31.68
ST2 - V1	73.89	114.21	-179.55	2452.69	330.60	36.92
ST2 - V2	-171.65	50.12	116.75	51.13	2460.69	201.05
ST2 - V3	114.48	-193.83	108.23	380.07	-7.44	2232.55

Table 12 - Static Tests – Local to Local - Stage 2

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

16. 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_**

17. 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:
seismic/BSC-ISI/L1/ITMX/Data/Static_Tests/

- L1_ISI_ITMX_Range_Of_Motion_20130214.mat

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-15677.43	354.00	16027.83	31705.26	37.74
ST1 - H2	-15607.16	731.00	16334.96	31942.12	38.03
ST1 - H3	-15649.00	427.00	15950.87	31599.87	37.62
ST1 - V1	-13891.84	-1399.00	11089.97	24981.82	29.74
ST1 - V2	-11988.38	624.00	13210.79	25199.18	30.00
ST1 - V3	-12912.43	679.00	14205.68	27118.11	32.28
ST2 - H1	-7245.15	2097.00	11419.01	18664.16	5.55
ST2 - H2	-6685.11	2597.00	11831.86	18516.97	5.51
ST2 - H3	-9165.07	-194.00	8836.26	18001.33	5.36
ST2 - V1	-9240.17	1261.00	11808.06	21048.23	6.26
ST2 - V2	-12981.14	-2308.00	8315.57	21296.71	6.34
ST2 - V3	-11624.82	-1024.00	9151.12	20775.94	6.18

Table 13 - Range of motion - Actuator drive in the LVEA

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

18. Linearity test

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

- L1_ISI_ITMX_Linearity_test_20130215.mat

The figures of the linearity test can be found on the SVN at:
seismic\BSC-ISI\L1\ITMX\Data\Figures\Linearity_Test\

- L1_ISI_ITMX_Linearity_test_20130215.fig

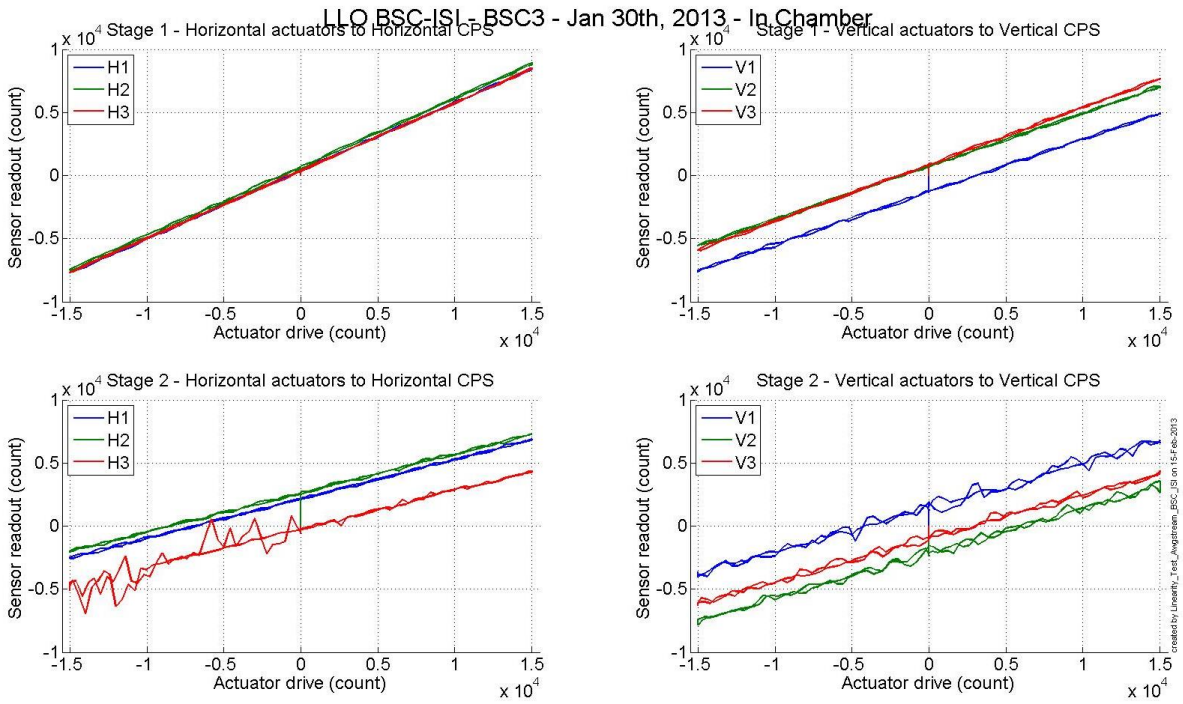


Figure 13 - Linearity test –L1 - BS – In LVEA

		Slope	Offset	Average slope	Variation from average(%)
Stage 1	ST1 - H1	0.5396	385.6500	0.5405	-0.1616
	ST1 - H2	0.5442	679.7500		0.6895
	ST1 - H3	0.5376	383.7700		-0.5279
	ST1 - V1	0.4166	-1277.3000	0.4293	-2.9684
	ST1 - V2	0.4196	736.8200		-2.2487
	ST1 - V3	0.4517	883.9200		5.2171
Stage 2	ST2 - H1	0.3122	2147.8000	0.3116	0.1786
	ST2 - H2	0.3093	2611.3000		-0.7423
	ST2 - H3	0.3134	-256.5200		0.5637
	ST2 - V1	0.3520	1469.3000	0.3508	0.3678
	ST2 - V2	0.3563	-2144.8000		1.5709
	ST2 - V3	0.3440	-954.9900		-1.9387

Table 14 - Slope – Offset Linearity test

Note all the results seem very coherent. On Stage 1 V1, V2 and V3 actuators seem a little off compared to the average slope (we don't meet the requirement of 2.5%). We had similar results on the test stand outside the chamber.
On Stage 2 CPS we can see that the data are noisy, it's probably due to people working in the LVEA. If we have more time we'll try to retake this test when the LVEA is quieter.

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

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

19. At the end station

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 for 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)

Measurements data can be found in the SVN at:
SeiSVN/seismic/BSC-ISI/L1/ITMX/Data/Transfer_Functions/Measurements/Undamped:

- LLO_ISI_BSC3_Data_L2L_10mHz_100mHz_ST1_ST2_20130307-024232.mat
- LLO_ISI_BSC3_Data_L2L_100mHz_700mHz_ST1_ST2_20130307-003939.mat
- LLO_ISI_BSC3_Data_L2L_700mHz_10Hz_ST1_ST2_20130306-142057.mat
- LLO_ISI_BSC3_Data_L2L_10Hz_100Hz_ST1_ST2_20130305-183045.mat
- LLO_ISI_BSC3_Data_L2L_100Hz_500Hz_ST1_ST2_20130305-171054.mat
- LLO_ISI_BSC3_Data_L2L_500Hz_1000Hz_ST1_ST2_20130305-160627.mat

Data after processing can be found in the SVN at:
SeiSVN/seismic/BSC-ISI/L1/ITMX/Data/Transfer_Functions/Simulations/Undamped

- LLO_ISI_BSC3_TF_L2L_Raw_10mHz_1000Hz_2013_03_07.mat

The transfer functions can be found in the SVN at:
seismic/BSC-ISI/L1/ITMX/Data/Figures/Transfer_Functions/Measurements/Undamped/

- LLO_ISI_BSC3_TF_L2L_Raw_from_ST1_ACT_to_ST1_CPS_2013_03_07.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST1_ACT_to_ST1_L4C_2013_03_07.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_CPS_2013_03_07.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_GS13_2013_03_07.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 21.1 Hz, 23.4Hz and 33.3Hz (matches within a few Hz our BSC 3 results).

Note 4: During the measurements, the Compensation filter for Stage 1 H1 Actuator was not turned on, that explains why its Magnitude is not as high as the others.

Note5: We had to retake both 10mHz to 100mHz and 100mHz to700mHz TF

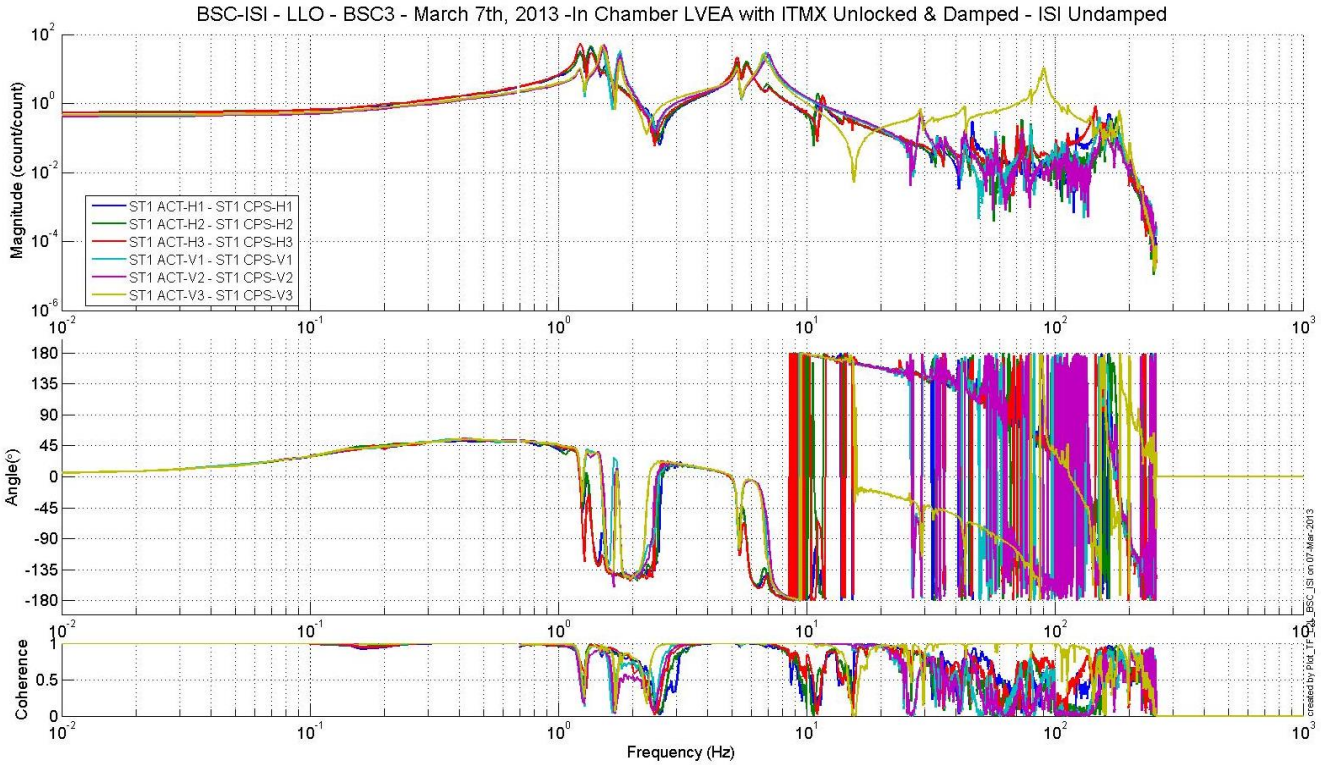


Figure 14 - TF ST1 ACT to ST1 CPS

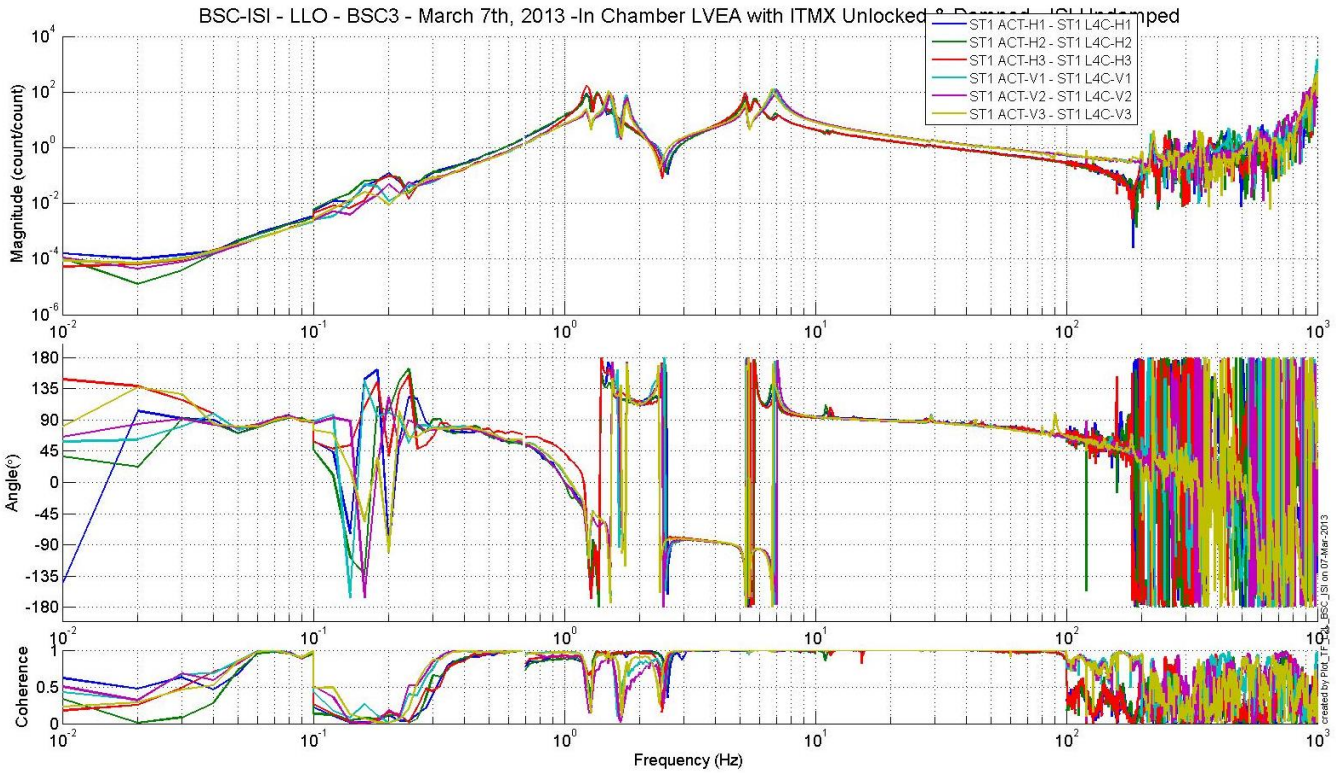


Figure 15 - TF ST1 ACT to ST1 L4C

Figure 16 - TF ST1 ACT to ST1 T240

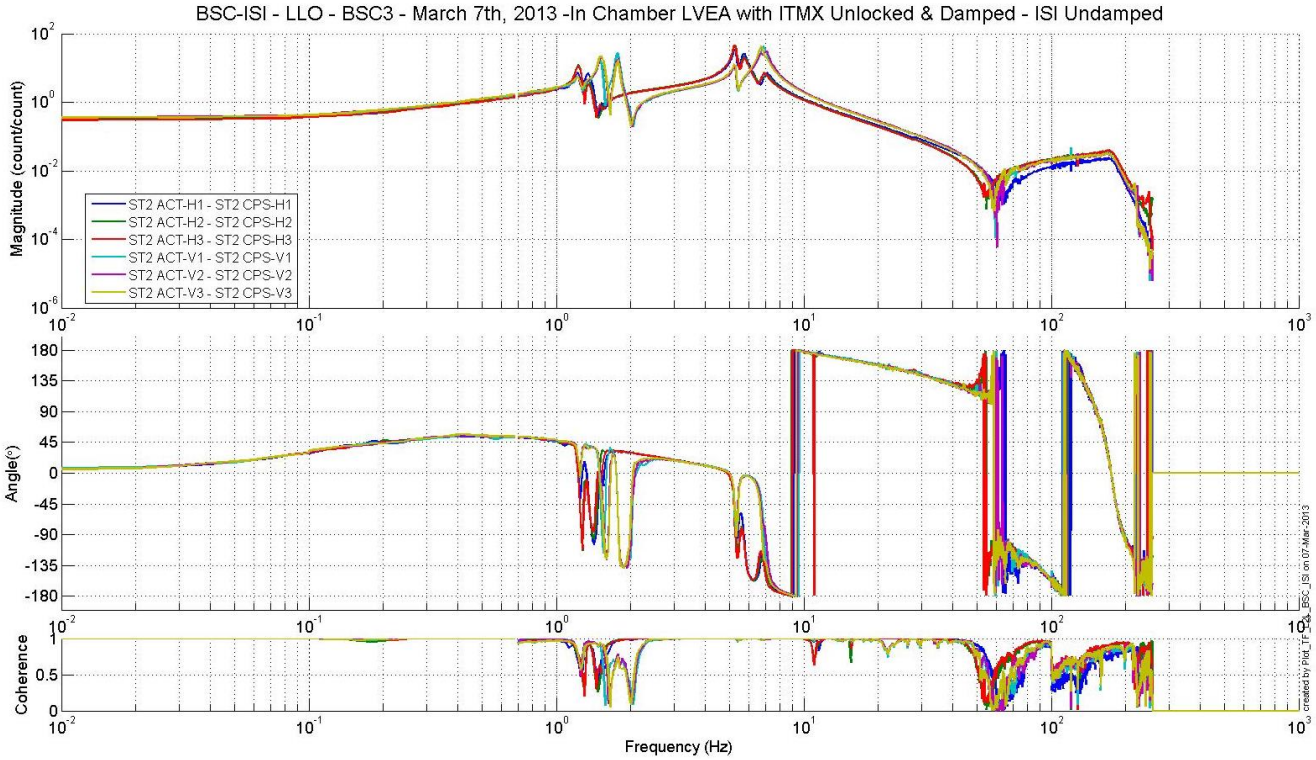


Figure 17 - TF ST2 ACT to ST2 CPS

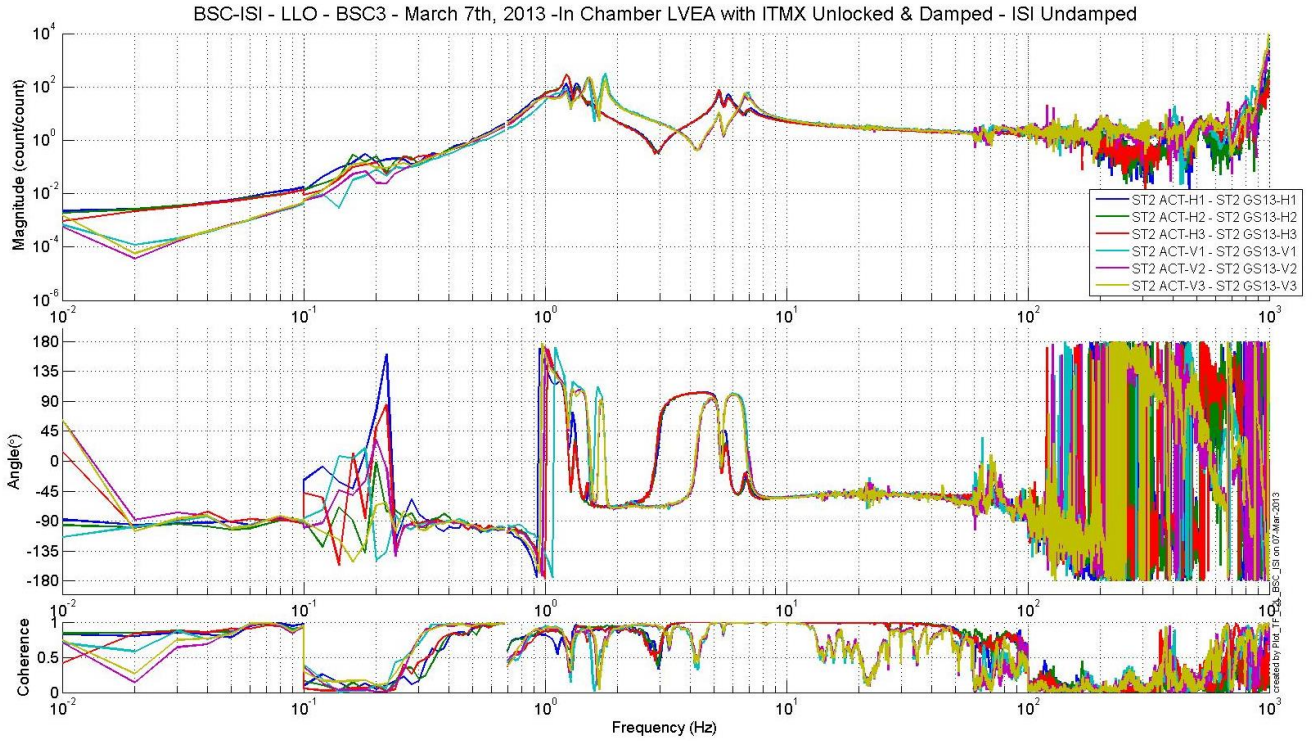


Figure 18 - TF ST2 ACT to ST2 GS13

20. 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/L1/ITMX/Scripts/Control_Scripts

- Comparison_TF_C2C_LHO_ISI_BSC3.m

The figure that shows the comparison between the transfer functions of BSC 1 ITMY and BSC 3 ITMX are located in the SVN at:
SeiSVN/seismic/BSC-ISI/L1/ITMY/Data/Figures/Transfer_Functions/Comparisons/L2L

- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST1_ACT_H_to_ST1_CPS_H_20121011_vs_20130307.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST1_ACT_V_to_ST1_CPS_V_20121011_vs_20130307.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST1_ACT_H_to_ST1_L4C_H_20121011_vs_20130307.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST1_ACT_V_to_ST1_L4C_V_20121011_vs_20130307.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST2_ACT_H_to_ST2_CPS_H_20121011_vs_20130307.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST2_ACT_V_to_ST2_CPS_V_20121011_vs_20130307.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST2_ACT_H_to_ST2_GS13_H_20121011_vs_20130307.fig
- LLO_ISI_BSC3_Chamber_vs_LLO_ISI_BSC1_Comparison_TF_L2L_ST2_ACT_V_to_ST2_GS13_V_20121011_vs_20130307.fig

Main differences are:

- The DC gains (cables resistance is different due to the length difference)

- Resonances of the rigid body modes [1; 10]Hz (different payload) It is especially visible from 1 to 2 Hz on all sensors.
- Resonance at 20.5 Hz on stage 2 sensors (4^{th} vertical mode of the quad? –cf https://lhocds.ligo-wa.caltech.edu/wiki/Resonances)
- Similar at high frequencies

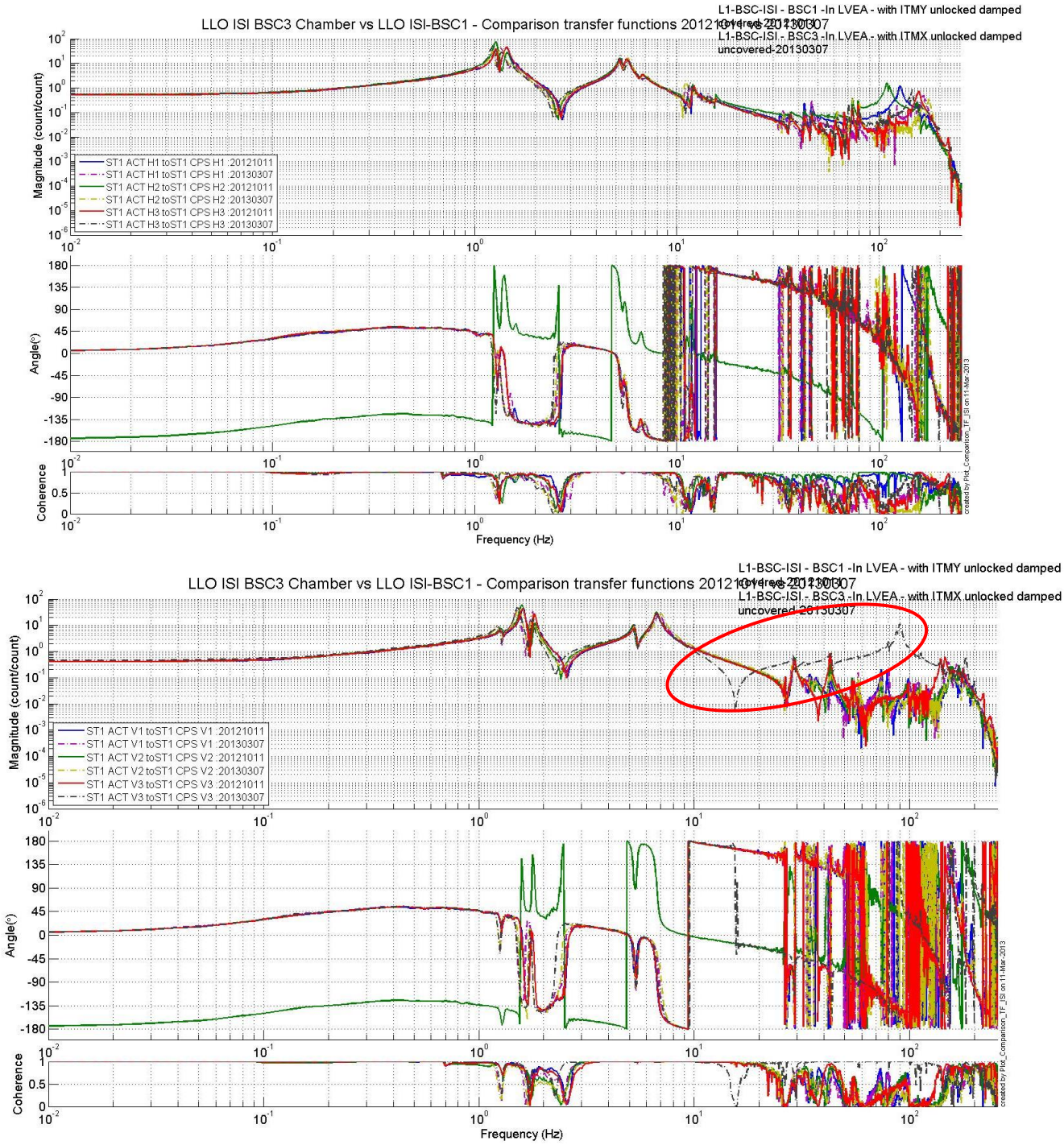
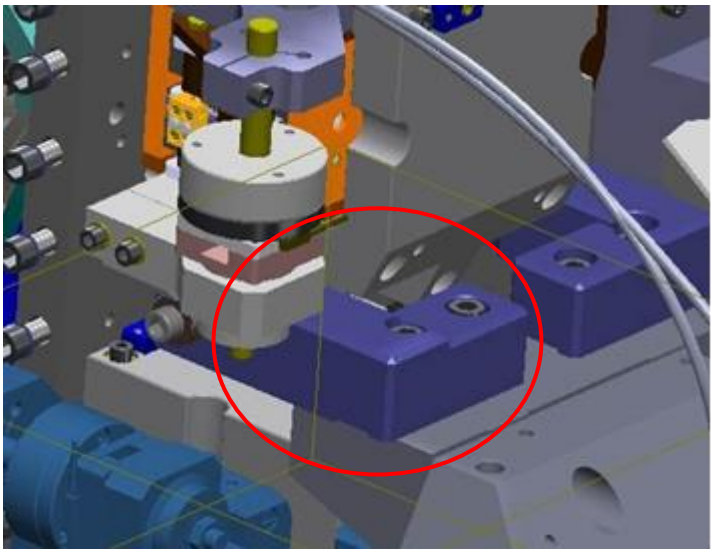
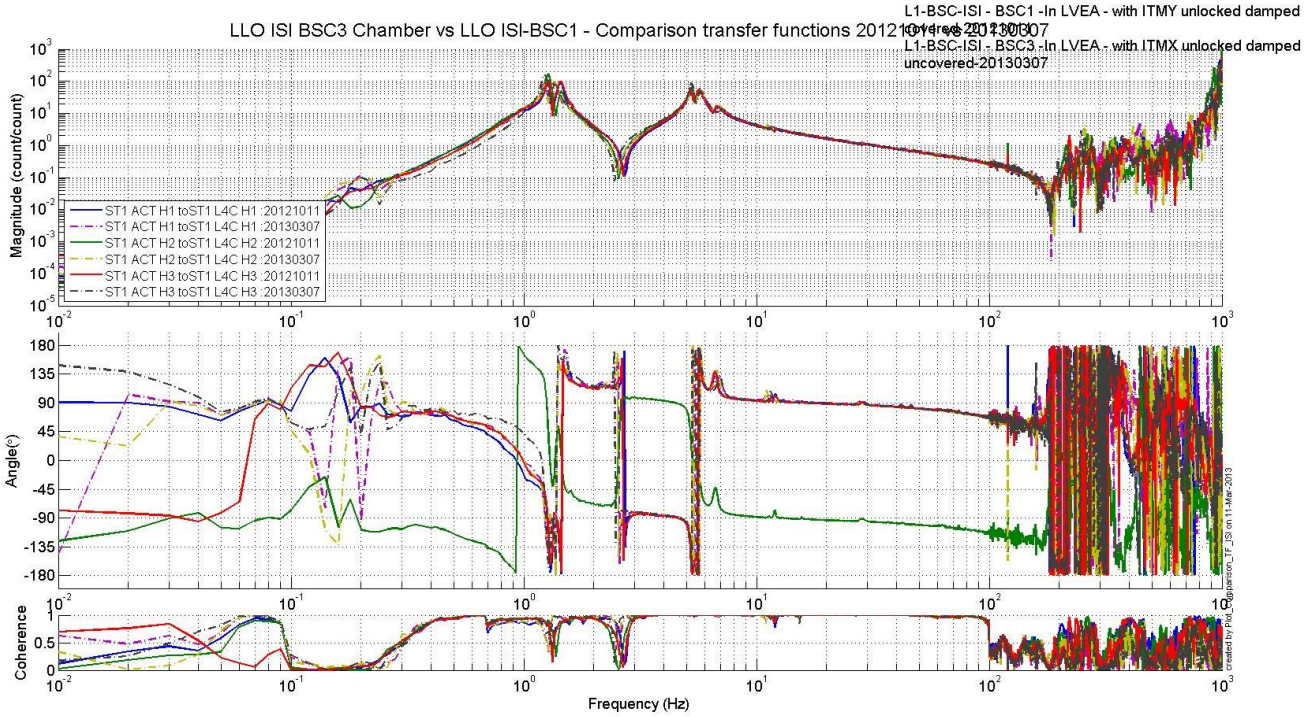


Figure 19 - Transfer functions comparison - ST1 ACT to ST1 CPS

Note: we can notice that Stage 1 ACT V3 to Stage CPS V3 resonances were at different frequencies on BSC 1 compared to BSC 3. After further investigation, we found out that this zero at 17 Hz was caused by an untorqued Bracket on Stage 0-1 V1 Actuator:




LLO ISI BSC3 Chamber vs LLO ISI-BSC1 - Comparison transfer functions 20121011 vs 20130307
L1-BSC-ISI - BSC1 -In LVEA - with ITMY unlocked damped uncovered-20130307
L1-BSC-ISI - BSC3 -In LVEA - with ITMX unlocked damped uncovered-20130307
Magnitude (count/count)
ST1 ACT H1 toST1 L4C H1 :20121011
ST1 ACT H1 toST1 L4C H1 :20130307
ST1 ACT H2 toST1 L4C H2 :20121011
ST1 ACT H2 toST1 L4C H2 :20130307
ST1 ACT H3 toST1 L4C H3 :20121011
ST1 ACT H3 toST1 L4C H3 :20130307
Angle(°)
Coherence
Frequency (Hz)

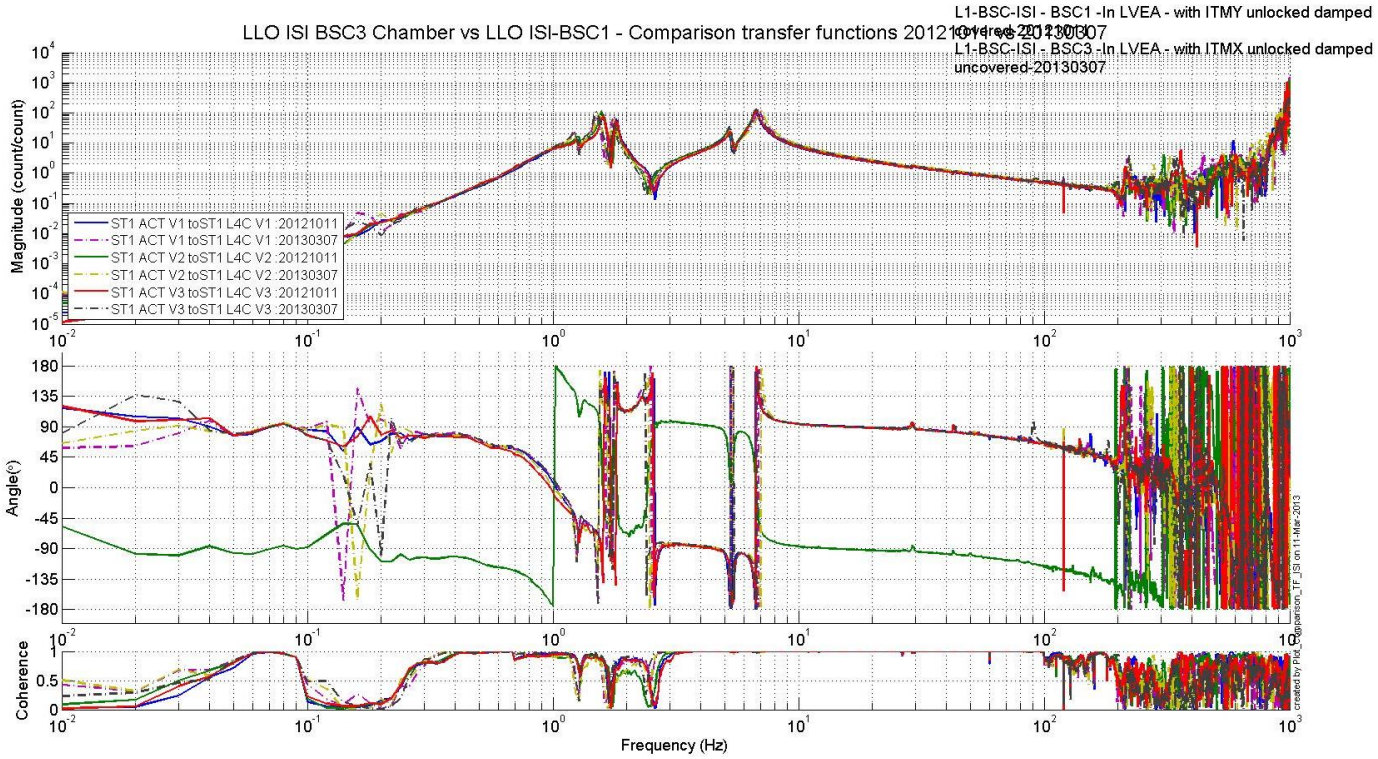
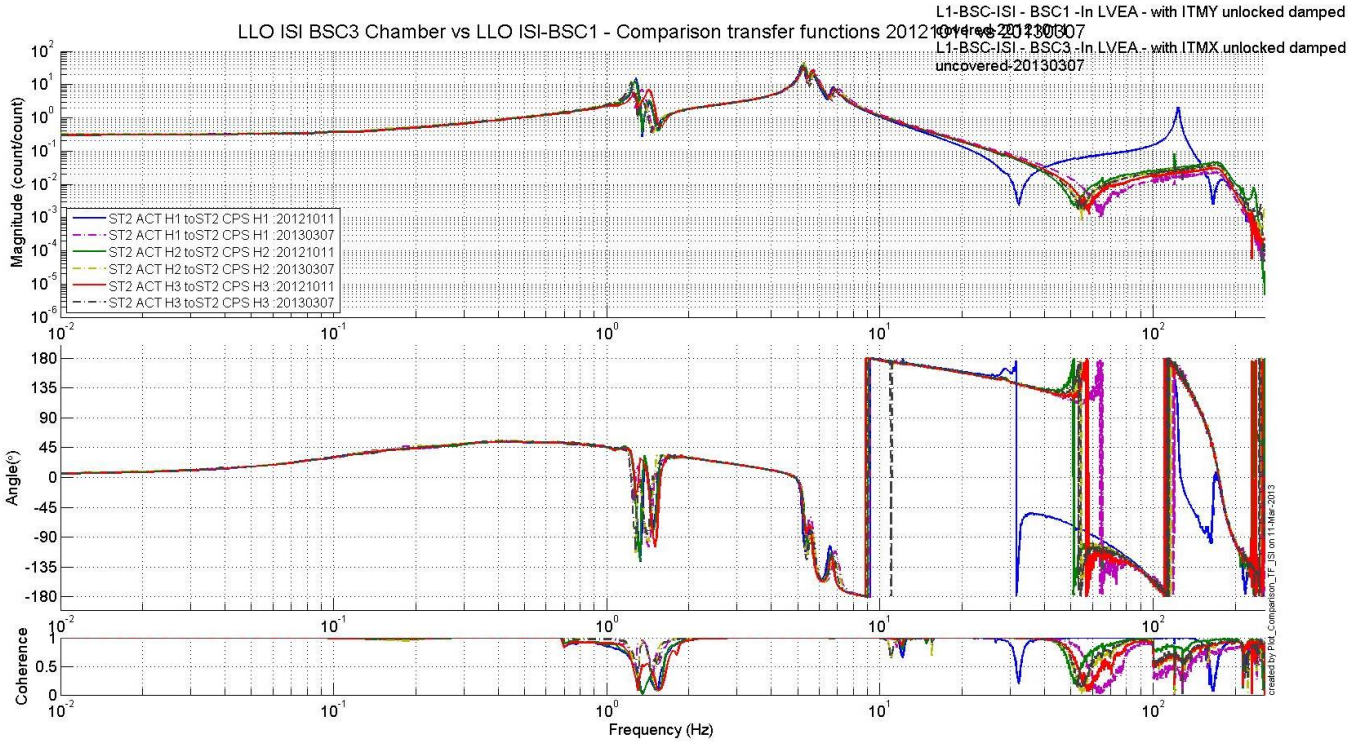


Figure 20 - Transfer functions comparison - ST1 ACT to ST1 L4C



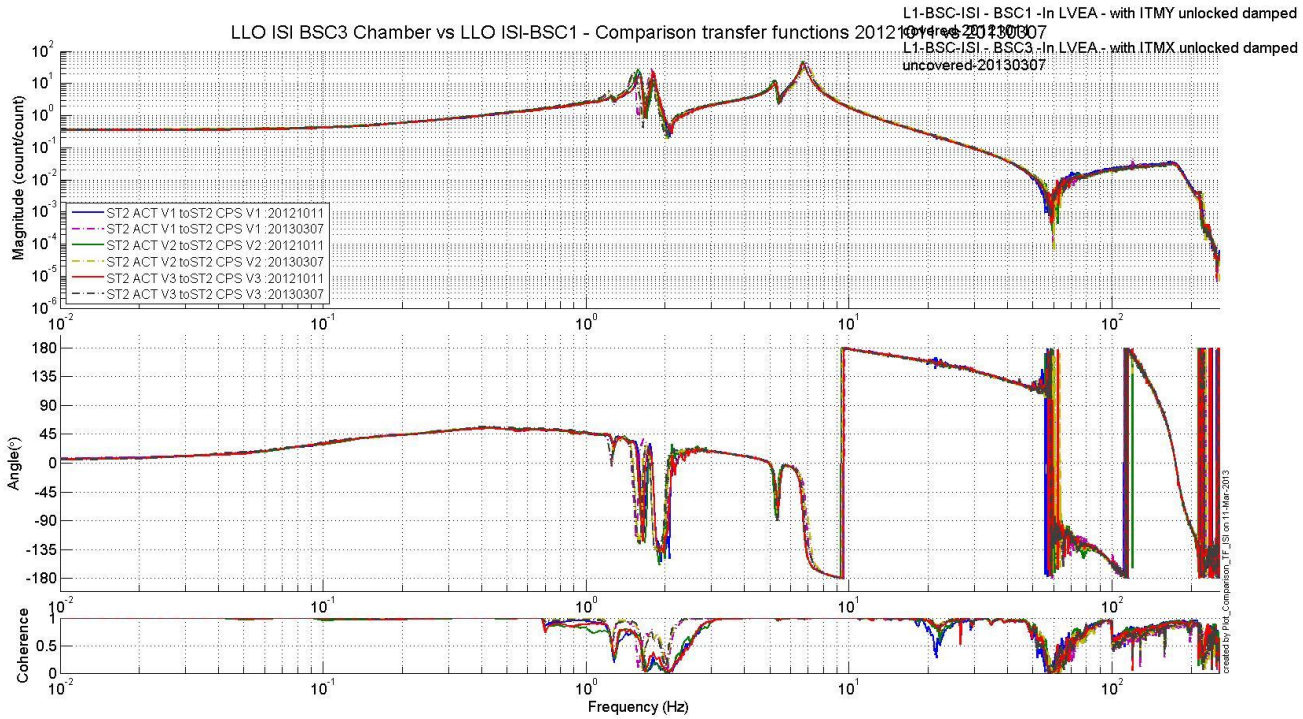


Figure 21 - Transfer functions comparison - ST2 ACT to ST2 CPS

Note: we can notice that Stage 1 ACT H1 to Stage CPS H1 resonances are at different frequencies on BSC 3 compared to BSC 1.

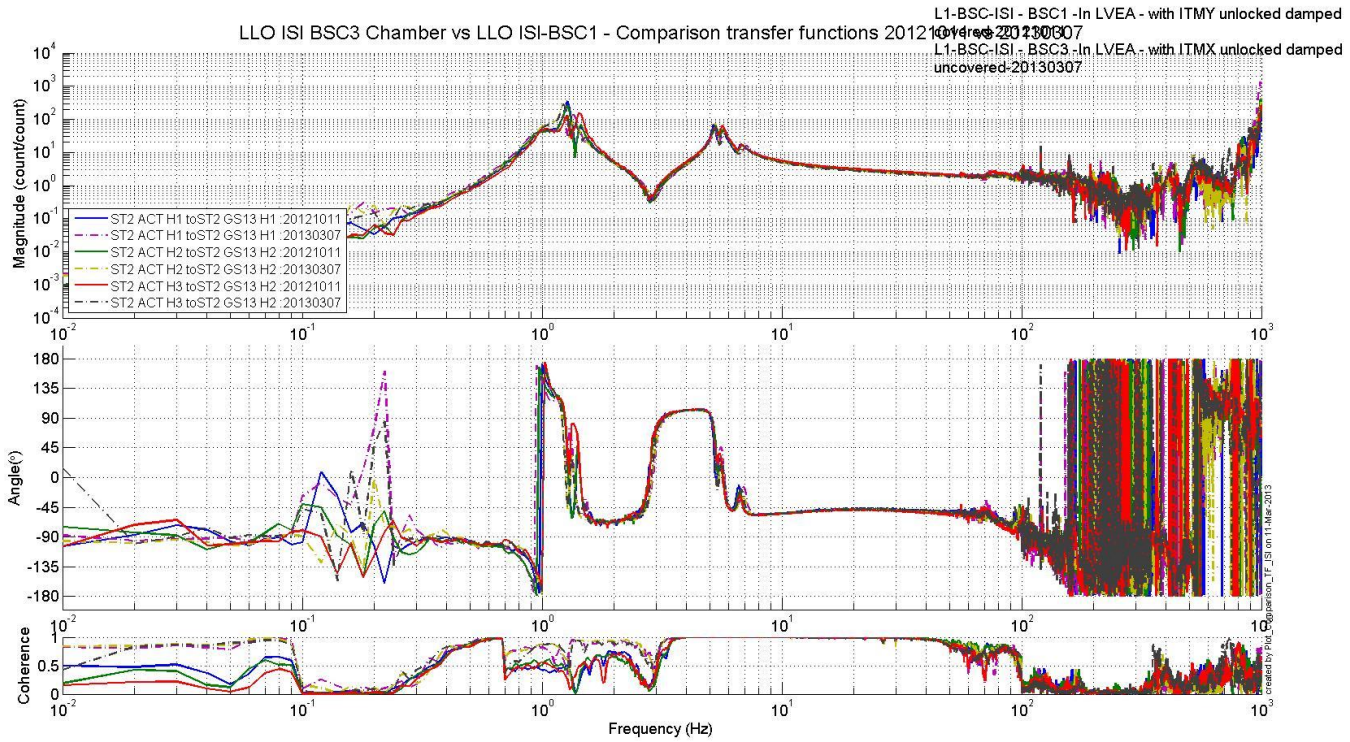


Figure 22 - Transfer functions comparison – ST2 ACT to ST2 GS13

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

After torqueing the Stage 0-1 V1 Actuator Bracket, we re took the Transfer Function to make sure, we solved our issue and here are the results we had:

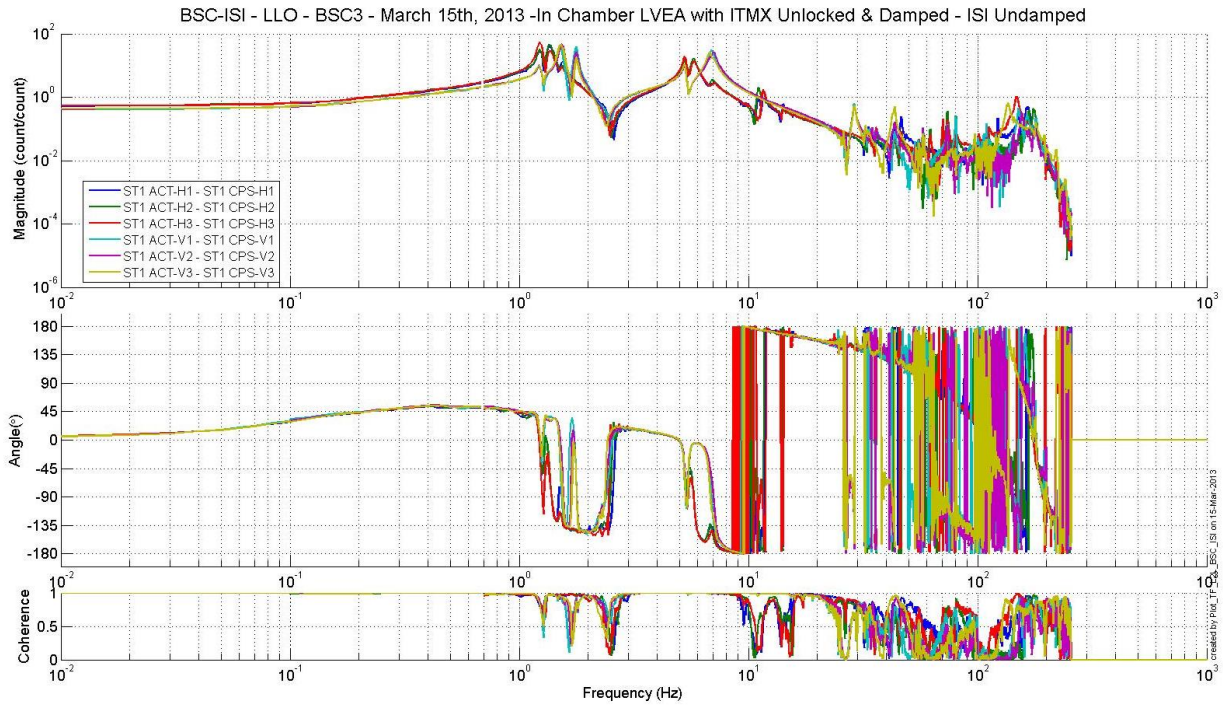


Figure 23: Transfer functions - ST1 ACT to ST1 CPS

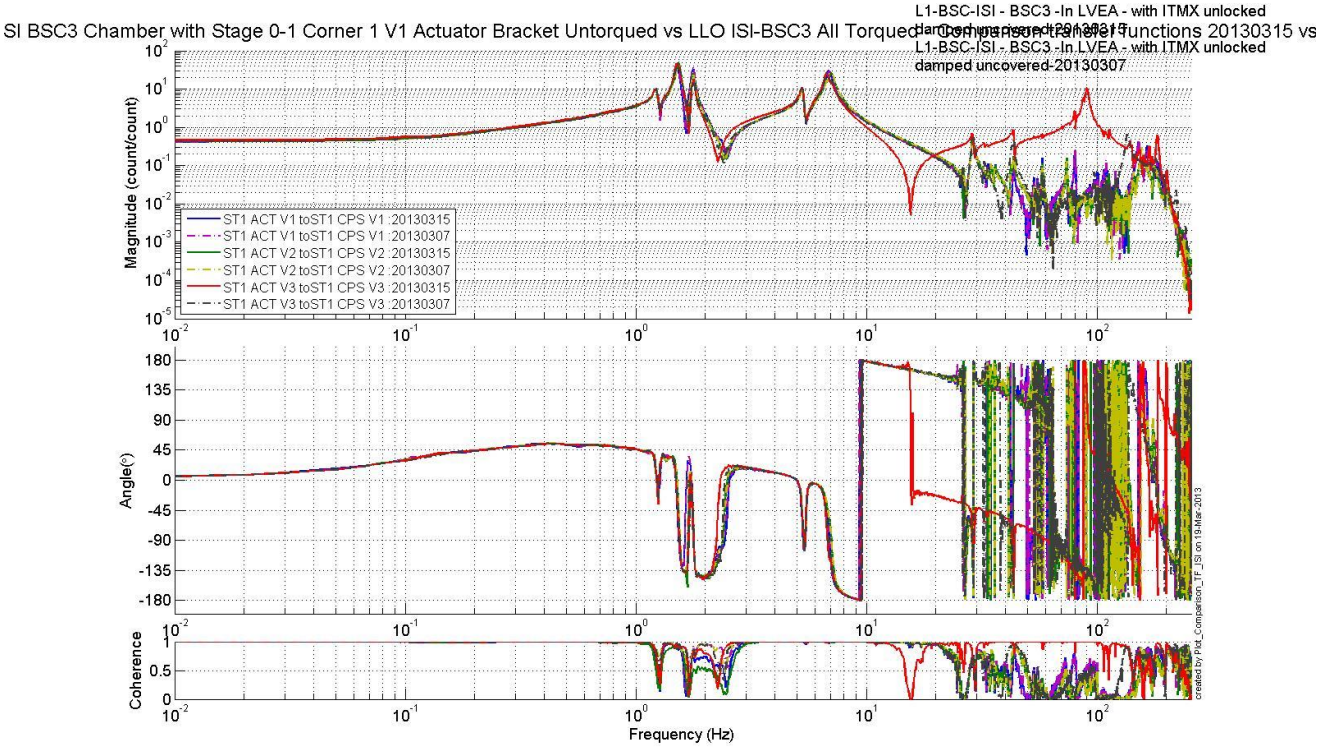


Figure 24: Comparison of the Transfer functions - ST1 ACT to ST1 CPS between BSC 3 with the Stage 0-1 V1 Actuator Bracket Untorqued (03/07/2013) and Torqued (03/15/2013)

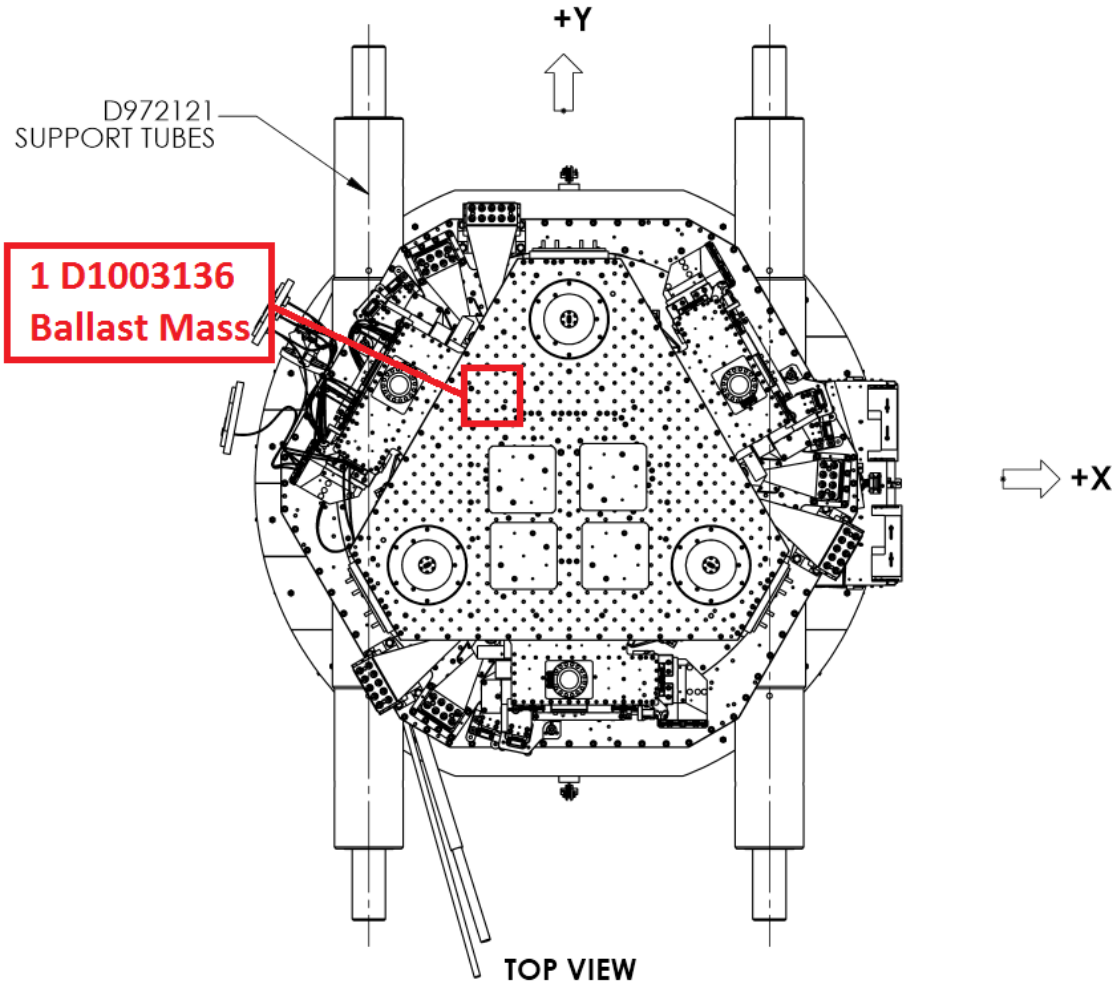
On these figures, we can clearly see that torqueing this bracket solved our issue.

Looking at Figure 21, we can also conclude that Stage 1-2 H1 CPS on LLO BSC1 has the same issue and that next time the dome is opened, we'll have to go back and make sure everything is torqued in the neighborhood of Stage 1-2 H1 CPS.

7. Conclusion Phase II-a

All results appear satisfying; apart from a few tests

- Linearity test: Stage 1 V1, V2 and V3 actuators seem a little off compared to their average slope but nothing too alarming and looking at the other tests, everything seems normal.
- The comparisons of the Transfer Functions between BSC 3 and BSC 1 that has already been approved show us that this BSC 3 is good to go.
- Mass Budget: we saw a 16 kgs difference between the mass budget on the test stand before install and the mass budget in chamber after install (+19 kgs on Stage 2 and –3 kgs on Stage 1). Without being alarming, this change was worth being written down in the Testing Report. Because of that we had to add another D1003136 Ballast Mass on top of the Keel Plate in order to be able to balance the ISI. We decided to start a new stack located as shown below:



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