LIGO Laboratory / LIGO Scientific Collaboration

LIGO- E1100306 *LIGO* October 2nd, 2012

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

E1100306 – V1

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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 ISI-BSC3 (ITMX) in the High Bay before its move to the LVEA (Test stand). First set of tests were done during August 2012. But because of Hurricane Isaac and a power outage of ~30 hours in the LVEA causing corrosion on the BSC Lockers (without A/C, the Temperature and Humidity went up inside the cleanroom, causing condensation on the BSC and thus oxidation. The only parts really affected were the Lockers and after further investigations, it turns out that it is because they are made of a different type of Aluminum than the rest of the ISI: stronger but less resistant to oxidation!). After noticing that, we had to swap the Lockers and sent the oxidized set through clean and bake, and so we decided to restart the Testing from scratch.

This is the third "aLigo BSC-ISI" built and tested with the "aLigo electronic" at the LLO site. The testing procedure document E1000486-v3 was used.

All results are posted on the SVN at:
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/X2/Data/BSC3/

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

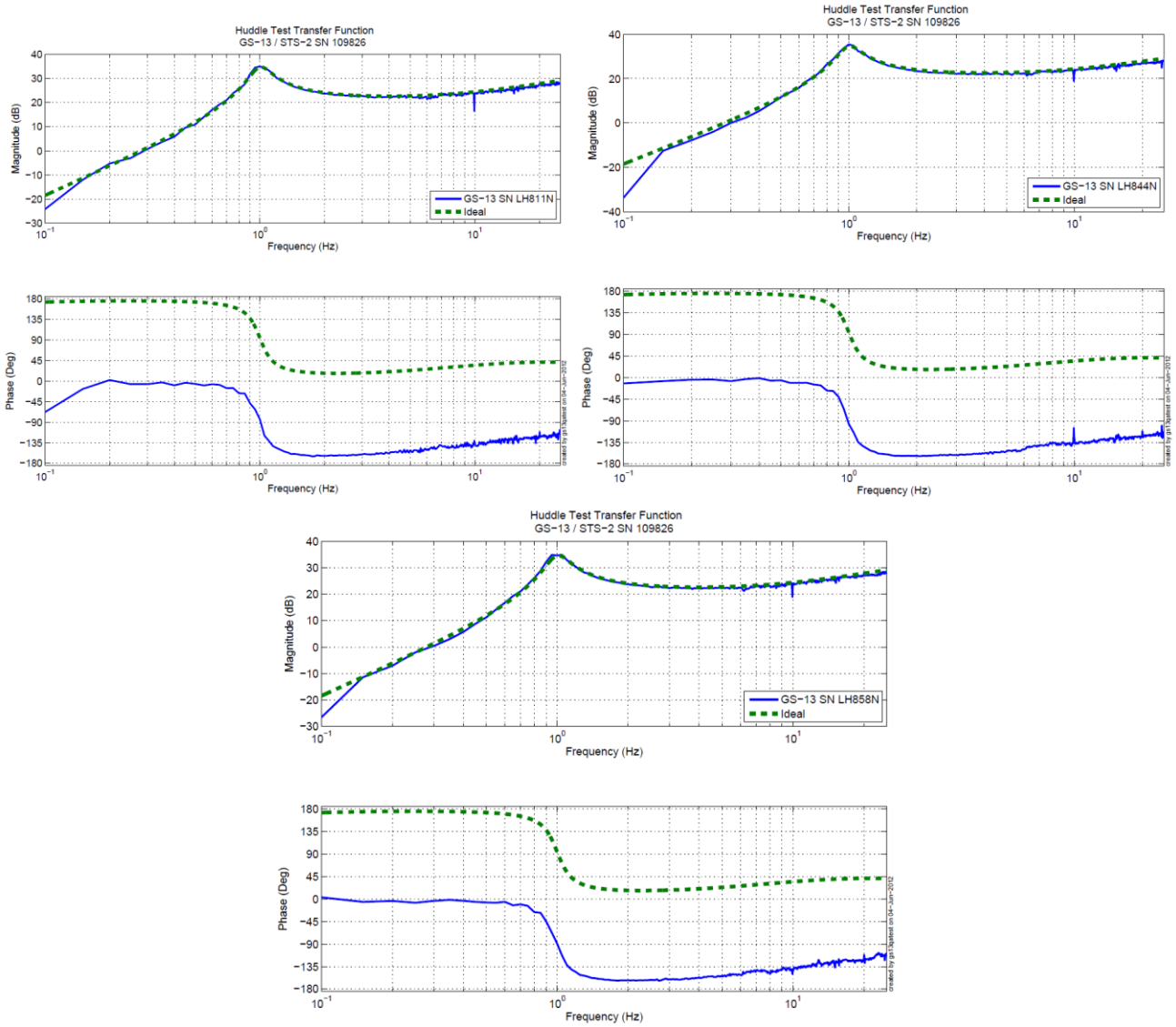

Figure 1: Huddle Test Transfer Function of the Horizontal GS-13 SN 811, 844 & 858 after aLIGO modifications

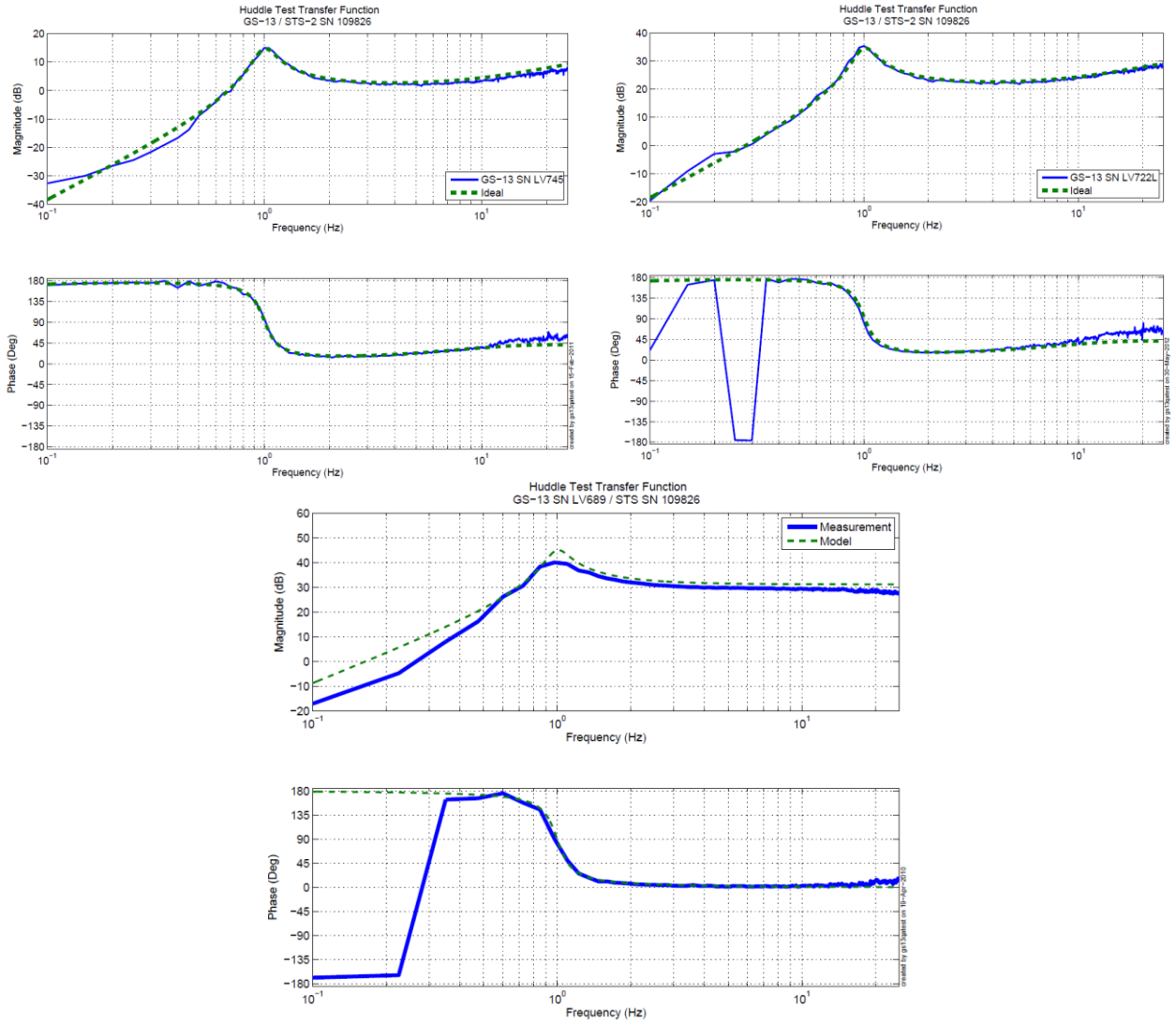

Figure 2: Huddle Test Transfer Function of the Vertical GS-13 SN 745, 722 & 689 after aLIGO modifications

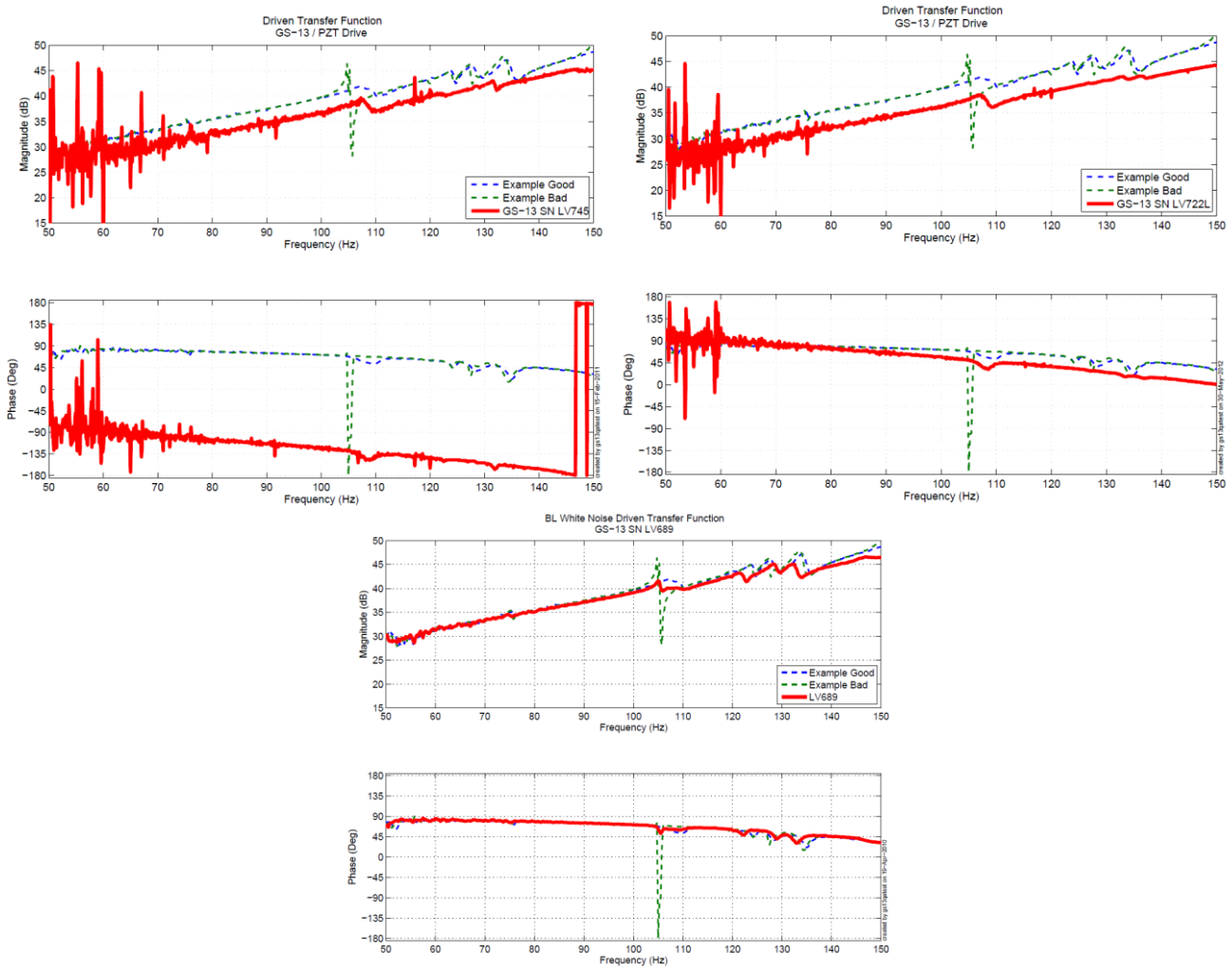

Figure 3: Driven Transfer Function of the Vertical GS-13 SN 745, 722 & 689 after aLIGO modifications

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/

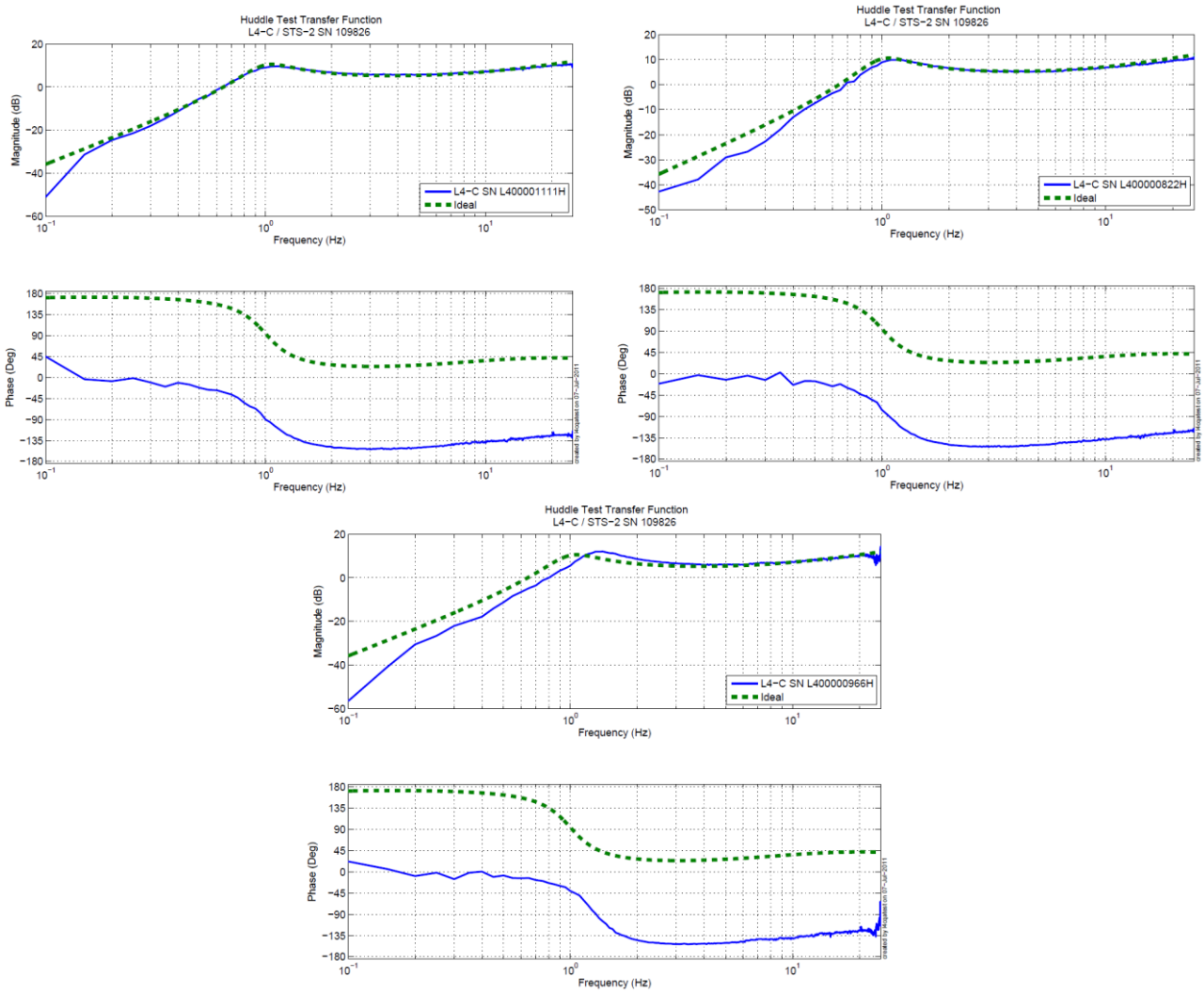

Figure 4: Huddle Test Transfer Function of the Horizontal L4-C SN 1111, 822 & 966

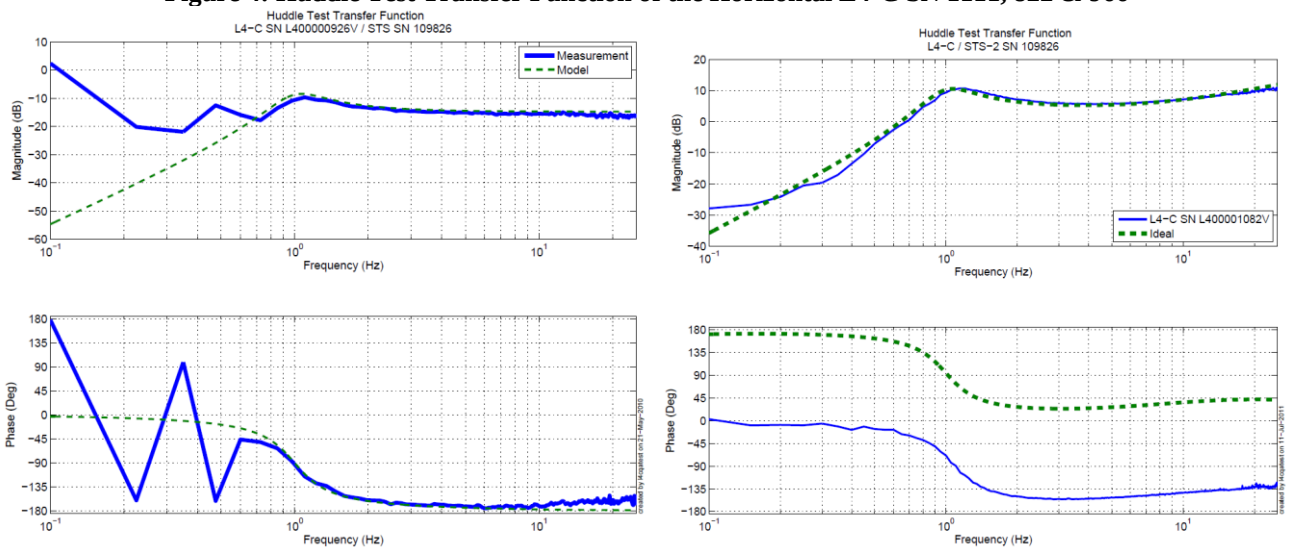

Figure 5: Huddle Test Transfer Function of the Vertical L4-C SN 1081, 926 & 1082

Note: No record of the Huddle Test Transfer Function for the Horizontal L4-C SN 1081

E1000136 and E1100740 spreadsheets provide the status of each individual L4C at LLO site for HAM-ISI and BSC-ISI and the installation location of the geophones.

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.

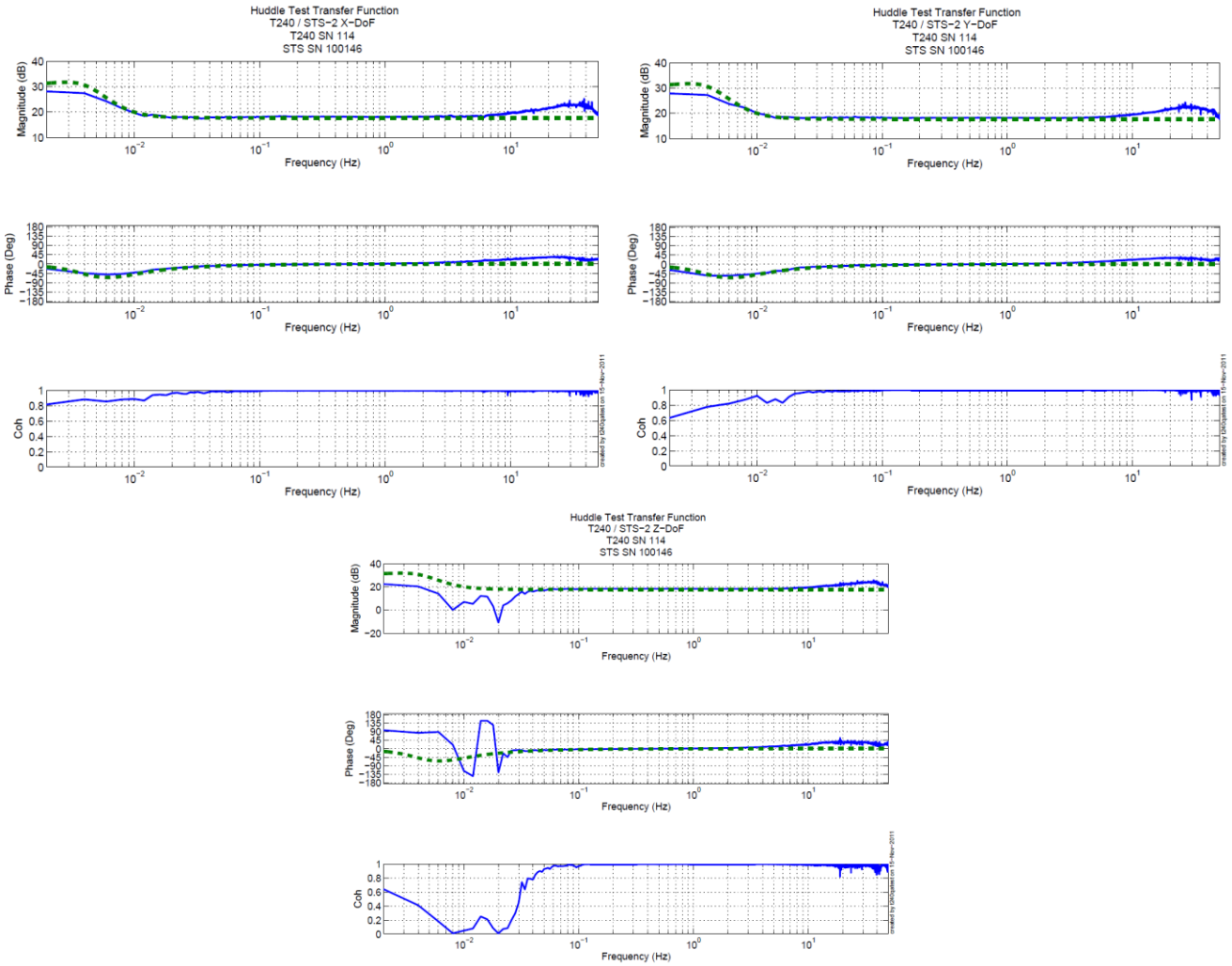

Figure 6: Huddle Test Transfer Function of the X, Y & Z axis of the T240 SN 114

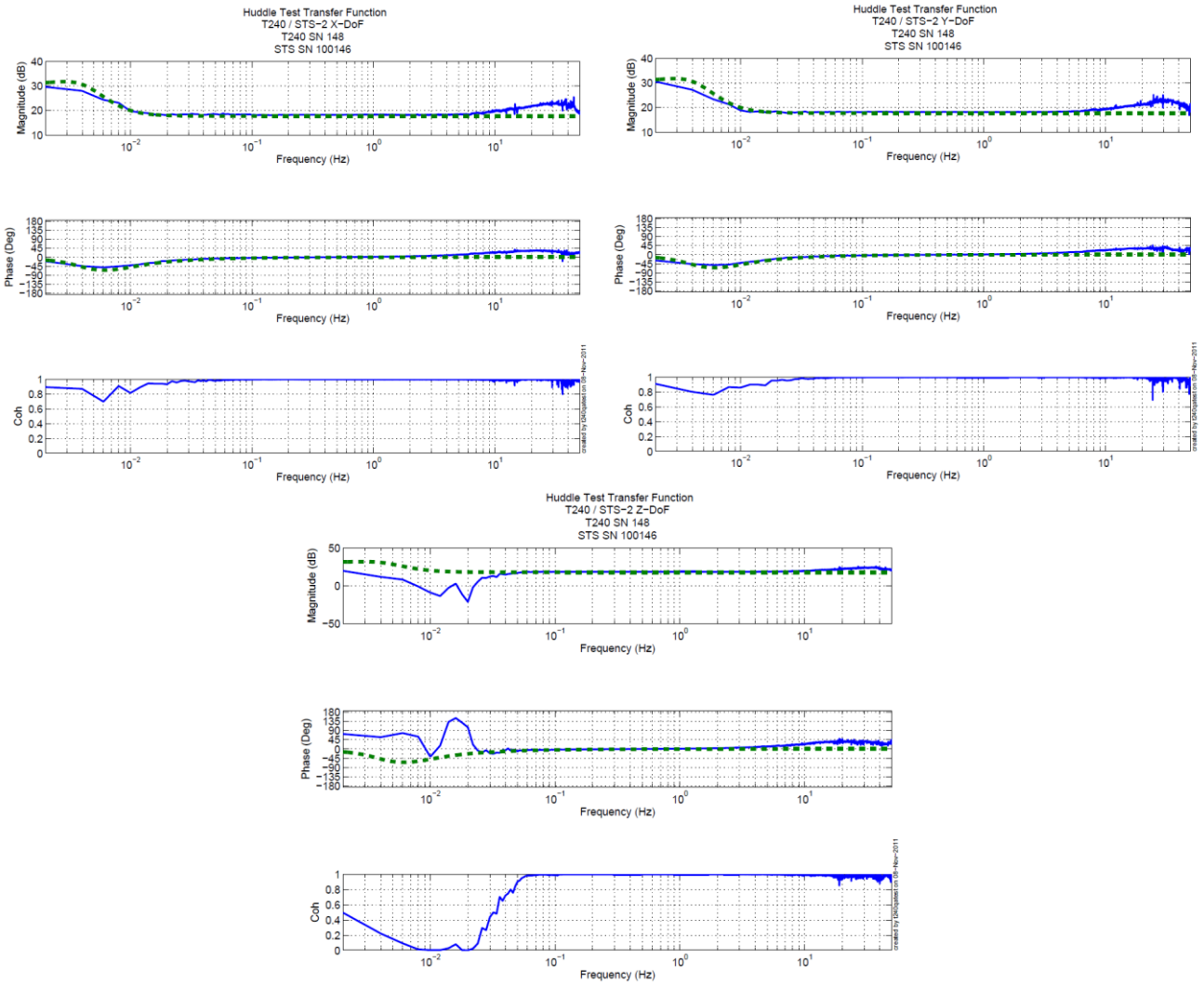

Figure 7: Huddle Test Transfer Function of the X, Y & Z axis of the T240 SN 148

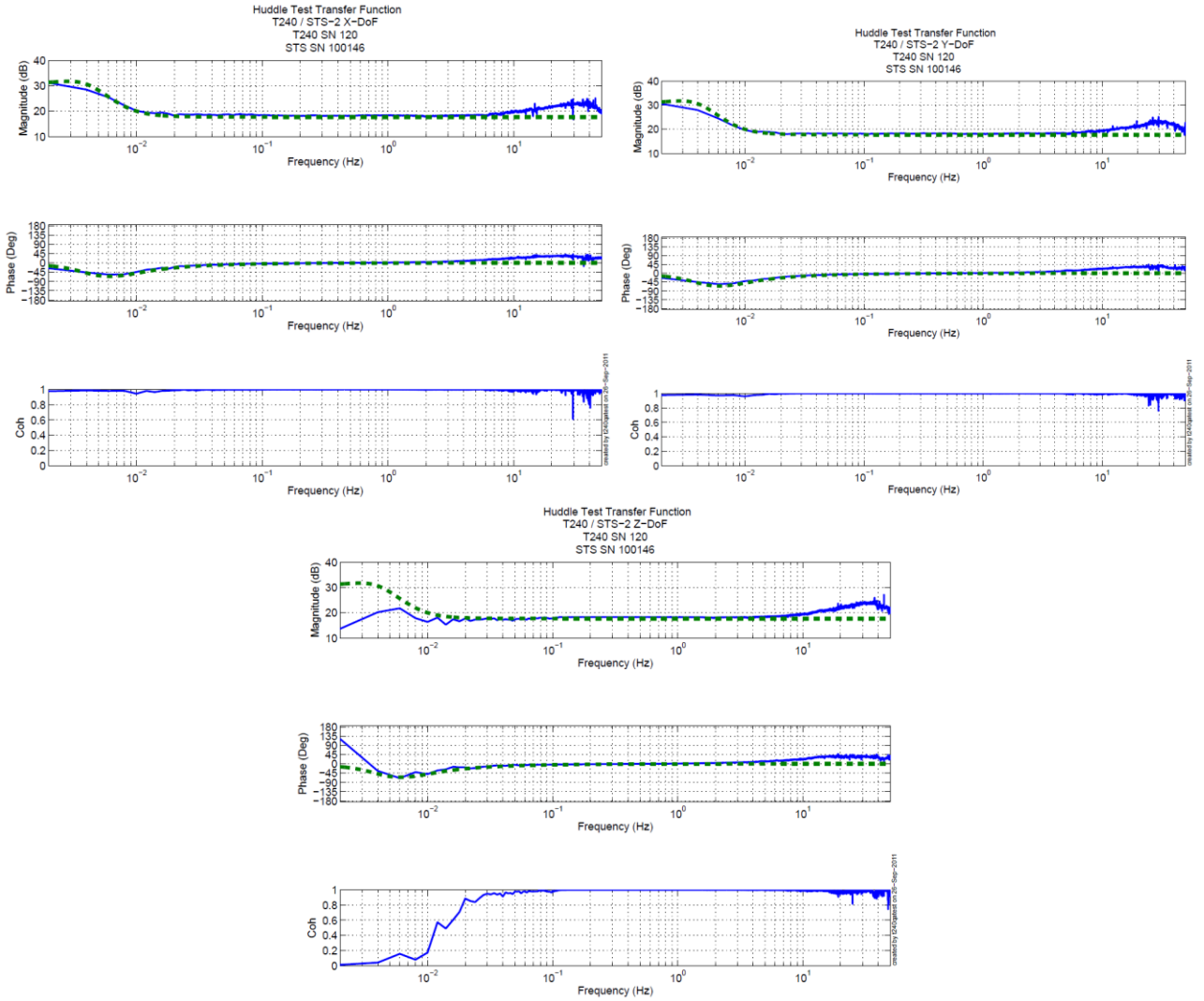

Figure 8: Huddle Test Transfer Function of the X, Y & Z axis of the T240 SN 120

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.

	Stage 0-1	Stage 1-2
H1	Actuator Serial #: L026 Operator Name: Smith, Lane Date: 8/13/2009 Time: 3:18 PM Actuator Coil Resistance: 6.45 Ohms, PASS Ambient Temperature: 73.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.518 Y Travel Limit (inches): 0.207 Z Travel Limit (inches): 0.504	Actuator Serial #: S083 Operator Name: Gordon, Matt Date: 4/13/2011 Time: 3:29 PM Actuator Coil Resistance: 10.56 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.646 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.507
H2	Actuator Serial #: L025 Operator Name: Smith, Lane Date: 8/12/2009 Time: 10:56 AM Actuator Coil Resistance: 6.39 Ohms, PASS Ambient Temperature: 71.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.523 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.503	Actuator Serial #: S075 Operator Name: Gordon, Matt Date: 4/13/2011 Time: 1:30 PM Actuator Coil Resistance: 10.23 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.662 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.512
H3	Actuator Serial #: L068 Operator Name: Gordon, Matt Date: 11/19/2009 Time: 1:27 PM Actuator Coil Resistance: 6.28 Ohms, PASS Ambient Temperature: 73.1 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.532 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.503	Actuator Serial #: S093 Operator Name: Gordon, Matt Date: 4/14/2011 Time: 1:11 PM Actuator Coil Resistance: 10.46 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.661 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.513
V1	Actuator Serial #: L003 Operator Name: Smith, Lane Date: 8/12/2009 Time: 3:17 PM Actuator Coil Resistance: 6.40 Ohms, PASS Ambient Temperature: 71.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.520 Y Travel Limit (inches): 0.204 Z Travel Limit (inches): 0.504	Actuator Serial #: S072 Operator Name: Gordon, Matt Date: 4/13/2011 Time: 10:09 AM Actuator Coil Resistance: 10.31 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.665 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.512
V2	Actuator Serial #: L029 Operator Name: Smith, Lane Date: 8/11/2009 Time: 4:56 PM Actuator Coil Resistance: 6.35 Ohms, PASS Ambient Temperature: 72.5 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.527 Y Travel Limit (inches): 0.193 Z Travel Limit (inches): 0.483	Actuator Serial #: S080 Operator Name: Gordon, Matt Date: 4/13/2011 Time: 2:33 PM Actuator Coil Resistance: 10.57 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.634 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.514
V3	Actuator Serial #: L0093 Operator Name: Gordon, Matt Date: 11/21/2009 Time: 11:03 AM Actuator Coil Resistance: 6.29 Ohms, PASS Ambient Temperature: 68.9 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.529 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.504	Actuator Serial #: S097 Operator Name: Gordon, Matt Date: 4/14/2011 Time: 2:06 PM Actuator Coil Resistance: 10.58 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.684 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.512

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

II. Tests to be performed during assembly

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

The HAM-ISI 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 0-1		Stage 1-2	
Actuator	**Actuator S/N**	**Actuator**	**Actuator S/N**
H1	L026	**H1**	S083
H2	L025	**H2**	S075
H3	L068	**H3**	S093
V1	L003	**V1**	S072
V2	L029	**V2**	S080
V3	L093	**V3**	S097

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 0-1	CPS S/N	ADE board serial #
H1	13552	15689
H2	13626	15842
H3	13466	12660
V1	13622	15682
V2	13621	15857
V3	12909	12419

Table 2 - Capacitive position sensors' inventory – Stage 1

CPS Stage 1-2	CPS S/N	ADE board serial #
H1	13236	12547
H2	13637	15903
H3	13435	12588
V1	13467	12518
V2	13414	12450
V3	13461	12584

Geophones GS13	Serial Number	POD
H1	811	2
H2	844	34
H3	858	103
V1	745	18
V2	722	1
V3	689	88

Table 3 - GS13 inventory

Geophones L4C	Serial Number	POD
H1	1111	2
H2	822	57
H3	966	139
V1	1081	118
V2	926	121
V3	1082	144

Table 4 - L4C inventory

Geophones T240	Serial Number	POD
1	114	12
2	148	17
3	120	31

Table 5 - 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	S1102219
Interface Chassis - Corner 2		S1106356
Interface Chassis - Corner 3		S1106358
Anti-Alliasing Chassis - Corner 1	D1002693	S1106137
Anti-Alliasing Chassis - Corner 2		S1106138
Anti-Alliasing Chassis - Corner 3		S1106136
Anti-image Chassis	D070081	S1000249
Binary Input Chassis	D1001726	S1101287
Binary Input Chassis		S1101285
Binary Output Chassis	D1001728	S1101322
T240 Interface - Corner 1	D1002694	S1104420
T240 Interface - Corner 2		S1104422
T240 Interface - Corner 3		S1104426
I/O Chassis	n/a	XP 005
Coil driver Pod 1	D0902744	S1103354
Coil driver Pod 2		S1000316
Coil driver Pod 3		S1103313

Table 6 - Electronic equipment

Note: We had to replace the anti-image Chassis S1000251 by S1000249 because it was causing Stage 0-1 H1 Actuator to have only half of his actuating range.

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)**
A	127	**A**	114
B	125	**B**	118
C	129	**C**	115

Table 7 - 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".

So far (LHO 2 first Units and LLO 2 first Units):

	Max	Min	Average
Stage 0-1	.129"	.120"	.1257"
Stage 1-2	.130"	.114"	.1232"

The values of this LLO 3rd Unit seem coherent with the ones of the previous Units.

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

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

This test has not been performed on LLO Unit 2.

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

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

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

- ***Step 10 - Mass budget***

The figure below presents the location of the masses on both stages.

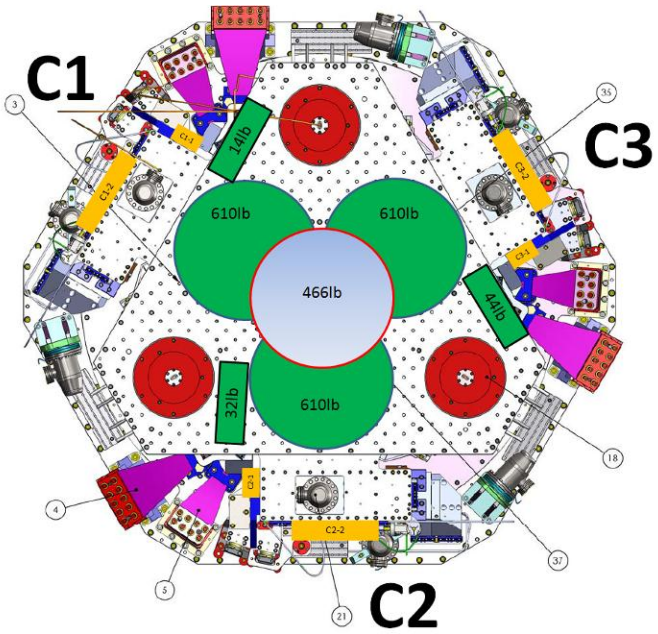

Figure 9: Masses distribution

Stage 1:

Stage 1		
Location	**Weight (lb)**	**Weight (Kg)**
C1-1	12	5.44
C1-2	15	6.80
C1-3	4.5	2.04
C2-1	0	0.00
C2-2	0	0.00
C2-3	15	6.80
C3-1	12	5.44
C3-2	15	6.80
C3-3	13.5	6.12
Total	**87**	**39.46**

Table 8 - Payload Stage 1

Nominal payload: 108.9Kg – 240lb
Added masses are 69Kg – 152lb lighter than expected.
Total mass of stage 1=916Kg - 2019lb

Stage 2:

10/1/2012	D972213	D972215	D0901075		D071200							
			5 kg	10 kg	01	02	03	04	05	06		
	610	230	11	22	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
A	1										610	276.69
B	1										610	276.69
C	1										610	276.69
D		2									460	208.65
E-1											0	0.00
E-2											0	0.00
E-3											0	0.00
F1					3		2	1	6		113.8	51.62
F2					3	1	2	3	3		85	38.56
F3					1	1	3	1	3		71.5	32.43
Stage 2	3	2	0	0	7	2	7	5	12	0	2560.3	1161.33

Table 9 - Payload Stage 2

Nominal payload: 1183.4Kg – 2609lb
The added masses is 22.1Kg – 48.7lbs lighter than expected.

Total nominal mass of Stage 2: 2913.9Kg – 6424lb
Error on the nominal overall mass of stage 2: 22.1/2913.9=0.8%

Summary:

Unit 3

	Plan	8/13/2012	% diff from Plan	Mass Diff from Plan
Stage 1	108.86	39.46	-63.75	-69.40
Stage 2	1183.42	1161.33	-1.87	-10.66

LLO Unit 1 & 2 Results:

Unit 1

	Plan	Original	3/1/2012	3/9/2012	% Diff from Plan	Mass Diff from Plan
Stage 1	108.86	148.10	19.50	36.29	-66.67	-72.57
Stage 2	1183.42	989.42	1089.07	1096.83	-7.32	-86.59

Unit 2

	Plan	6/12/2012	% diff from Plan	Mass Diff from Plan
Stage 1	108.86	60.06	-44.83	-48.81
Stage 2	1183.42	1071.93	-9.42	-111.49

LLO Unit 3 is the first one to use these Silver Plated Eastwood Bolts for the Spring Blades and we can see the benefits of it especially on Stage 2!

Previous Units Results:

	Plan	LHO Unit 1	LHO Unit 2	LLO Unit 1	**LLO Unit 2**	Avg (4 1st Units)	STD	**LLO Unit 3**
Stage 1	108.86	35.6	58.6	36.29	**60.06**	47.64	11.71	**39.46**
Stage 2	1183.42	1082.4	1059.5	1096.83	**1071.93**	1077.67	13.72	**1161.33**
Stage 1	175.86	-9.79	48.50	-8.04	52.20	20.72	% of Diff/LLO Unit 3	
Stage 2	1.90	-6.80	-8.77	-5.55	-7.70	-7.20		

Note: This Unit is the first one with the Silver Plated Eastwood Bolts for the Blades. Since the Silver Plating allows a better friction with the Nitronic of the Barrel Nuts, we decided to go back to the initial torque value for these bolts: 110 ft.lbs.

Even if the mass budget on Stage 1 is light compared to the original plan, by comparing it with the Previous Units built at LHO & LLO, we can see that this Unit is in the general tendency:

- Stage 2 Mass Budget is the closest one to the Plan built to date: less than 2% difference.
- Stage 1 Mass Budget is in the general tendency of the four first previous Units.

Not only that but this Unit is the closest one to the theoretical Mass Plan ever built!

In conclusion, the BSC-ISI seems to benefit a lot from these new bolts.

Note: This Unit is the last one built with the D1100570-V1 & D1100564-V1 Angled Blade Spacers. Starting on next Unit at LLO, we will use the Version 2 of these Angled Blade Spacers on both Stages to try to come even closer to the Plan Mass Budget. This Version 2 has a slightly different launching angle than the first Version and that should bring the whole BSC-ISI closer to the Plan Mass Budget.

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

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

When we first Unlocked the BSC (both Stages), we had an initial twist of :

- -0.002" on corner 1
- +0.0045" on corner 2
- -0.005" on corner 3

But these numbers don't have a lot of sense since the BSC was not balanced. So after leveling individually both stage (starting with Stage 2) and then adjusting the weight on the BSC fully Unlocked, here are the values of the twist:

	Stage 0-2 (both Stage unlocked after leveling)	
D.I at Lockers	**Dial indicators V**	**Dial indicators H**
A	0	-10.5
B	0	-3
C	0	-14.5

Table 10: Initial Dial Indicators read-out (both Stage Unlocked)

After a few iterations, to center each Locker horizontally, here are the final values of the Dial:

	Stage 0-2 (both Stage unlocked after leveling)	
D.I at Lockers	**Dial indicators V**	**Dial indicators H**
A	0	0
B	1	0
C	0	0

Table 11: Final Dial Indicators read-out (both Stage Unlocked)

Measurements using the CPS sensors when the stages are locked and unlocked have been done Step III.2.

Note: After the lockers swap, when we opened the Lockers without correcting the twist, we found some very similar results showing that the twist comes from the Blade/Flexure and is consistent.

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.

	Type of Cable	Corner 1	Corner 2	Corner 3
St 0-1 V Actuators	Pigtail	D1100150 – S1107139	D1100151 – S1107215	D1100151 – S1107218
	Extension	D1100148 – S1106976	D1100148 – S1106972	D1100148 – S1106939
St 0-1 H Actuators	Pigtail	D1100150 – S1107133	D1100151 – S1107165	D1100151 – S1107219
	Extension	D1100148 – S1106932	D1100148 – S1106934	D1100148 – S1106960
St 1-2 V Actuators	Pigtail	D1100150 – S1107140	D1100150 – S1107132	D1100151 – S1107220
	Extension	D1100148 – S1106948	D1100148 – S1106947	D1100148 – S1106961
St 1-2 H Actuators	Pigtail	D1100150 – S1107134	D1100150 – S1107088	D1100151 – S1107147
	Extension	D1100148 – S1106967	D1100148 – S1106946	D1100148 – S1106957
L4C	Pigtail	D1100154 – S1107333	D1100154 – S1107330	D1100155 – S1104249
	Extension	D1100152 – S1107246	D1100153 – S1107284	D1100153 – S1107269
GS-13	Pigtail	D1100154 – S1107336	D1100155 – S1107379	D1100155 – S1104252
	Extension	D1100153 – S1107313	D1100153 – S1104571	D1100153 – S1107277
T240		D1100153 – S1107280	D1100153 – S1107283	D1100152 – S1107259

Note: Some changes might occur later in the cabling. Indeed, installing our first BSC-ISI in chamber gave us a better idea of where to put which length of cable (to be able to reach their feed through…).

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***

	Pressure (counts)		
Sensors	**Corner 1**	**Corner 2**	**Corner 3**
ST1-L4C-P	100.1	100.54	100.07
ST1-L4C-D	0.19051	-0.98714	-0.075725
ST1-GS13-P	100.3	77.345	77.27
ST1-GS13-D	-0.62561	0.3819	-0.2195
ST1-T240-P	154.72	153.9	154.04

Nominal Value for the Pressure Readout: 100 counts

Test mitigation:

On LLO BSC Unit 1, L4C-P in Corner 1 was giving strange signal, but it didn't come from the pressure sensor, it was coming from the interface SN S1106357. This interface was replaced with S1102219.

Replacing the Interface Chassis of Corner 1 fixed the issue we had about the pressure sensor Readout on the GS-13. This issue is still here on Corner 2 & 3, but we know the problem comes from the interfaces used for these Corners. That explains why we have reading ~77 counts on these GS-13's.

The Pressure value on the Trillium is ~150 counts, which is not realistic. We've always had that issue (probably due to the Interfaces) but we know that a pressure readout of ~150 counts means that the pressure sensor works (otherwise the pressure readout is 30 counts!).

So we know we have good pressure sensors in this Unit's pods.

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.

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	Table locked		Table unlocked		Difference locked - unlocked	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**mil**
ST1 - H1	134.25	44.599	455.63	67.804	-321.38	-0.38
ST1 - H2	283.15	28.549	-33.747	57.589	316.90	0.38
ST1 - H3	79.286	16.59	-502.79	51.582	582.08	0.69
ST1 - V1	-26.259	49.102	46.069	84.512	-72.33	-0.09
ST1 - V2	286.47	47.697	237.8	144.6	48.67	0.06
ST1 - V3	183.76	25.814	867.87	187.06	-684.11	-0.81
ST2 - H1	-1180.7	93.857	874.55	74.748	-2055.25	-0.61
ST2 - H2	-24.412	105.24	1078.1	87.874	-1102.51	-0.33
ST2 - H3	650.42	141.84	687.52	80.724	-37.10	-0.01
ST2 - V1	987.77	283.78	1082.9	269.19	-95.13	-0.03
ST2 - V2	271.16	120.69	1277.3	415.84	-1006.14	-0.30
ST2 - V3	543.82	177.08	598.8	464.92	-54.98	-0.02

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

Acceptance criteria:

- In the locked position, all mean values must be lower than 400 counts for stage 1 CPS and 1600 counts for stage 2 CPS (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")

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

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

Test Failure mitigation:

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

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

Step 4- Performance of the limiters

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

	CPS read out		Calculated after calibration	
Sensors	**"-Z" (Counts)**	**"+Z" (Counts)**	**"-Z" (mil)**	**"+Z" (mil)**
ST1 - V1 - ST2 LCK	-16015.0	17452	-19.1	20.8
ST1 - V2 - ST2 LCK	-17324.0	16732	-20.6	19.9
ST1 - V3 - ST2 LCK	-17443.0	17257	-20.8	20.5
ST2 - V1 - ST1 LCK	-32768.0	32767.0	-9.8	9.8
ST2 - V2 - ST1 LCK	-32768.0	32767.0	-9.8	9.8
ST2 - V3 - ST1 LCK	-32768.0	32767.0	-9.8	9.8

	CPS read out		Calculated after calibration	
Sensors	**"-RZ" (Counts)**	**"+RZ" (Counts)**	**"-RZ" (mil)**	**"+RZ" (mil)**
ST1 - H1 - ST2 LCK	14252.0	-10172.0	17.0	-12.1
ST1 - H2 - ST2 LCK	15661.0	-17769.0	18.6	-21.2
ST1 - H3 - ST2 LCK	17458.0	-12369.0	20.8	-14.7
ST2 - H1 - ST1 LCK	-17069.0	27978.0	-5.1	8.3
ST2 - H2 - ST1 LCK	-32768.0	20060.0	-9.8	6.0
ST2 - H3 - ST1 LCK	-18637.0	28206.0	-5.5	8.4

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

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

Sensors	Push in positive direction	Push in negative direction	Mil	Mil	Railing	Actuator Gap Check
ST1 - H1	-21000	16158	-25	19		OK
ST1 - H2	-20731	16790	-25	20		OK
ST1 - H3	-17324	18257	-21	22		OK
ST1 - V1	19279	-23239	23	-28		OK
ST1 - V2	22434	-24887	27	-30		OK
ST1 - V3	22075	-26512	26	-32		OK
ST2 - H1	32767	-32768	10	-10	X	OK
ST2 - H2	32767	-32768	10	-10	X	OK
ST2 - H3	32767	-32768	10	-10	X	OK
ST2 - V1	32767	-32765	10	-10	X	OK
ST2 - V2	32767	-32768	10	-10	X	OK
ST2 - V3	32767	-32768	10	-10	X	OK

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

Acceptance criteria:

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

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

- ***Step 5 - Sensors Powespectra***

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

/seismic/BSC-ISI/X2/BSC3/Data/Figures/Spectra/Undamped/

- LLO_ISI_BSC3_Powerspectra_ct_ST1_Unlocked_ST2_Unlocked_2012_09_26.fig
- LLO_ISI_BSC3_Powerspectra_ct_ST1_Locked_ST2_Locked_2012_09_26.fig
- LLO_ISI_BSC3_Powerspectra_ct_ST1_Locked_ST2_Unlocked_2012_09_26.fig
- LLO_ISI_BSC3_Powerspectra_ct_ST1_Unlocked_ST2_Locked_2012_09_26.fig
- LLO_ISI_BSC3_Tilted_ASD_CT_LOC_ST1_L4C_2012_10_01.fig
- LLO_ISI_BSC3_Tilted_ASD_m_LOC_ST1_L4C_2012_10_01.fig
- LLO_ISI_BSC3_Tilted_ASD_CT_LOC_ST2_GS13_2012_10_01.fig
- LLO_ISI_BSC3_Tilted_ASD_m_LOC_ST2_GS13_2012_10_01.fig

/seismic/BSC-ISI/X2/BSC3/Data/Spectra/Undamped

- LLO_ISI_BSC3_ASD_m_LOC_CPS_T240_L4C_GS13_2012_09_24_205825.mat
- LLO_ISI_BSC3_ASD_m_L4C_GS13_Stage_Tilted_2012_10_01.mat

Stage locked – unlocked

The powerspectra are measured in four different configurations:

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

The series of plots below present calibrated powerspectra:

- The de-whitening filters are suppressed

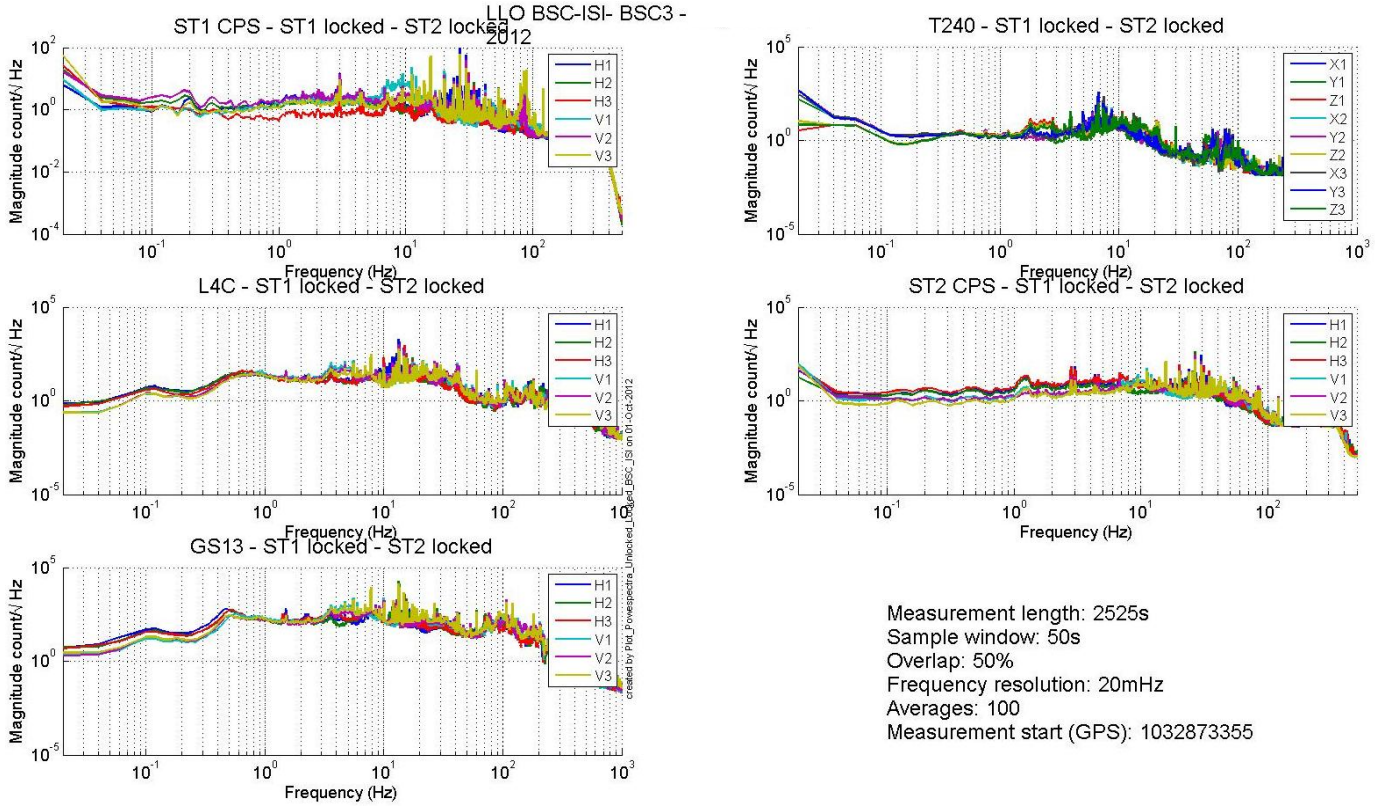


Figure 10: Spectra Stage 1 Locked Stage 2 Locked

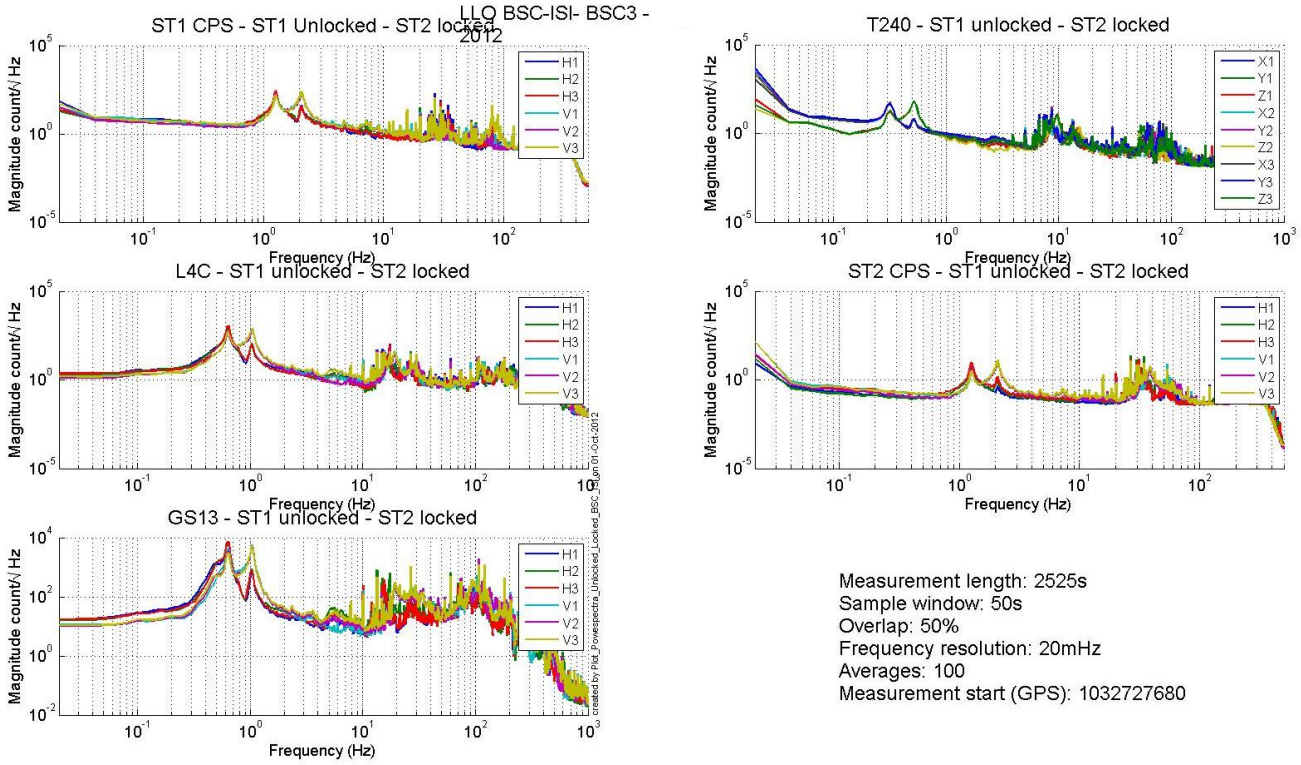


Figure 11: Spectra Stage 1 Unlocked Stage 2 Locked

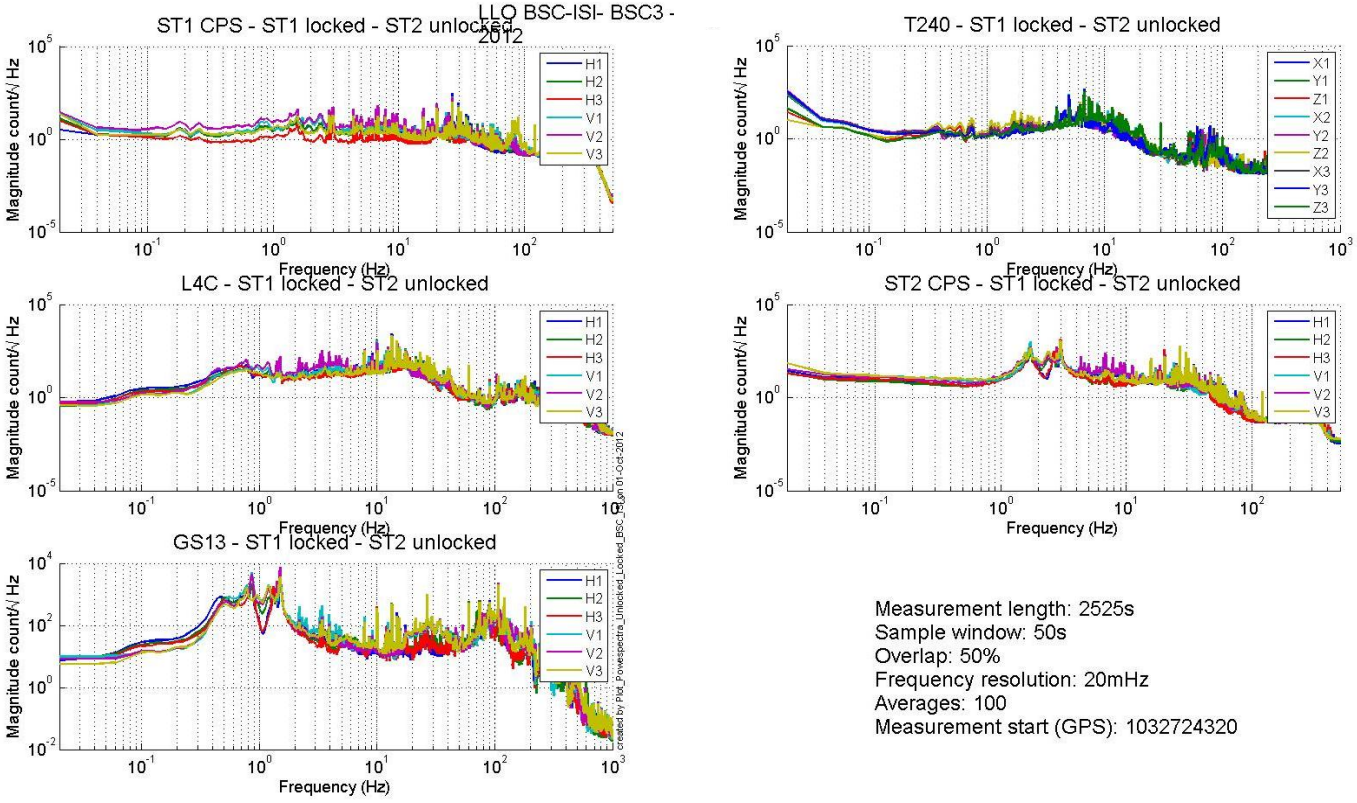


Figure 12: Spectra Stage 1 Locked Stage 2 Unlocked

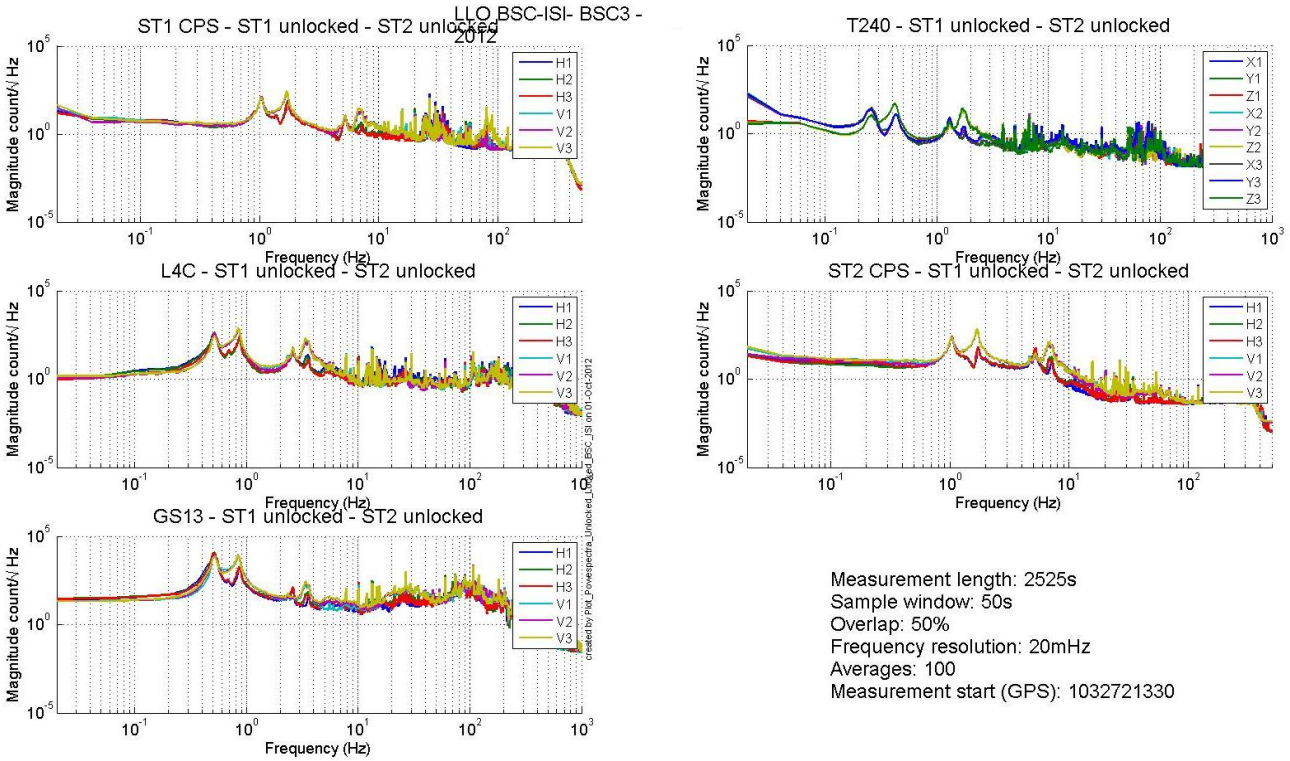


Figure 13: Spectra Stage 1 Unlocked Stage 2 Unlocked

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

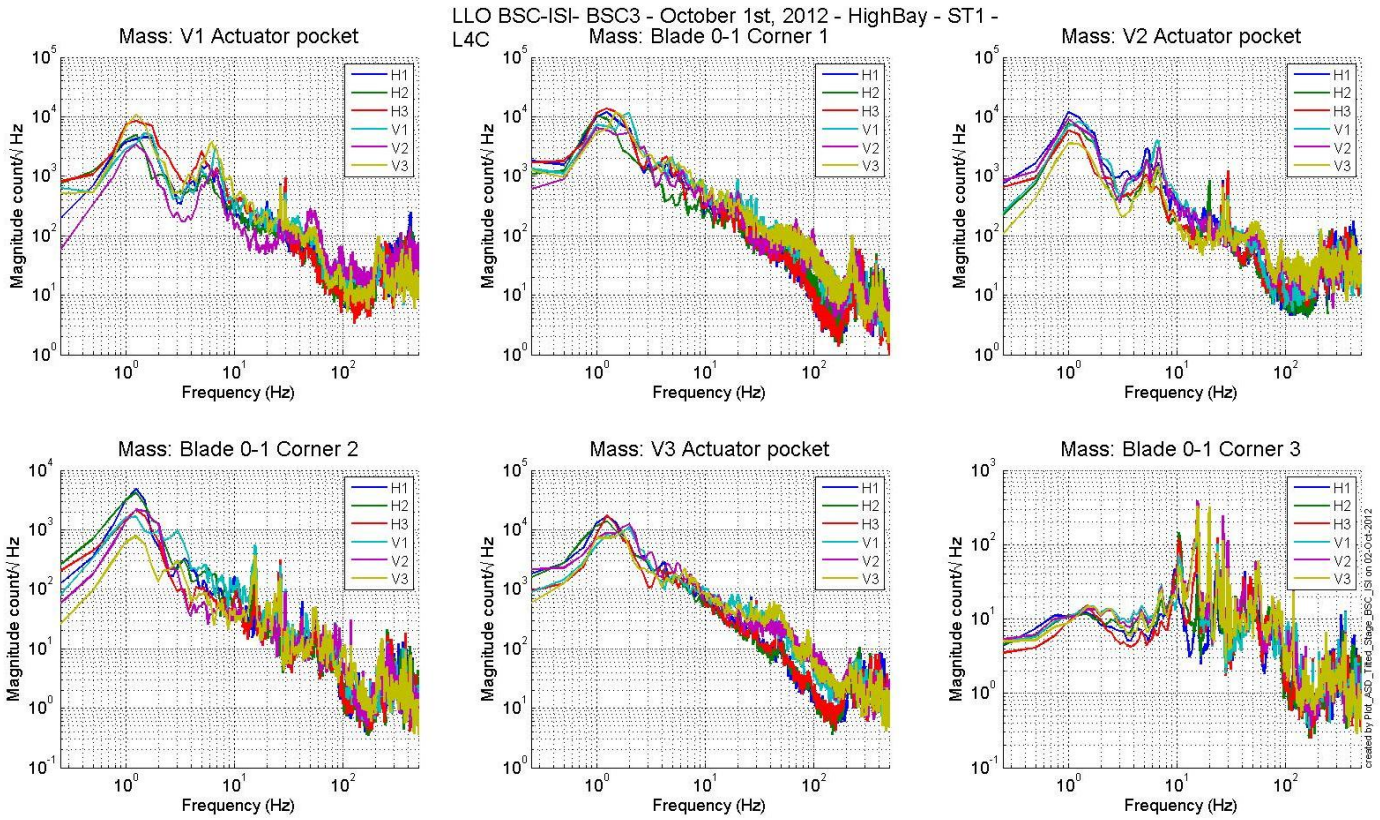


Figure 14 - ST1 L4C – Tilted

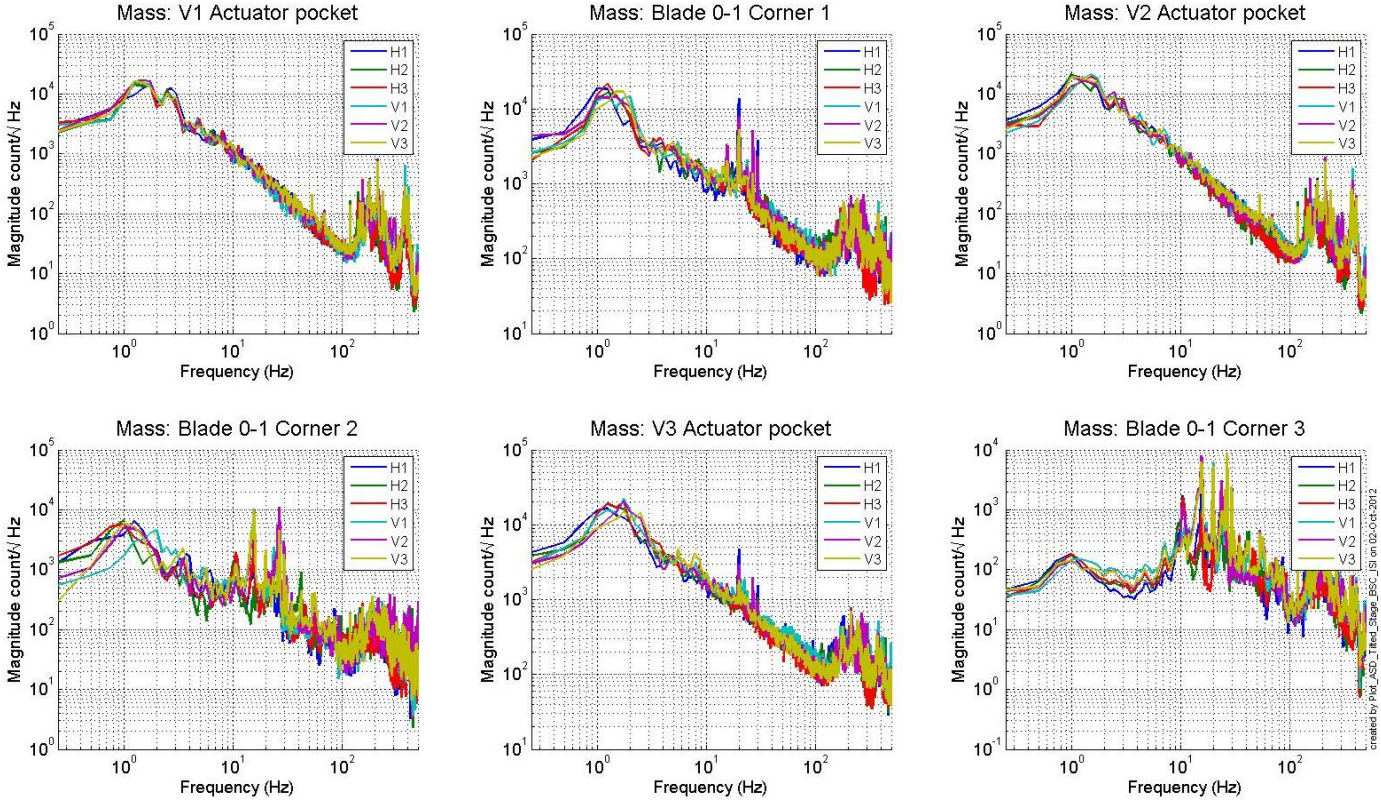


Figure 15 - ST1 GS13 – Tilted

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

Resistances of the couple actuator + cables are reported in the table below:

Actuator	Coil driver name	Resistance (Ω)
ST1 H1	Coil1 Coarse 1	6.7
ST2 H1	Coil 1 Fine 1	10.7
ST2 V1	Coil 1 Fine 2	10.6
ST1 V1	Coil 1 Coarse 2	6.7
ST1 H2	Coil 2 Coarse 1	6.8
ST2 H2	Coil 2 Fine 1	10.5
ST2 V2	Coil 2 Fine 2	11
ST1 V2	Coil 2 Coarse 2	6.7
ST1 H3	Coil 3 Coarse 1	6.6
ST2 H3	Coil 3 Fine 1	10.9
ST2 V3	Coil 3 Fine 2	10.8
ST1 V3	Coil 3 Coarse 2	6.8

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: __** **Failed: _X_** **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.

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-16875	498	16044	32919	39
ST1 - H2	-15944	1	16975	32919	39
ST1 - H3	-15162	-462	17430	32592	39
ST1 - V1	-14887	174	15160	30047	36
ST1 - V2	-14703	395	15414	30117	36
ST1 - V3	-15290	1012	17183	32473	39
ST2 - H1	-9241	943	11042	20283	6
ST2 - H2	-8897	1164	11222	20119	6
ST2 - H3	-9103	725	10527	19630	6
ST2 - V1	-10648	1315	13156	23804	7
ST2 - V2	-10469	1388	13255	23724	7
ST2 - V3	-11000	782	12564	23564	7

Table 14 - Range of motion - Local drive

Acceptance criteria:

- Amplitude must be at least 32000 counts (+/-0.02") for H Stage 1 CPS
- Amplitude must be at least 29000 counts (~0.010") for V Stage 1 CPS
- Amplitude must be at least 19000 counts (+/-0.02") for H Stage 2 CPS
- Amplitude must be at least 23000 counts (~0.010") for V Stage 2 CPS
- 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

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. Stage 1 is loaded with 3 x 10Kg masses and the measurements are repeated three times (by rotating the masses).

	No load	Load 15 Kg	Load 30Kg	Diff 1	Diff 2
V1	299.91	0.00	-14898.67	-299.91	-15198.58
V2	590.17	0.00	-14459.33	-590.17	-15049.50
V3	1345.10	0.00	-13750.33	-1345.10	-15095.43

-15114.50444	count
-17.99345767	mil
-1224.135579	lb/in
1.358938067	**%**

The blades from stage 0 to stage 1 are too soft by 1.35%.

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).

	No load	Load	Diff
V1	2233.10	-23029.67	25262.77
V2	1935.30	-23403.67	25338.97
V3	1489.80	-23895.33	25385.13

25328.96	count
7.54	mil
1448.19326	lb/in
1.147217777	%

The blades from stage 1 to stage 2 are too soft by 1.14%.

Note:

A dirty assembly was build at LASTI for fit-check and testing purpose before the first assembly at LHO & LLO. During balancing, the total added mass on top of stage 2 to simulate the payload was far from nominal. Investigations on the blades stiffness showed an extra softness of the blade of both stages. But the mass deduction to compensate this extra softness didn't explain the difference with the nominal payload. In order to be closer to the nominal payload, the angles of the blade spacers were corrected (correction equivalent to +253lb on stage 0-1 blade and +507lb on stage 1-2 blade). These discrepancies between the initial design and assembly can be explained by:

- Inaccuracy in Solidworks estimation. It might underestimate masses of actual components (metal parts, hardware, instruments...)
- Measurement errors of the blade stiffness
- Machining errors (launch angles, assembly stack up...)
- Extra compliance due to the stages deformation

This is the third Unit built at LLO, but the first one using Silver Plated Eastwood SHCS to clamp the Spring Blade which allows a better friction coefficient and thus for the same torque value more clamping force than with the previous Stainless Eastwood Bolts. Since our first Unit, we also use oversized .5015" dowel pins, with the Blade brought as far back as possible to guarantee repeatability. The very good results on the Mass Budget and on this Vertical Spring Constant Test show us that switching from the Stainless to the Silver Plated Bolts was the right decision!

Facts:

- Nominal load on Stage 0-1 blades is 8240 lb (per initial design estimation)
- -1.35% of 8240 lb is -111.24 lbs.
- +253 lb are compensated per ST1 - launch angle correction (E1100284, line 9)
- So we should be at +253-111.24= 142 lb over nominal (64kg).

But in reality, we are 80 kg too light, so we have 80 + 64 = 144 kg unexplained!
Therefore, we will have another iteration of angled Blade Spacers made for our last two Units, with different launching angle to try to come closer to the Plan.

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

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

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

The static tests results are reported in the SVN at :
/seismic/BSC-ISI/X2/BSC3/Data/Static_Tests/

- LLO_ISI_BSC3_Offset_Local_Drive_20120926.mat

Actuators \ Sensors	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - H1	4366.9	1762.3	1756.9	22.3	-21.9	-9.3
ST1 - H2	1757.6	4376.1	1761.9	-1.9	-4.5	-17.3
ST1 - H3	1742.9	1758.3	4338.5	2.4	6.1	17.2
ST1 - V1	73.5	-151.6	119.1	3540.7	-658.7	-650.4
ST1 - V2	108.4	36.9	-159.0	-631.0	3529.7	-695.8
ST1 - V3	-152.8	117.1	79.1	-664.1	-625.3	3803.9

Table 15 - Static test - Local to local - Stage 1

Actuators \ Sensors	ST1 - H1 (min, max)		ST1 - H2 (min, max)		ST1 - H3 (min, max)		ST1 - V1 (min, max)		ST1 - V2 (min, max)		ST1 - V3 (min, max)	
ST1 - H1	4333.0	4462.0	1716.0	1780.0	1744.7	1794.0	-15.0	29.0	-23.2	-7.0	14.0	19.8
ST1 - H2	1715.0	1770.8	4224.0	4393.3	1705.0	1786.2	-15.5	8.5	-22.5	46.2	-8.7	7.0
ST1 - H3	1734.0	1748.5	1716.0	1759.7	4246.0	4363.1	-17.8	2.0	-5.3	3.8	8.8	65.4
ST1 - V1	33.3	79.0	-184.6	-161.6	75.4	109.0	3481.0	3587.0	-665.0	-616.5	-607.9	-588.0
ST1 - V2	91.0	132.0	34.0	87.0	-178.3	-135.0	-614.8	-597.3	3385.0	3560.3	-664.8	-615.0
ST1 - V3	-159.1	-102.0	93.0	128.0	31.0	76.0	-648.9	-591.0	-636.0	-570.0	3347.0	3604.1

Table 16: Static Test – Local to Local – Stage 1 Results (min & max) from the previous BSC Units

Actuators \ Sensors	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - H1	2389.6	351.6	353.7	-33.6	-46.3	-64.9
ST2 - H2	341.7	2365.1	371.0	-15.6	-27.2	-81.4
ST2 - H3	340.5	351.3	2313.9	-56.5	-33.8	-66.4
ST2 - V1	66.6	115.7	-215.2	2769.6	274.8	-106.4
ST2 - V2	-200.0	50.3	99.7	-80.5	2599.9	225.5
ST2 - V3	101.3	-229.2	79.8	250.7	-46.4	2707.1

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

Actuators	Sensors											
	ST2 – H1 (min, max)		ST2 - H2 (min, max)		ST2 - H3 (min, max)		ST2 - V1 (min, max)		ST2 - V2 (min, max)		ST2 - V3 (min, max)	
ST1 - H1	2316.0	2439.3	349.5	383.5	337.0	371.0	1.7	18.0	-77.9	50.1	-10.4	36.0
ST1 - H2	324.0	366.4	2338.0	2454.7	336.3	373.0	-65.8	27.0	-85.9	62.3	-12.0	51.4
ST1 - H3	311.0	406.5	341.5	411.4	2332.0	2390.7	-77.1	31.0	-79.7	59.4	-134.8	53.9
ST1 - V1	65.0	107.4	122.0	142.3	-220.0	-203.1	2773.0	3018.1	213.4	349.0	-62.2	59.5
ST1 - V2	-244.0	-153.0	68.7	180.9	94.0	127.0	-161.4	15.1	2891.9	2937.0	242.7	400.9
ST1 - V3	78.5	163.2	-202.1	-152.6	41.0	97.0	266.3	349.0	-140.0	-27.4	2830.1	2960.0

Table 18: Static Test – Local to Local – Stage 2 Results (min & max) from the previous BSC Units

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

Reference tables for acceptance criteria:

Actuators	Sensors					
	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - H1	4380	1750	1750	0	0	0
ST1 - H2	1750	4380	1750	0	0	0
ST1 - H3	1750	1750	4380	0	0	0
ST1 - V1	50	-170	90	3500	-650	-650
ST1 - V2	90	50	-170	-650	3500	-650
ST1 - V3	-170	90	50	-650	-601	3500

Table - Main couplings – Static – Stage 1

Actuators	Sensors					
	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - H1	2401	360	360	0	0	0
ST2 - H2	360	2401	360	0	0	0
ST2 - H3	360	360	2377	0	0	0
ST2 - V1	80	130	-200	3050	330	0
ST2 - V2	-200	80	130	0	2950	330
ST2 - V3	130	-200	80	330	0	2950

Table - Main couplings – Static – Stage 2

Test result: **Passed: __** **Failed: X** **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 table below shows the main and the cross-coupling when the actuators are driven in the Cartesian basis:

The static tests results are reported in the SVN at :
/seismic/BSC-ISI/X2/BSC3/Data/Static_Tests/

- LLO_ISI_BSC3_Offset_Cartesian_Drive_20120926.mat

Actuators	Sensors					
	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - X	1745	-863	-862	1	-17	-12
ST1 - Y	22	1519	-1485	3	-7	-22
ST1 - Z	8	-19	-6	746	748	824
ST1 - RX	-18	126	-165	-2937	2470	486
ST1 - RY	-196	110	100	-1173	-1955	3310
ST1 - RZ	3191	3186	3172	-12	-24	8

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

Actuators	Sensors											
	ST1 - H1 (min, max)		ST1 - H2 (min, max)		ST1 - H3 (min, max)		ST1 - V1 (min, max)		ST1 - V2 (min, max)		ST1 - V3 (min, max)	
ST1 - X	1733.6	1803.0	-868.3	-839.0	-859.8	-812.0	-26.0	23.0	-3.0	0.4	-26.1	32.5
ST1 - Y	-32.0	12.3	1493.0	1527.9	-1505.1	-1463.8	-15.6	14.3	-11.4	55.2	-46.6	-14.0
ST1 - Z	-33.0	-3.0	-14.0	0.6	-27.5	16.0	728.5	772.0	709.0	758.3	711.0	784.6
ST1 - RX	-7.3	40.0	152.1	189.0	-150.8	-137.0	-2918.3	-2877.0	2408.0	2469.0	413.8	452.0
ST1 - RY	-196.5	-162.0	77.0	111.0	64.2	120.0	-1185.9	-1119.0	-1955.6	-1871.0	2959.0	3182.3
ST1 - RZ	3162.0	3230.0	3124.0	3229.0	3166.0	3213.3	-20.5	18.0	-32.9	23.0	-27.0	43.6

Table 20 - Static test cartesian drive – Cartesian to local – Stage 1 Results (min & max) from the previous BSC Units

Actuators \ Sensors	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - X	665	-1354	658	-63	16	1
ST2 - Y	1158	-18	-1137	-89	-43	-103
ST2 - Z	9	-1	-13	1019	956	929
ST2 - RX	-276	-25	283	-2398	2289	-112
ST2 - RY	156	-319	157	-1474	-1257	2644
ST2 - RZ	1758	1766	1741	-101	8	-66

Table 21 - Static test cartesian drive – Cartesian to local – Stage 2

Actuators \ Sensors	ST2 - H1 (min, max)		ST2 - H2 (min, max)		ST2 - H3 (min, max)		ST2 – V1 (min, max)		ST2 - V2 (min, max)		ST2 - V3 (min, max)	
ST2 - X	670.0	716.0	-1389.8	-1312.0	653.0	676.0	-34.4	31.0	-79.0	15.0	-77.7	44.0
ST2 - Y	1144.0	1198.0	-52.5	18.0	-1193.9	-1153.0	-33.0	42.0	-136.0	10.0	-62.0	15.0
ST2 - Z	-3.0	19.9	-15.5	12.1	-33.0	14.0	1017.9	1133.0	939.0	1135.0	982.4	1104.0
ST2 - RX	-312.0	-277.0	-3.0	45.5	243.5	288.0	-2572.0	-2469.1	2352.0	2574.0	-153.7	-49.0
ST2 - RY	116.6	200.0	-405.4	-303.0	116.0	189.0	-1595.0	-1499.7	-1513.4	-1123.3	2762.7	2972.0
ST2 - RZ	1738.0	1797.0	1715.0	1822.0	1728.0	1792.0	-81.3	46.0	-122.0	7.0	-64.0	47.5

Table 22 - Static test cartesian drive – Cartesian to local – Stage 2 Results (min & max) from the previous BSC Units

Reference table static test Cartesian to local:

Actuators \ Sensors	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - X	1800	-820	-820	0	0	0
ST1 - Y	0	1500	-1500	0	0	0
ST1 - Z	0	0	0	772	750	700
ST1 - RX	0	160	-160	-2950	2450	450
ST1 - RY	-200	110	70	-1150	-2000	3050
ST1 - RZ	3200	3200	3200	0	0	0

Table 23 - Reference table - Cartesian to Local - Stage 1

Actuators \ Sensors	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - X	700	-1350	650	0	0	0
ST2 - Y	1200	0	-1150	0	0	0
ST2 - Z	0	0	0	1100	1100	1100
ST2 - RX	-300	0	300	-2500	2500	-50
ST2 - RY	200	-300	200	-1500	-1400	3000
ST2 - RZ	1800	1800	1800	40	40	40

Table 24 - Reference table - Cartesian to Local - Stage 2

Acceptance criteria:

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

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

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

The static tests results are reported in the SVN at :
/seismic/BSC-ISI/X2/Data/BSC3/Static_Tests/

- LLO_ISI_BSC3_Offset_Cartesian_Drive_20120926.mat

Actuators	Sensors					
	ST1 - X	ST1 - Y	ST1 - Z	ST1 - RX	ST1 - RY	ST1 - RZ
ST1 - X	1732	-1	-7	-1	-5	12
ST1 - Y	-8	1747	-6	2	-4	16
ST1 - Z	-12	1	775	15	58	0
ST1 - RX	5	368	7	3052	19	-15
ST1 - RY	-387	12	67	25	3188	12
ST1 - RZ	-18	19	-27	2	12	3314

Table 25 - Static Test - Cartesian to Cartesian – Stage 1

Actuators	Sensors											
	ST1 - X (min, max)		ST1 - Y (min, max)		ST1 - Z (min, max)		ST1 - RX (min, max)		ST1 - RY (min, max)		ST1 - RZ (min, max)	
ST1 - X	1715.0	1772.1	-12.4	9.0	4.1	10.9	-13.5	6.0	-20.6	1.0	-2.0	59.0
ST1 - Y	-9.1	8.7	1720.0	1734.4	-12.4	11.0	-10.0	31.2	-54.3	3.0	-4.0	24.4
ST1 - Z	-15.0	10.2	-8.7	17.0	729.0	753.0	-25.0	6.2	-27.0	3.9	-14.9	-4.0
ST1 - RX	-6.0	40.8	351.9	380.0	-25.0	-5.2	2985.0	3058.0	-23.5	7.0	-9.0	29.0
ST1 - RY	-384.6	-342.0	-5.6	16.0	-19.7	5.0	-5.0	17.0	2901.0	3068.7	-5.1	9.8
ST1 - RZ	-12.9	24.0	-4.0	4.1	-21.0	16.0	-6.0	19.5	-2.0	20.0	3276.0	3346.1

Table 26 - Static Test - Cartesian to Cartesian – Stage 1 Results (min & max) from the previous BSC Units

Actuators	Sensors					
	ST2 - X	ST2 - Y	ST2 - Z	ST2 - RX	ST2 - RY	ST2 - RZ
ST2 - X	1333	40	-24	38	22	-16
ST2 - Y	32	1337	-43	-5	3	14
ST2 - Z	6	13	968	-38	10	-9
ST2 - RX	21	-11	-155	4007	64	-9
ST2 - RY	33	-1	-47	112	4086	-8
ST2 - RZ	-13	18	-69	21	2	2536

Table 27 - Static Test - Cartesian to Cartesian – Stage 2

Actuators	Sensors											
	ST2 - X (min, max)		ST2 - Y (min, max)		ST2 - Z (min, max)		ST2 - RX (min, max)		ST2 - RY (min, max)		ST2 - RZ (min, max)	
ST2 - X	1317.0	1377.4	-16.2	25.0	-53.4	29.0	-22.0	55.5	-18.6	24.0	-10.1	24.0
ST2 - Y	-10.0	13.0	1331.0	1358.0	-53.2	20.0	-53.0	59.0	-41.6	55.0	-26.2	34.0
ST2 - Z	-6.0	24.9	-17.2	2.0	1022.5	1114.0	-91.0	52.7	-73.0	28.0	-18.0	14.0
ST2 - RX	-62.3	8.0	-31.1	-8.5	-98.0	22.0	4223.0	4356.2	-105.3	58.0	-18.0	26.2
ST2 - RY	-8.0	40.3	-17.8	30.0	-127.1	56.9	15.0	241.5	4055.2	4319.0	-39.2	24.0
ST2 - RZ	-9.5	21.0	-7.2	9.0	-71.6	29.0	-35.0	73.9	-28.9	52.0	2509.0	2602.0

Table 28 - Static Test - Cartesian to Cartesian – Stage 2 Results (min & max) from the previous BSC Units

Reference table static test Cartesian to Cartesian:

Actuators	Sensors					
	ST1 - X	ST1 - Y	ST1 - Z	ST1 - RX	ST1 - RY	ST1 - RZ
ST1 - X	1750	0	0	0	0	0
ST1 - Y	0	1750	0	0	0	0
ST1 - Z	0	0	750	0	0	0
ST1 - RX	0	375	0	3000	0	0
ST1 - RY	-375	0	0	0	3000	0
ST1 - RZ	0	0	0	0	0	3300

Actuators	Sensors					
	ST2 - X	ST2 - Y	ST2 - Z	ST2 - RX	ST2 - RY	ST2 - RZ
ST2 - X	1350	10	30	0	25	20
ST2 - Y	-10	1350	20	-25	0	20
ST2 - Z	0	0	1100	-10	-30	20
ST2 - RX	10	-15	20	4300	30	20
ST2 - RY	30	0	30	40	4300	20
ST2 - RZ	0	10	30	-25	-15	2600

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

Note: We have highlighted in yellow the values that don't satisfy the acceptance criteria. But by comparing these values with the ones from the previous Units built at LHO and LLO, we can clearly see that they are similar to our previous results and therefore acceptable!

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

- ***Step 12 - Linearity test***

The linearity test figure are reported in the SVN at :
/seismic/BSC-ISI/X2/BSC3/Data/Figures/Linearity_Test/

- LLO_ISI_BSC3_Linearity_test_20121004.fig
- LLO_ISI_BSC3_Linearity_test_20121004.pdf

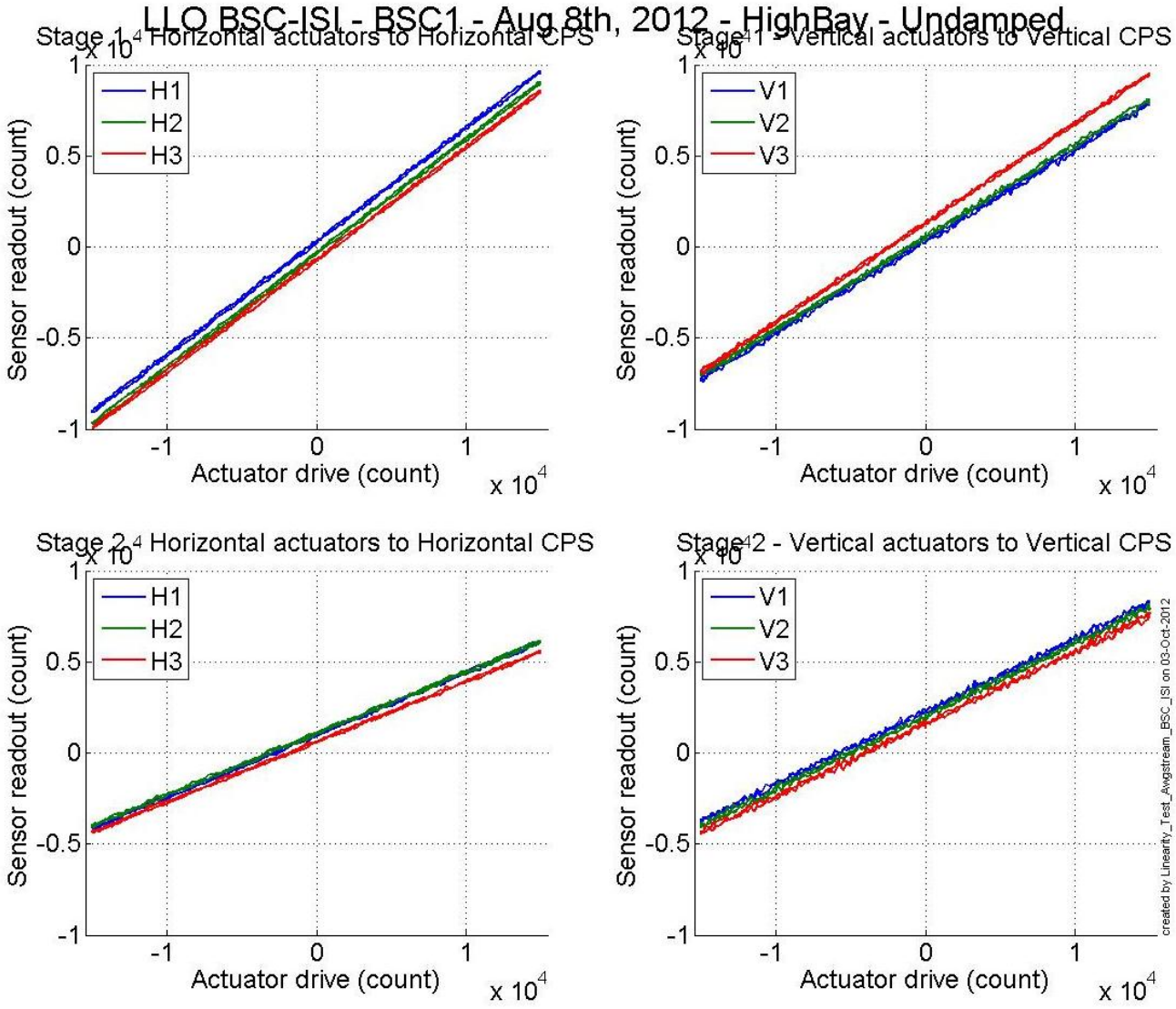


Figure 16 - Linearity Test

Slope – Offset:

		Slope	Offset	Average slope	Variation from average (%)
Stage 1	ST1 - H1	0.62119	303	0.6195	0.271
	ST1 - H2	0.62351	-333		0.645
	ST1 - H3	0.61384	-686		-0.916
	ST1 - V1	0.50231	325	0.5165	-2.755
	ST1 - V2	0.50374	549		-2.477
	ST1 - V3	0.54356	1335		5.232
Stage 2	ST2 - H1	0.34062	987	0.3356	1.488
	ST2 - H2	0.33679	1078		0.346
	ST2 - H3	0.32947	614		-1.834
	ST2 - V1	0.39743	2270	0.3974	0.014
	ST2 - V2	0.39906	2014		0.422
	ST2 - V3	0.39565	1603		-0.436

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

Previous Results:

		Averages (LHO Unit 1 & 2, LLO Unit 1 & 2)				Comparisons with LLO Unit 3	
		Slope	Offset	Average slope	Standard Deviation to Average Slope	% Slope Previous Units/ LLO Unit 3 Slope	% Average Slope of Previous Units / LLO Unit 3 Average Slope
Stage 1	ST1 - H1	0.631	36.584	0.624	0.002	-1.538	-0.68
	ST1 - H2	0.622	-130.014			0.201	
	ST1 - H3	0.618	60.969			-0.719	
	ST1 - V1	0.503	292.270	0.501	0.003	-0.138	2.95
	ST1 - V2	0.501	693.317			0.495	
	ST1 - V3	0.500	268.249			8.106	
Stage 2	ST2 - H1	0.345	899.569	0.343	0.002	-1.286	-2.11
	ST2 - H2	0.343	1702.082			-1.845	
	ST2 - H3	0.341	2331.741			-3.348	
	ST2 - V1	0.423	-878.881	0.419	0.003	-6.433	-5.43
	ST2 - V2	0.418	365.397			-4.810	
	ST2 - V3	0.415	-111.935			-4.892	

Looking at the average Slopes from the Previous BSC-ISI Units, we can see that this Unit follows the general trend.

Acceptance criteria:

- Horizontal and vertical slopes of the triplet actuators x BSC-ISI x sensors: Average slope +/- 2.5%

Note: The variation from average value on Stage 1 V1 and V3 is a little bit high (especially V3), such that we fail this test but looking at the comparisons with averages from the Previous Units, we can conclude that it is acceptable (within ~8%).
In order to find why Stage 1 V3 has a slightly different slope than the other Stage 1 V, we did a test that consists of driving Stage V3 in normal conditions and re-do this step with a different CPS box (Stage 1 H3) to make sure it is not coming from the CPS. With both a positive and a negative drive, we got very similar results, so in conclusion, this issue comes from the actuator V3.

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

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

Data files measurement of local to local transfer functions in SVN at:
/svncommon/SeiSVN/seismic/BSC-ISI/X2/BSC3/Data/Transfer_Functions/Measurements/Undamped

- LLO_ISI_BSC3_Data_L2L_10Hz_100Hz_ST1_ST2_20120927-153448.mat
- LLO_ISI_BSC3_Data_L2L_100mHz_700mHz_ST1_ST2_20120927-181139.mat
- LLO_ISI_BSC3_Data_L2L_700mHz_10Hz_ST1_ST2_20120928-015730.mat
- LLO_ISI_BSC3_Data_L2L_10mHz_100mHz_ST1_ST2_20120927-233431.mat
- LLO_ISI_BSC3_Data_L2L_100Hz_500Hz_ST1_ST2_20120927-141457.mat
- LLO_ISI_BSC3_Data_L2L_500Hz_1000Hz_ST1_ST2_20120927-131030.mat

Script file for processing and plotting local to local transfer functions in SVN at:
/seisvn/seismic/BSC-ISI/X2/Scripts/Control_Scripts

- Step_1_TF_L2L_10mHz_1000Hz_LLO_ISI_BSC2.m

Figures of local to local transfer functions (Main couplings) in SVN at:
/seisvn/seismic/BSC-ISI/X2/BSC3/Data/Figures/Transfer_Functions/Measurements/Undamped

- LLO_ISI_BSC3_TF_L2L_Raw_from_ST1_ACT_to_ST1_CPS_2012_09_28.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST1_ACT_to_ST1_L4C_2012_09_28.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_CPS_2012_09_28.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_GS13_2012_09_28.fig

Measured of local to local transfer functions in the SVN at:
/svncommon/seisvn/seismic/BSC-ISI/X2/BSC3/Data/Transfer_Functions/Simulations/Undamped

- LLO_ISI_BSC3_TF_L2L_Raw_10mHz_1000Hz_2012_06_06.mat

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

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

Note 3: We don't see any resonance of the Test Stand at 16Hz on Stage 1 CPS like LHO did.

Note 4: The first high frequency resonance observed on stage 1 by the L4C is at 216.4Hz. The next resonance is observed at 247.8Hz. The first mode of the blade has been measured at ~250Hz at LASTI, but it shouldn't be the Blades' resonances thanks to the Tuned Mass Dampers (tuned at 253 ± 4 Hz Hz) already installed on Stage 0-1 Blades on this Unit.

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. Also, we might have an issue with the GS-13 gain because they were saturating a lot, which can also explain the poor quality of the signal.

Note 6: On the ST2-ACT to ST2-GS13 transfer functions, the first high frequency resonances are observed at 120Hz (electric noise, harmonic of 60Hz?) and 141Hz.

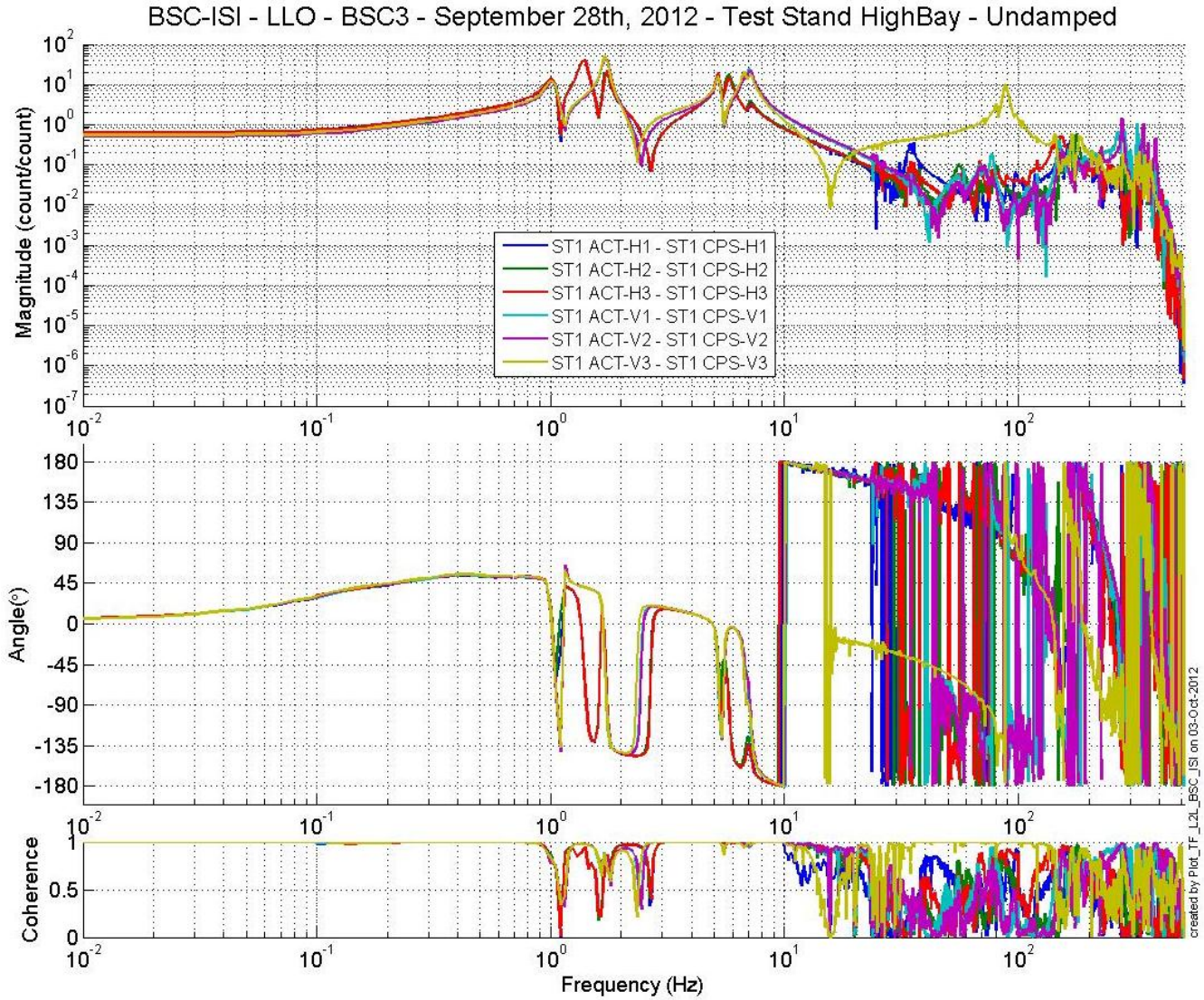


Figure 17: TF L2L Raw - ST1 Act to ST1 CPS

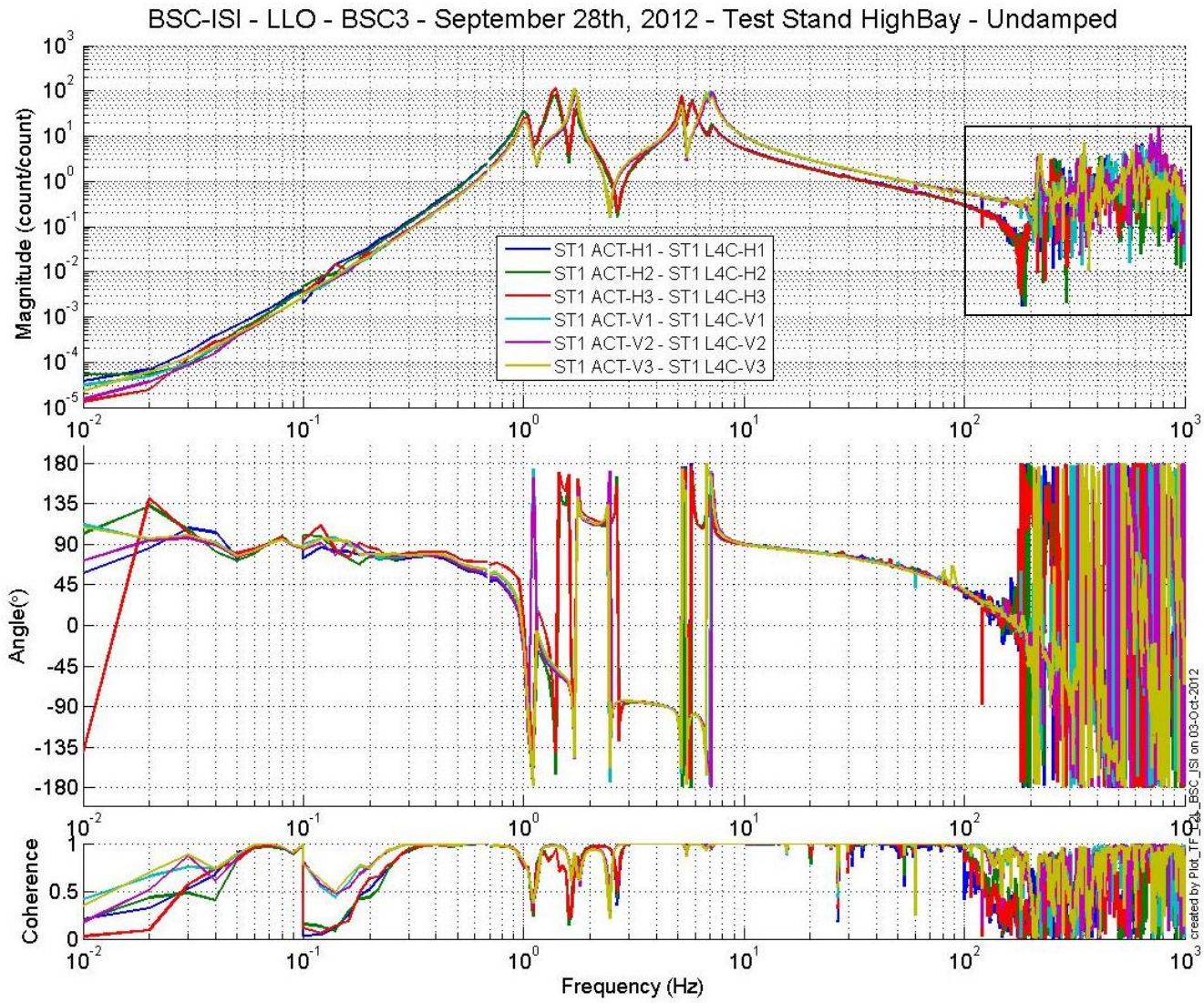
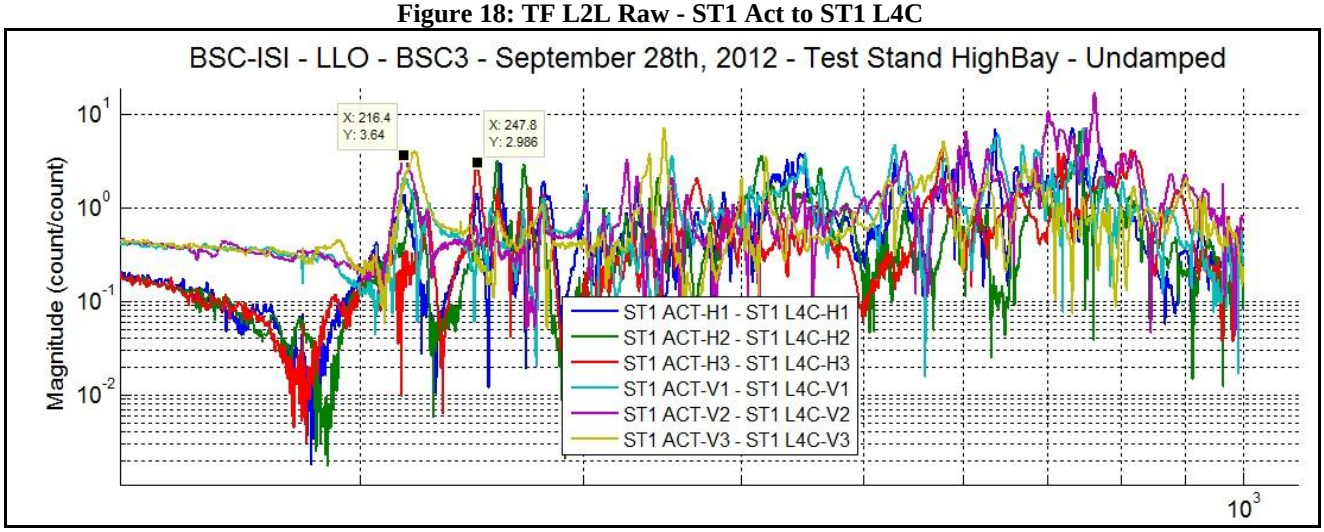


Figure 18: TF L2L Raw - ST1 Act to ST1 L4C



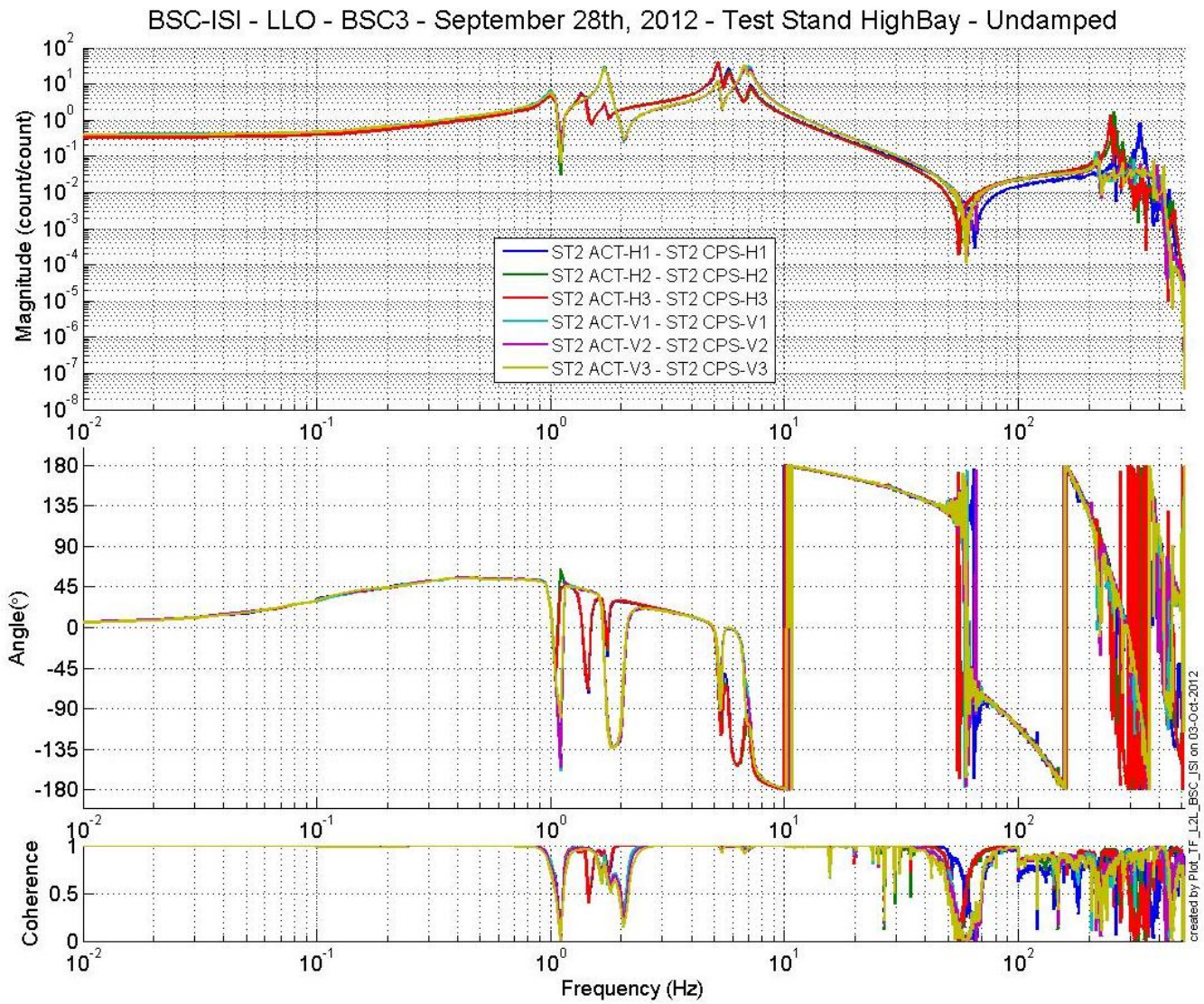


Figure 19: TF L2L Raw - ST2 Act to ST2 CPS

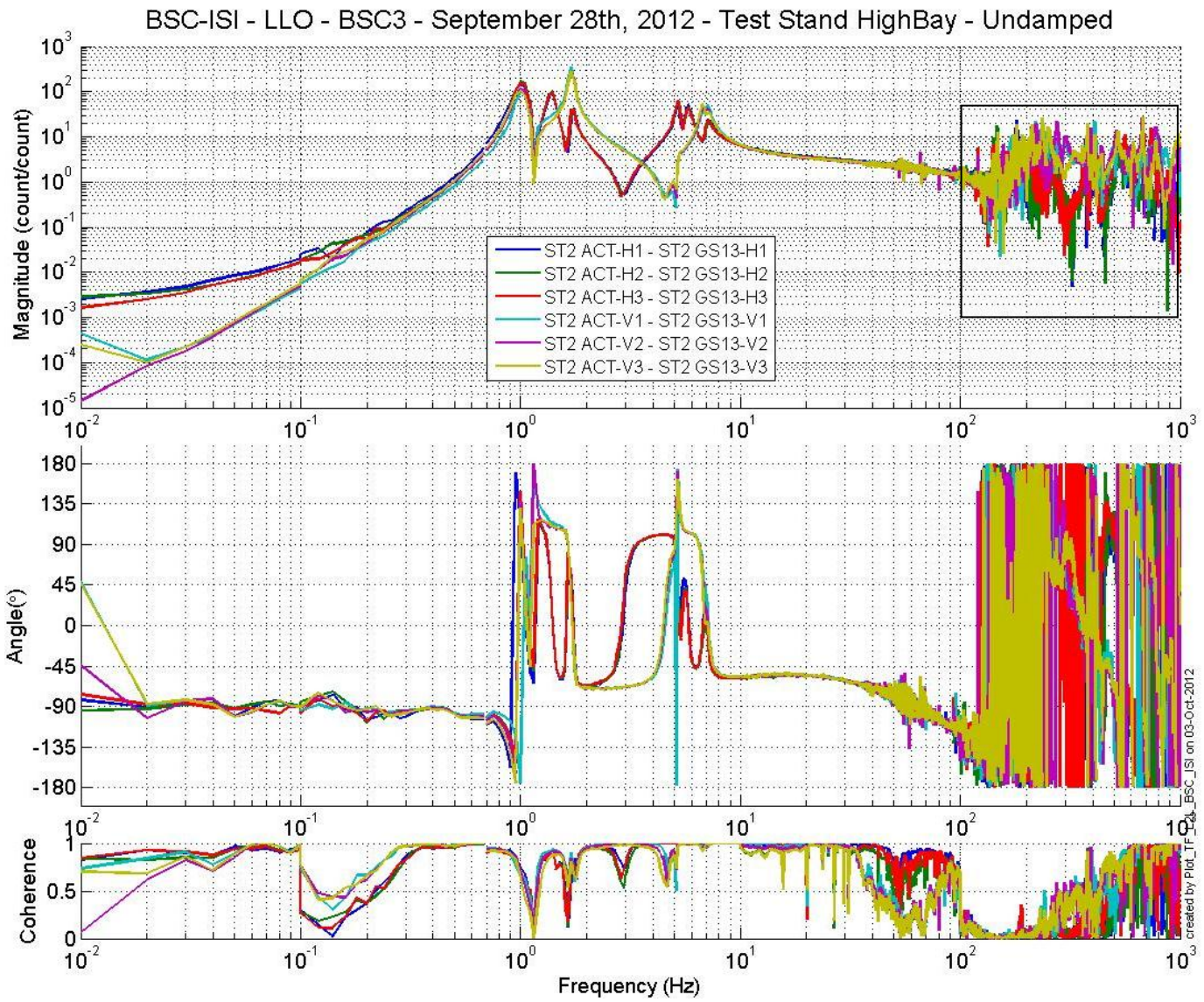
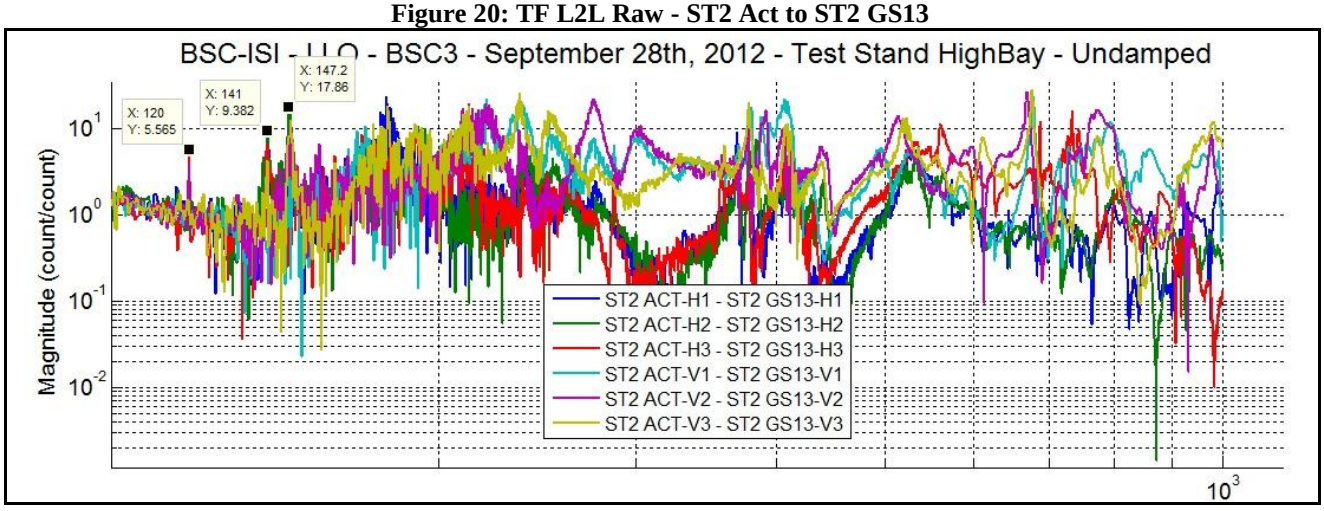


Figure 20: TF L2L Raw - ST2 Act to ST2 GS13



We then also decided to compare these results with previous Units (LHO BSC8 & LLO BSC2).

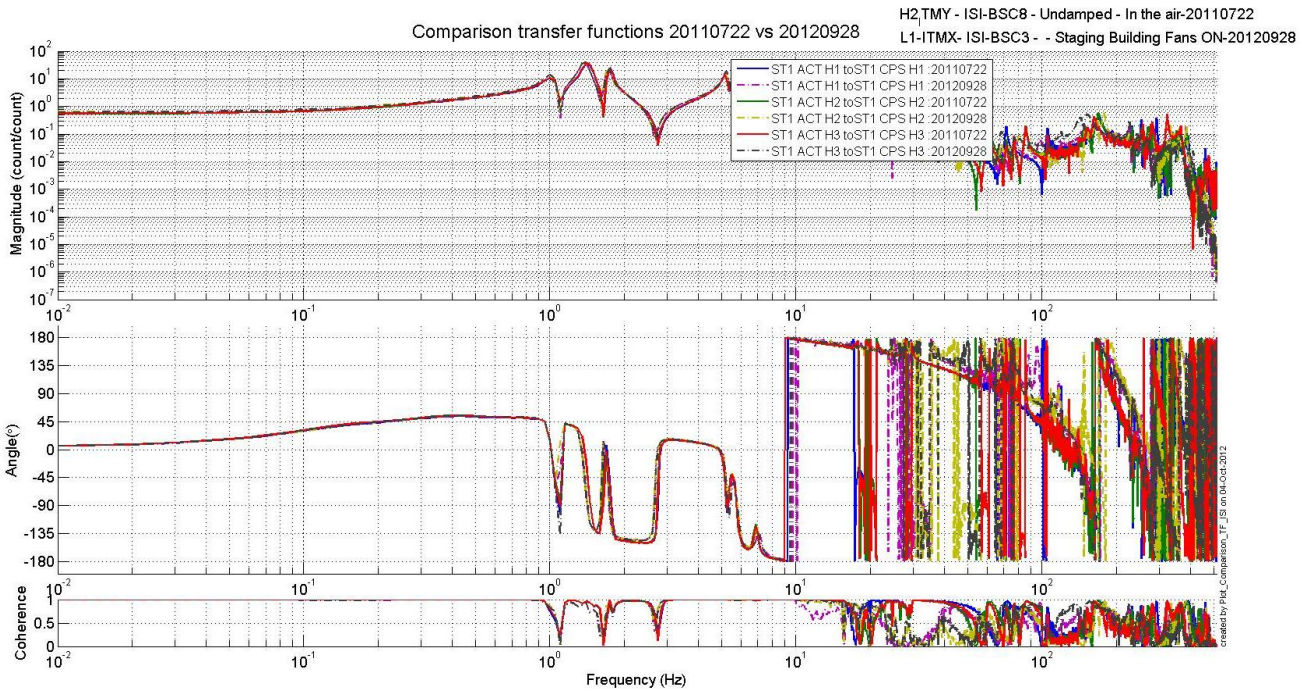


Figure 21: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 & BSC 2 – H ST1 Actuator to ST1 CPS

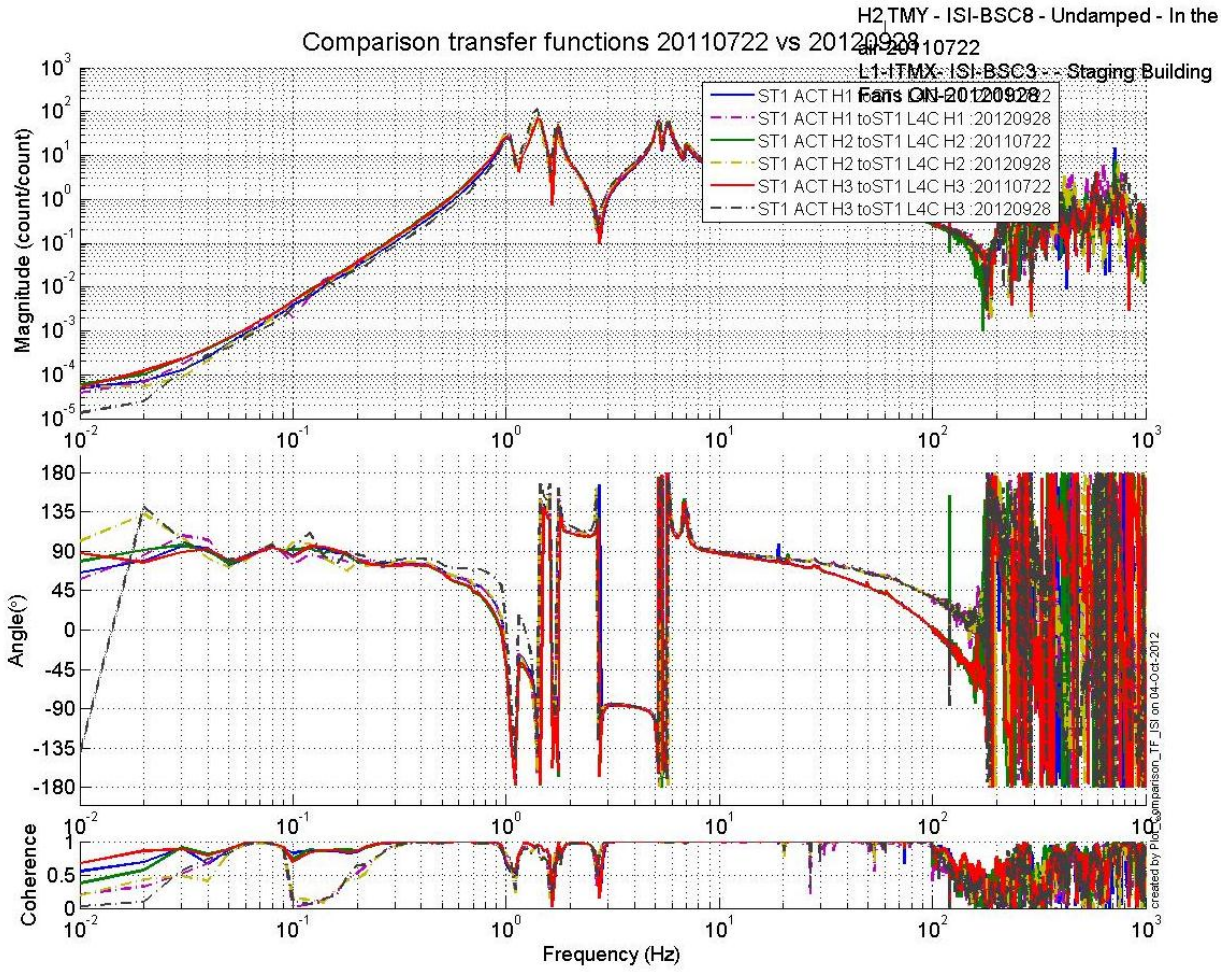


Figure 22: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 & BSC 2 – H ST1 Actuator to ST1 L4C

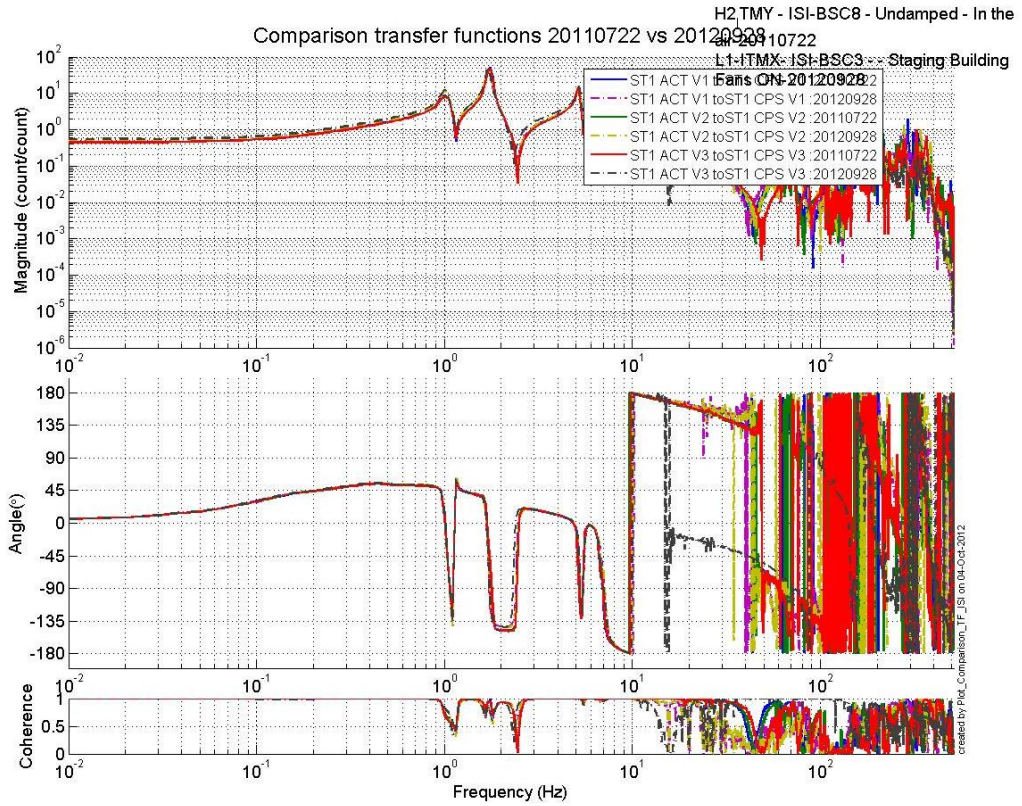


Figure 23: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 & BSC 2 – V ST1 Actuator to ST1 CPS

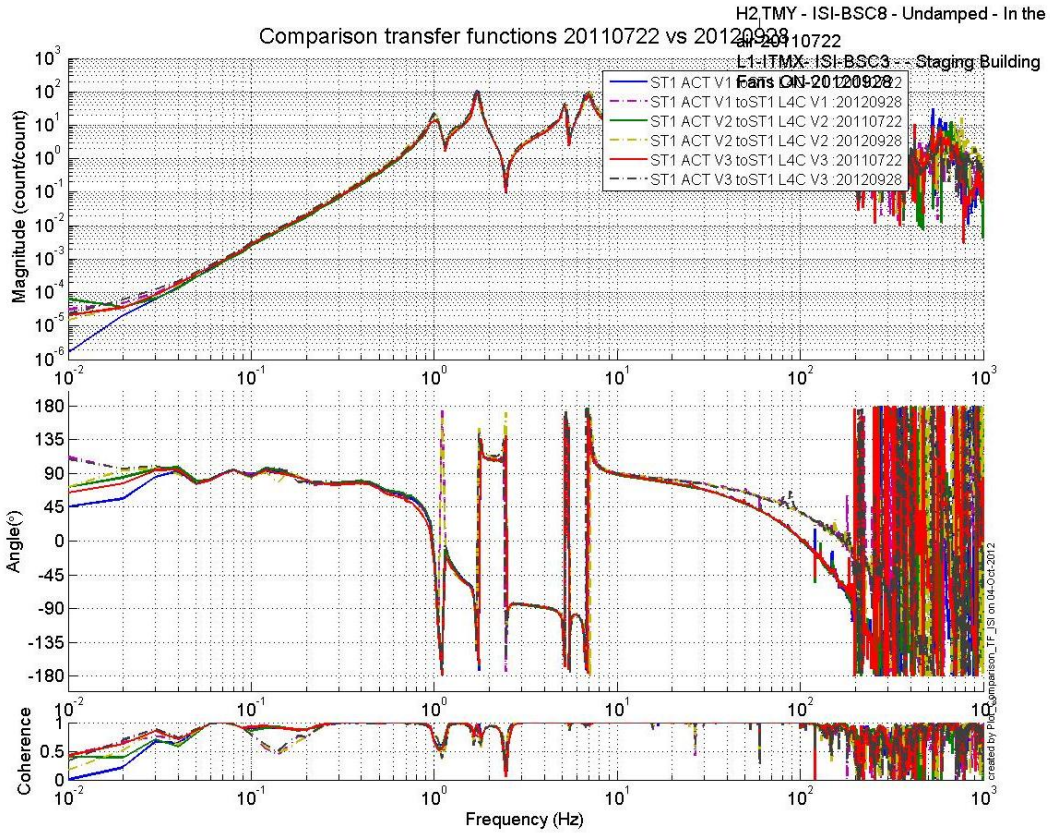


Figure 24: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 & BSC 2 – V ST1 Actuator to ST1 L4C

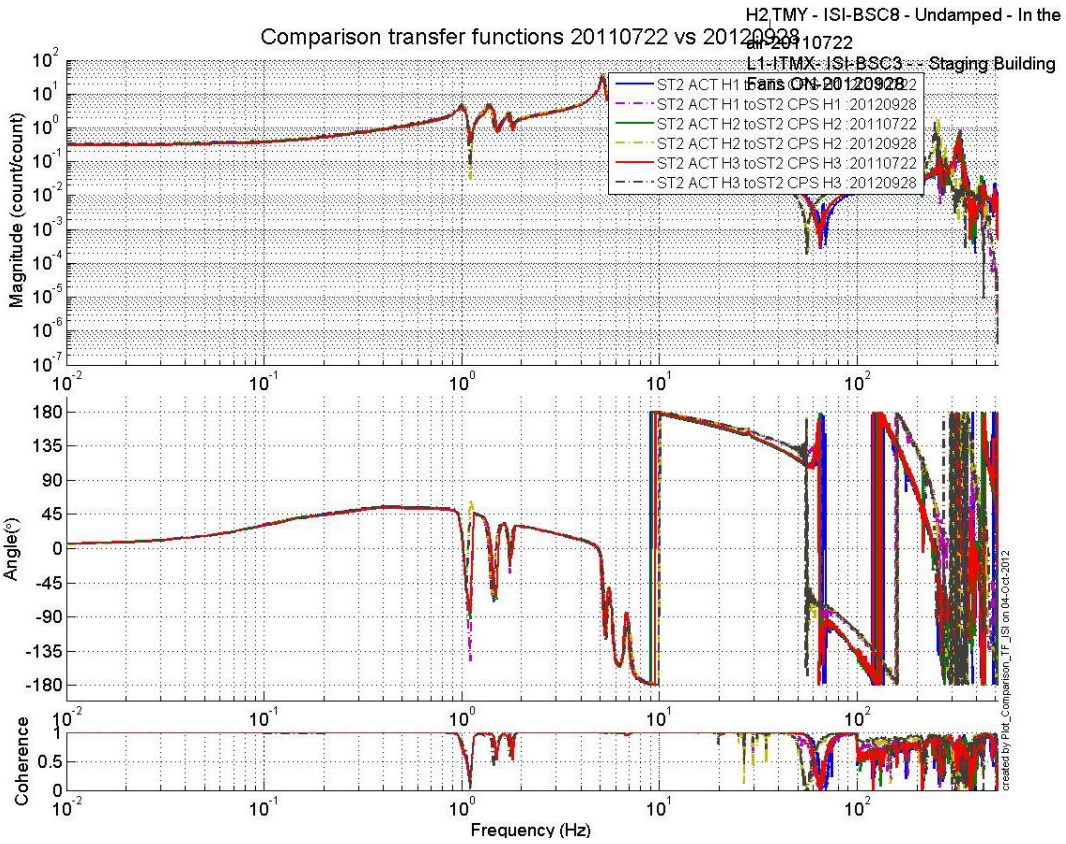


Figure 25: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 & BSC 2 – H ST2 Actuator to ST2 CPS

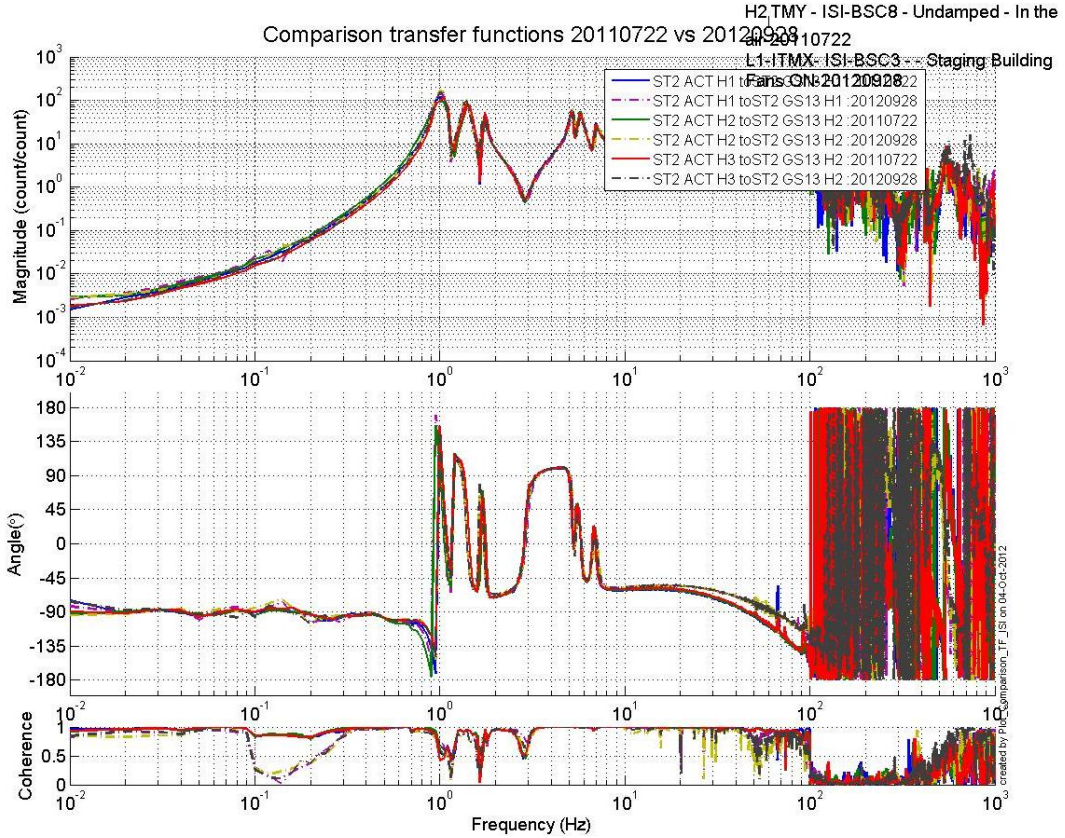


Figure 26: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 & BSC 2 – H ST2 Actuator to ST2 GS13

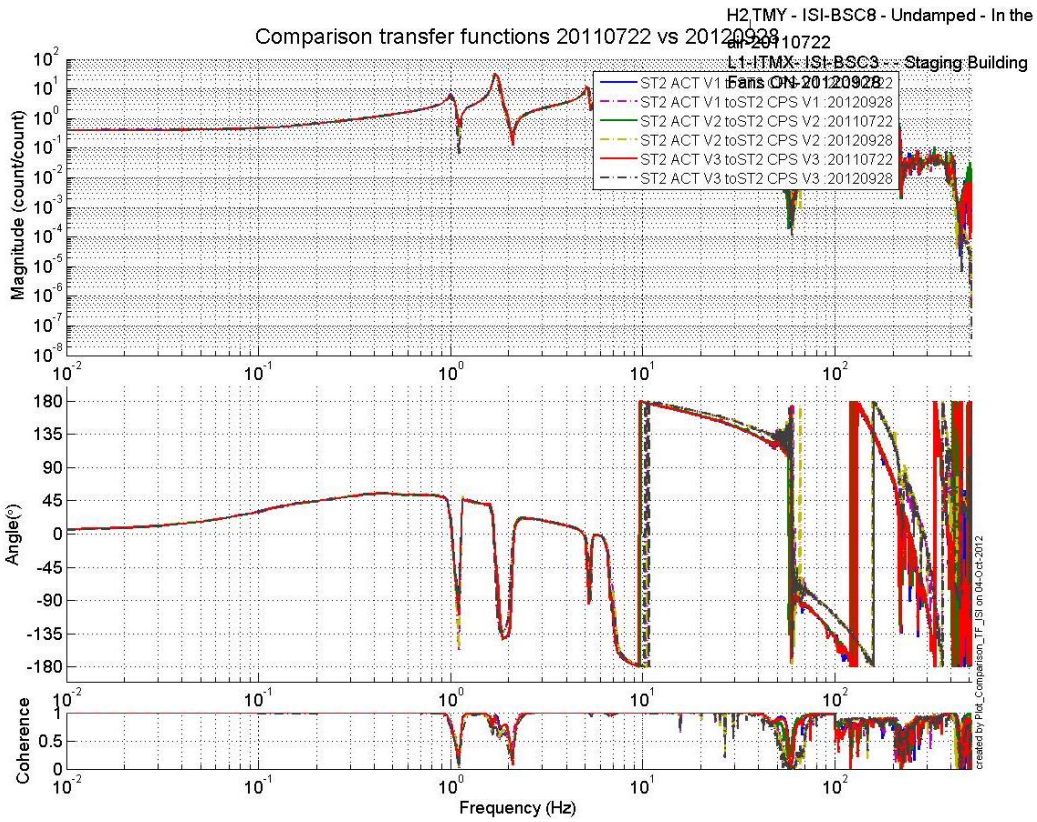


Figure 27: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 & BSC 2 – V ST2 Actuator to ST2 CPS

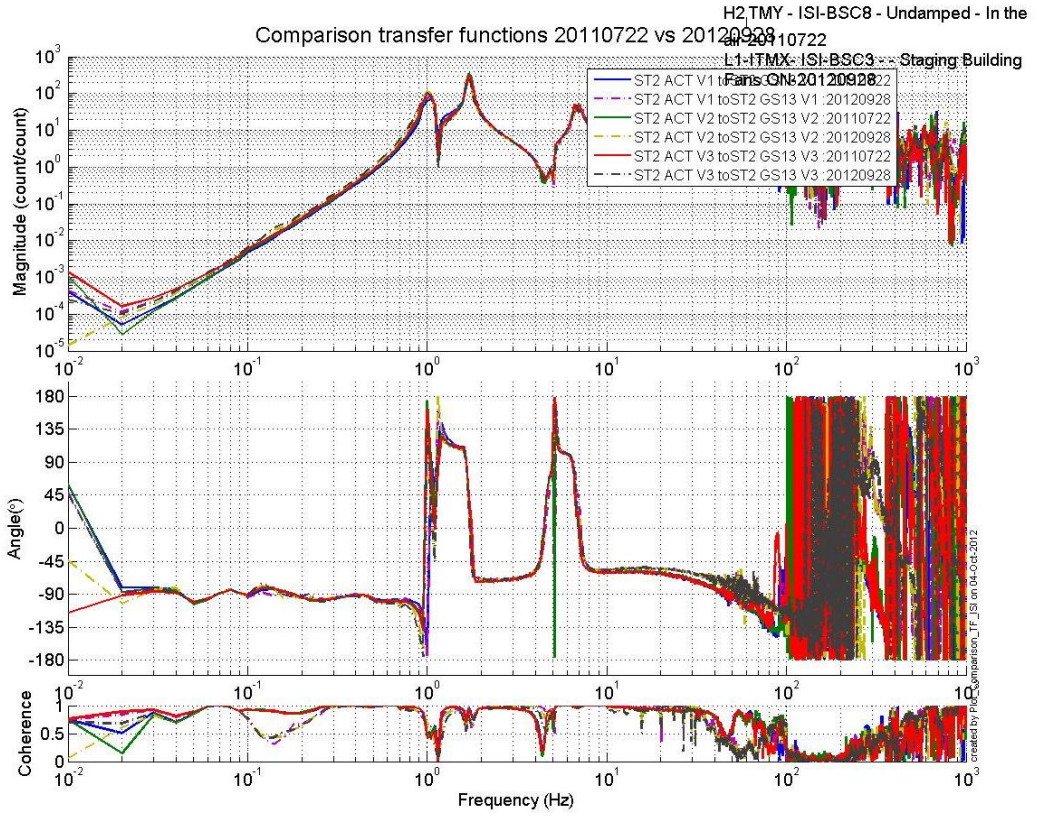


Figure 28: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 & BSC 2 – V ST2 Actuator to ST2 GS13

By comparing it to BSC 8 & BSC 2, we can conclude that BSC 3 is in the general trend of the previous BSCs built!

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

Due to schedule pressure, it was decided it was reasonable to postpone the following tests. They will be performed during Phase II.

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

Not performed

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

Not performed

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

Not performed

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

Not performed

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

Not performed

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

Not performed

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

Not performed

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

Data files measurement of damping Power Spectra in SVN at:
/svncommon/SeiSVN/seismic/BSC-ISI/X2/BSC3/Data/Spectra/Damping

- LLO_ISI_BSC3_ASD_m_L4C_GS13_Undamped_vs_Damping_2012_10_04_090654.mat

Figures of local to local transfer functions (Main couplings) in SVN at:
/seisvn/seismic/BSC-ISI/X2/BSC3/Data/Figures/Spectra/Damping

- LLO_ISI_BSC3_ASD_CT_CART_ST1_L4C_Undamped_vs_Damping_2012_10_04_090654.fig
- LLO_ISI_BSC3_ASD_m_CART_ST1_L4C_Undamped_vs_Damping_2012_10_04_090654.fig
- LLO_ISI_BSC3_ASD_CT_CART_ST2_GS13_Undamped_vs_Damping_2012_10_04_090654.fig
- LLO_ISI_BSC3_ASD_m_CART_ST2_GS13_Undamped_vs_Damping_2012_10_04_090654.fig

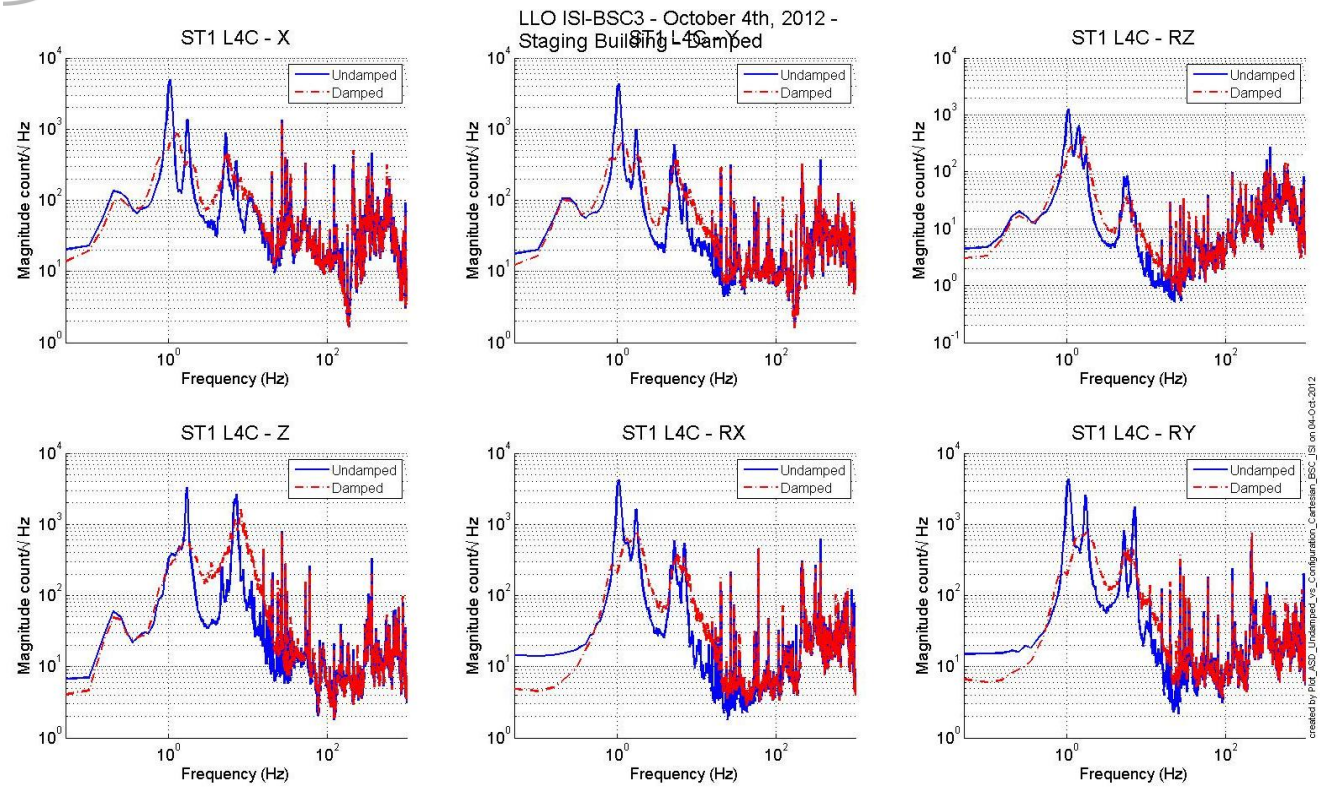


Figure 29: LLO ISI BSC3 ASD CT CART Stage 1 L4C Undamped vs Damping

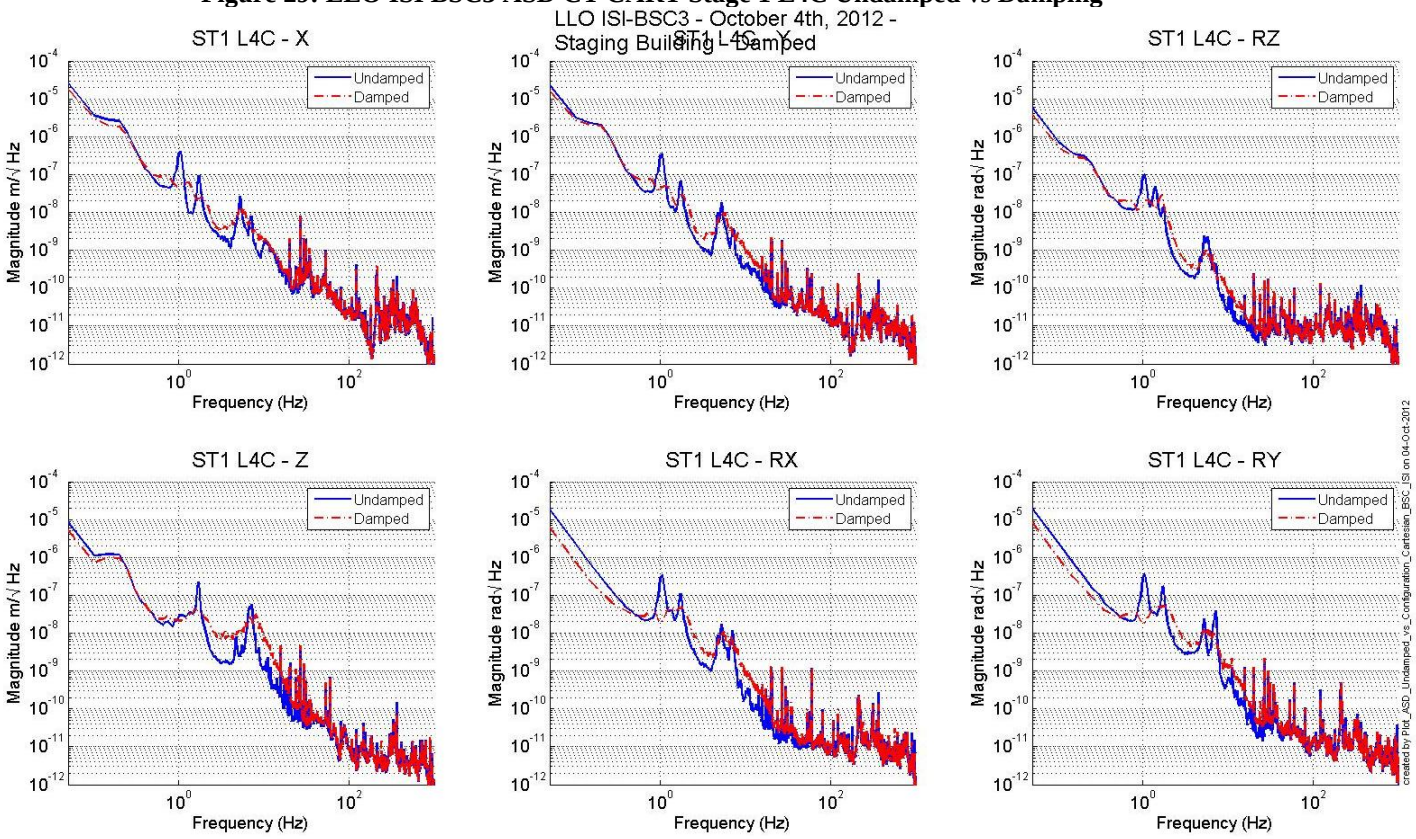


Figure 30: LLO ISI BSC2 ASD m CART Stage 1 L4C Undamped vs Damping

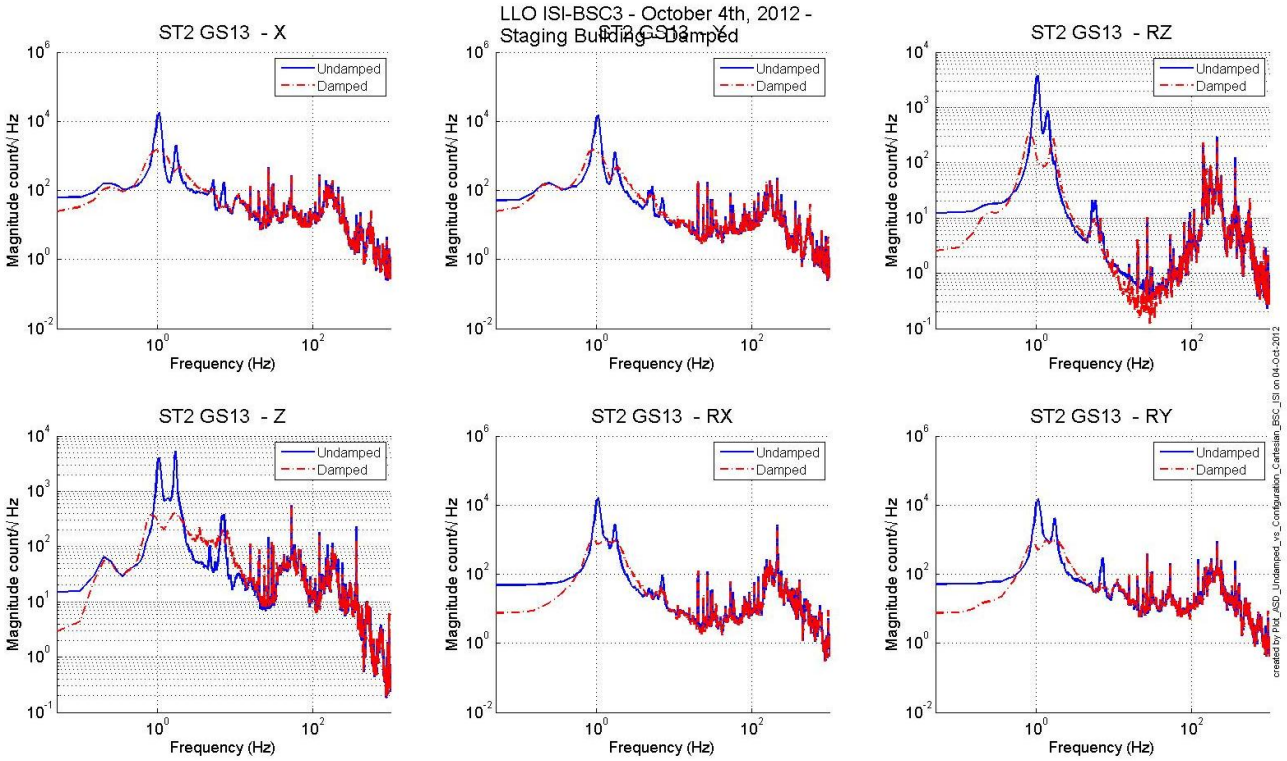


Figure 31: LLO ISI BSC3 ASD CT CART Stage 2 GS 13 Undamped vs Damping

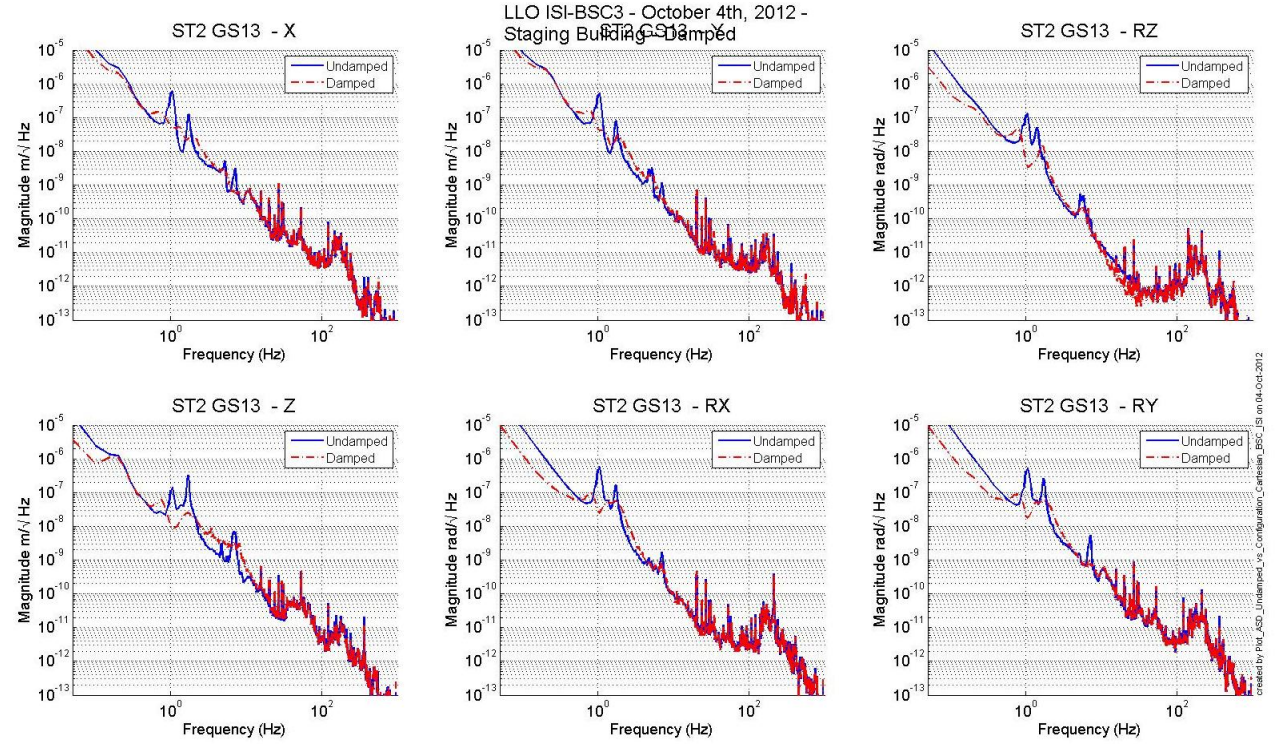


Figure 32: LLO ISI BSC3 ASD m CART Stage 2 GS 13 Undamped vs Damping

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

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

Not performed

IV. BSC-ISI testing Summary

This is the second "aLigo BSC-ISI" tested at LLO. The testing procedure document E1000483-v3 was used. Tests were done during September & October 2012.

The ISI-BSC3 is officially 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/X2/BSC3/Data

FAILED AND WAIVED TESTS

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

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

- **Step III. 6 Coil Driver, Cabling and Resistance Check** – This test fails by a very small amount but to be safe we will re-do it in the LVEA.
- **Step III. 10 & 11 Static Testing** – These tests fail but not by much and looking at the average values obtained from the previous Units, we can conclude that the criteria is maybe a little bit too strong.
- **Step III. 12 Linearity Test** – This test fails on Stage 1 V1 & V3 Actuators. V1 result is acceptable but V3 is twice as high as the criteria, so we'll keep an eye on it and re-do this test in the LVEA. It is more than likely that this test failed because of the actuator V3. We will keep an eye on it and like it is said above, re-check Step 6 Coil Driver, Cabling and Resistance Check.

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.15 – Change of bases – Cartesian to local - Simulations**
- **Step III.16 – Transfer functions – Cartesian to Cartesian - Simulations**
- **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**

The ISI-BSC will be moved from the HighBay to the LVEA test stand as soon as it has been approved.