LIGO Laboratory / LIGO Scientific Collaboration

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

E1100305 – 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 (ITMY) in the High Bay before its move to the LVEA (Teststand). Tests were done during May and June 2012.

This is the second "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 some GS-13 on this Unit due to an abnormal behavior. They are 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/

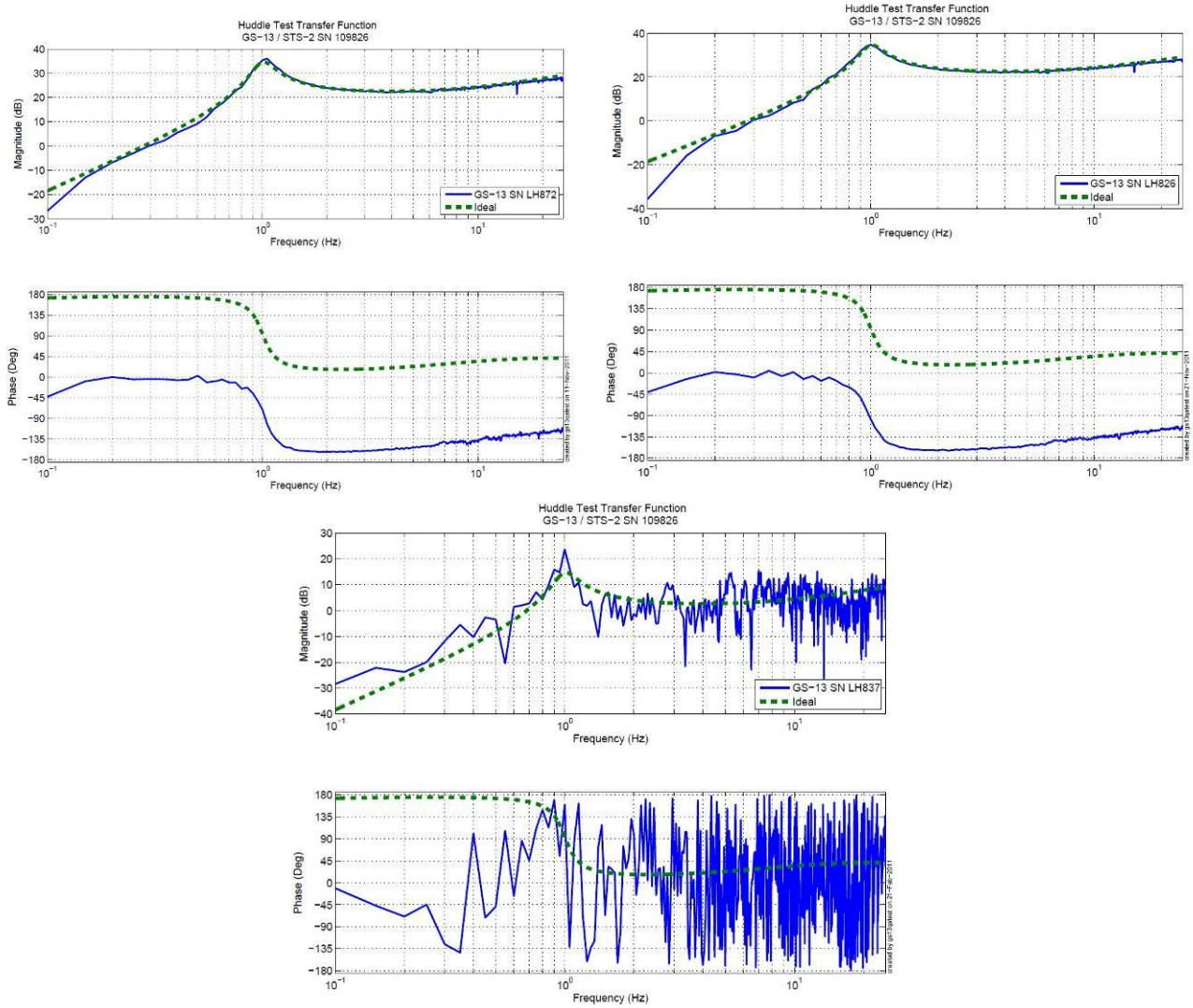


Figure 1: Huddle Test Transfer Function of the Horizontal GS-13 SN 872, 826 & 837 after aLIGO modifications

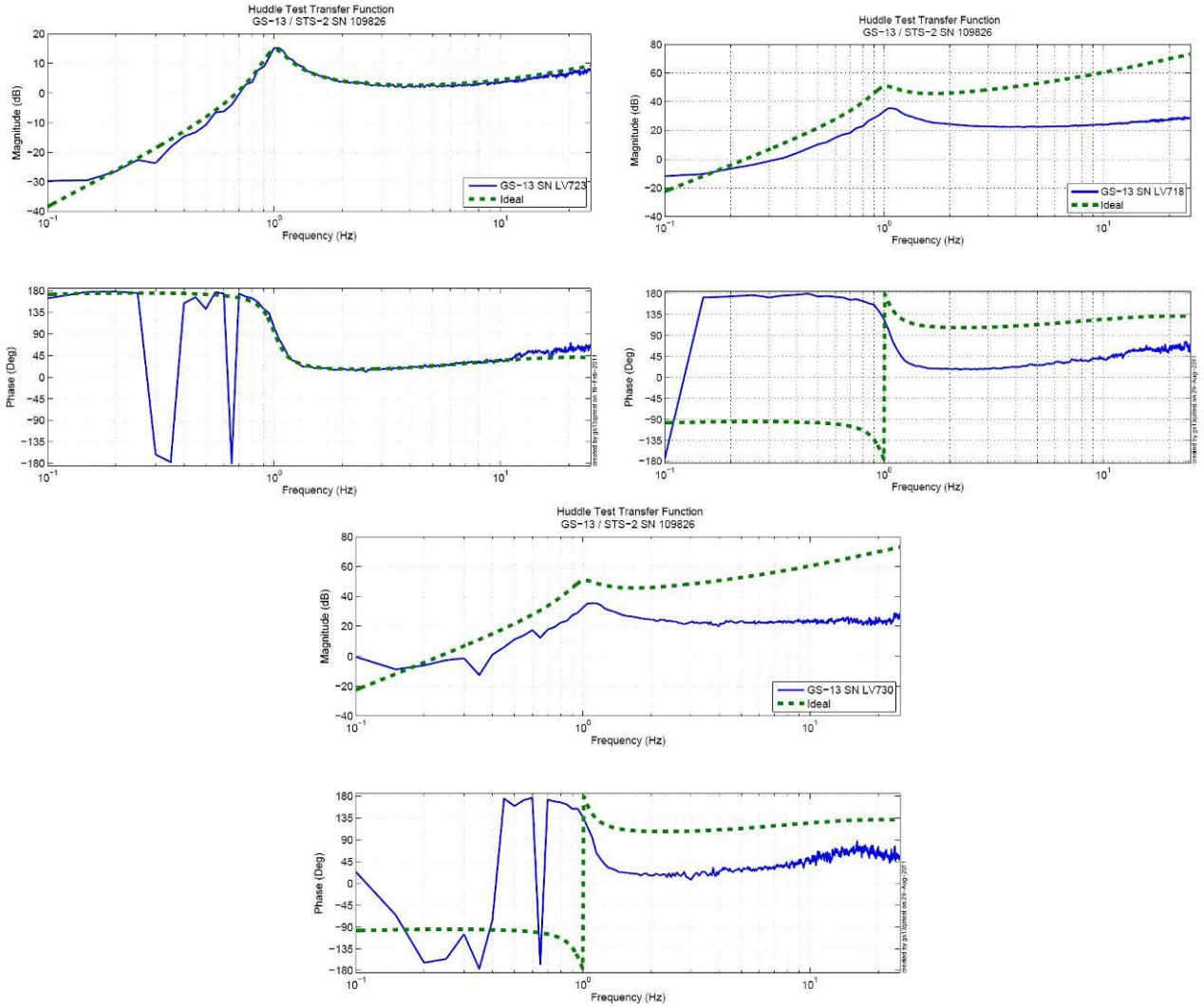


Figure 2: Huddle Test Transfer Function of the Vertical GS-13 SN 723, 718 & 730 after aLIGO modifications

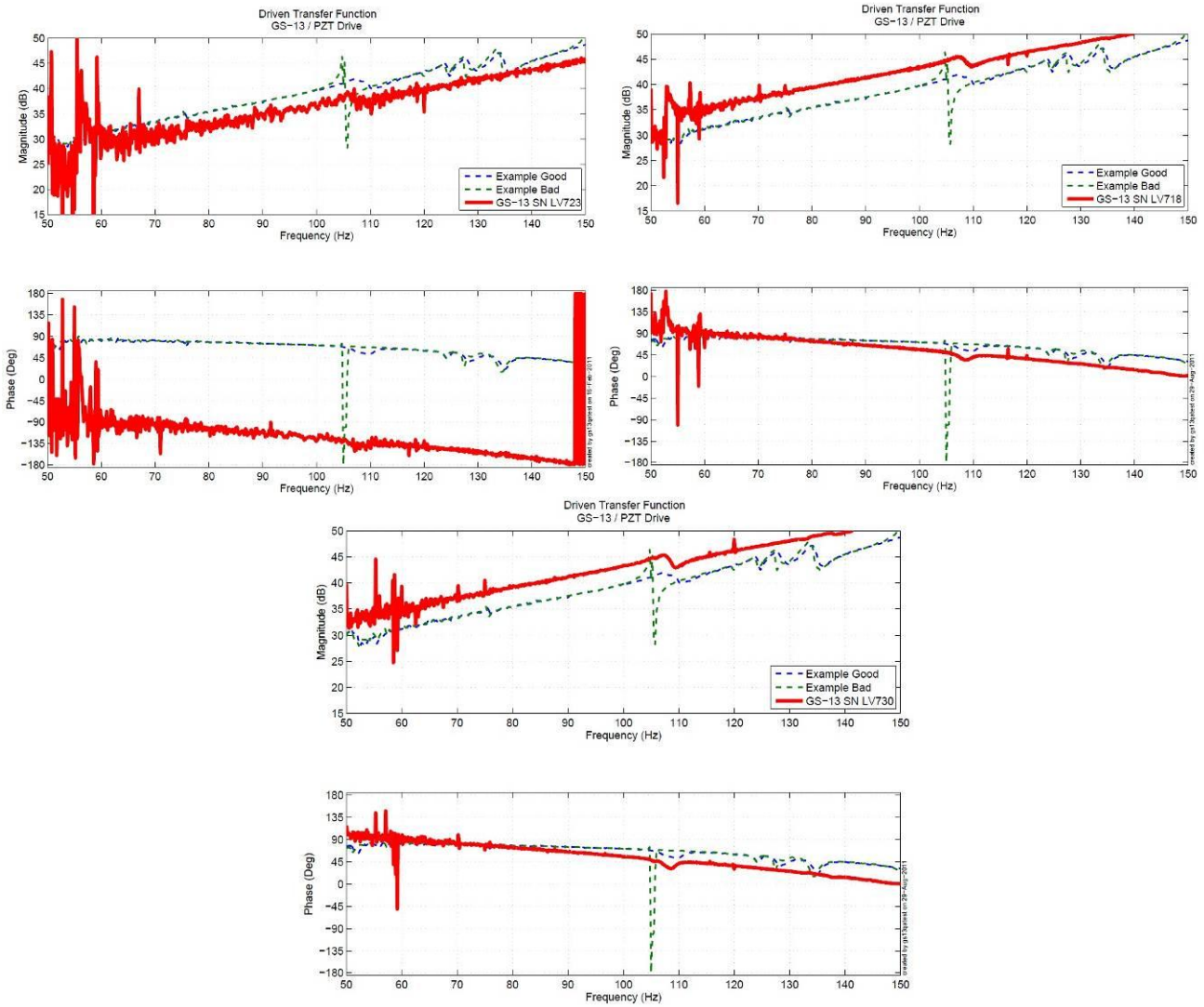


Figure 3: Driven Transfer Function of the Vertical GS-13 SN 723, 718 & 730 after aLIGO modifications

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/

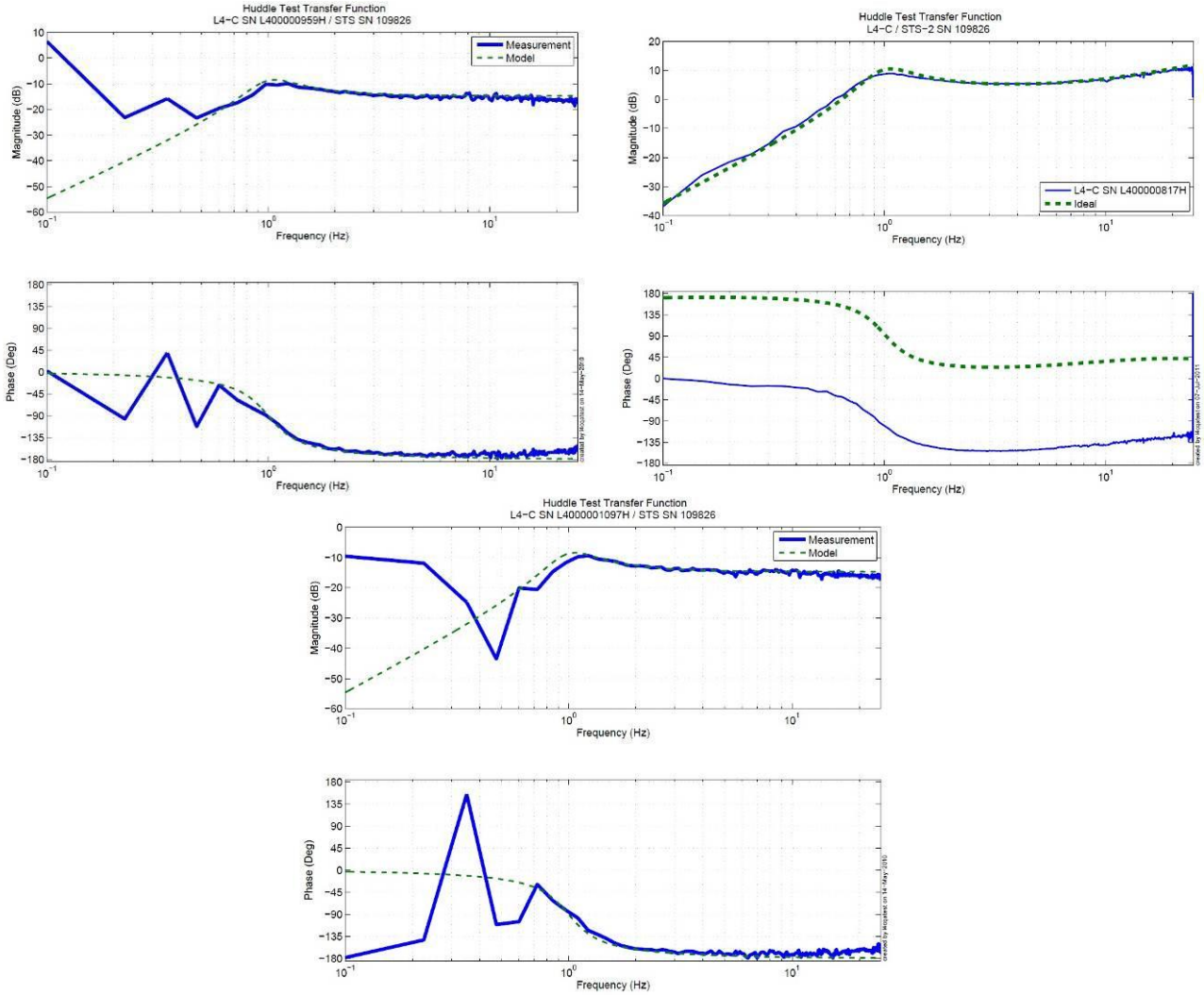


Figure 4: Huddle Test Transfer Function of the Horizontal L4-C SN 959, 817 & 1097

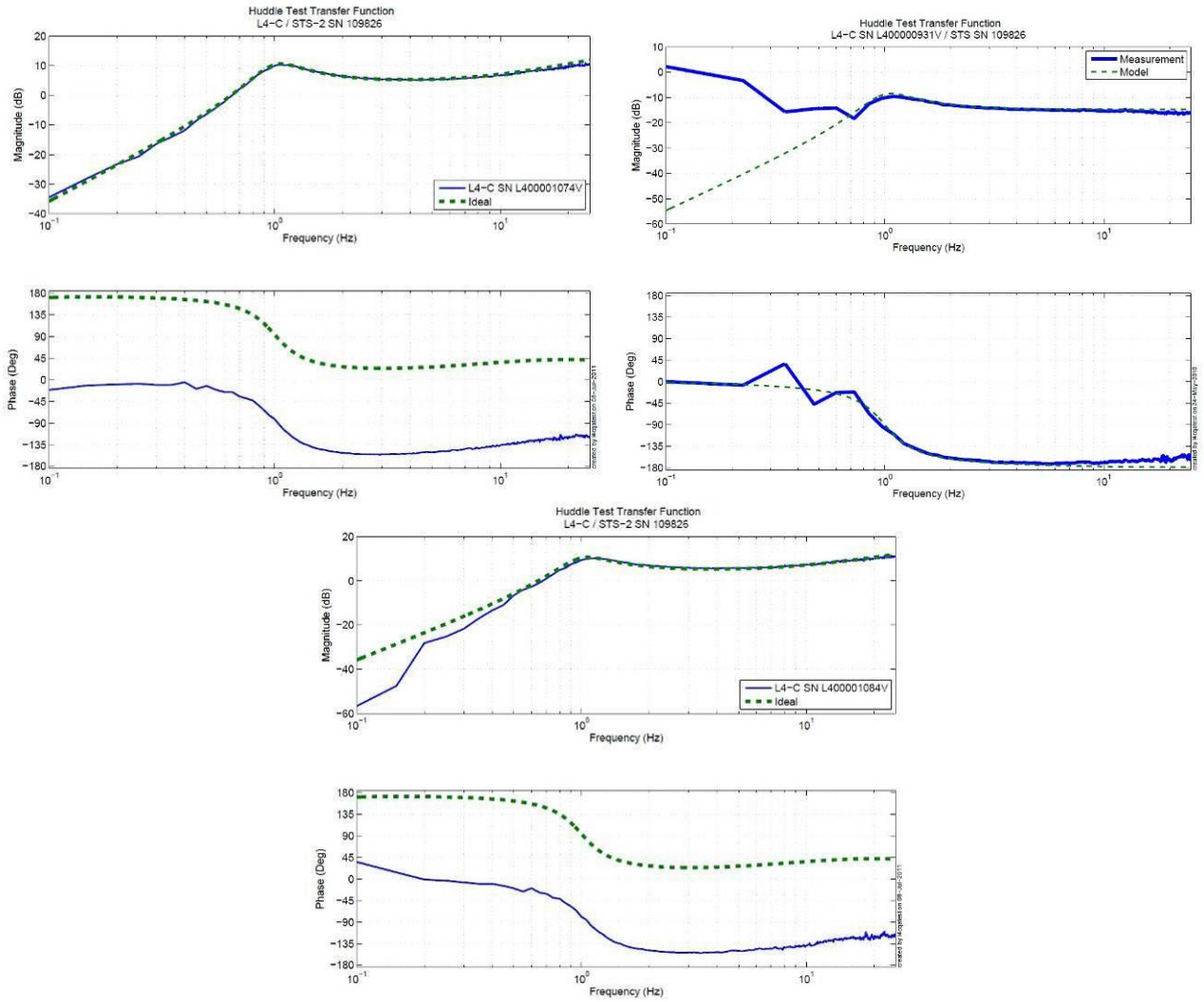


Figure 5: Huddle Test Transfer Function of the Vertical L4-C SN 1074, 931 & 1084

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 had to replace the 3 T240 because their Pressure Sensor was not working properly. The T240 that are on the ISI currently have working Pressure Sensor (since May 17th, 2012). 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.

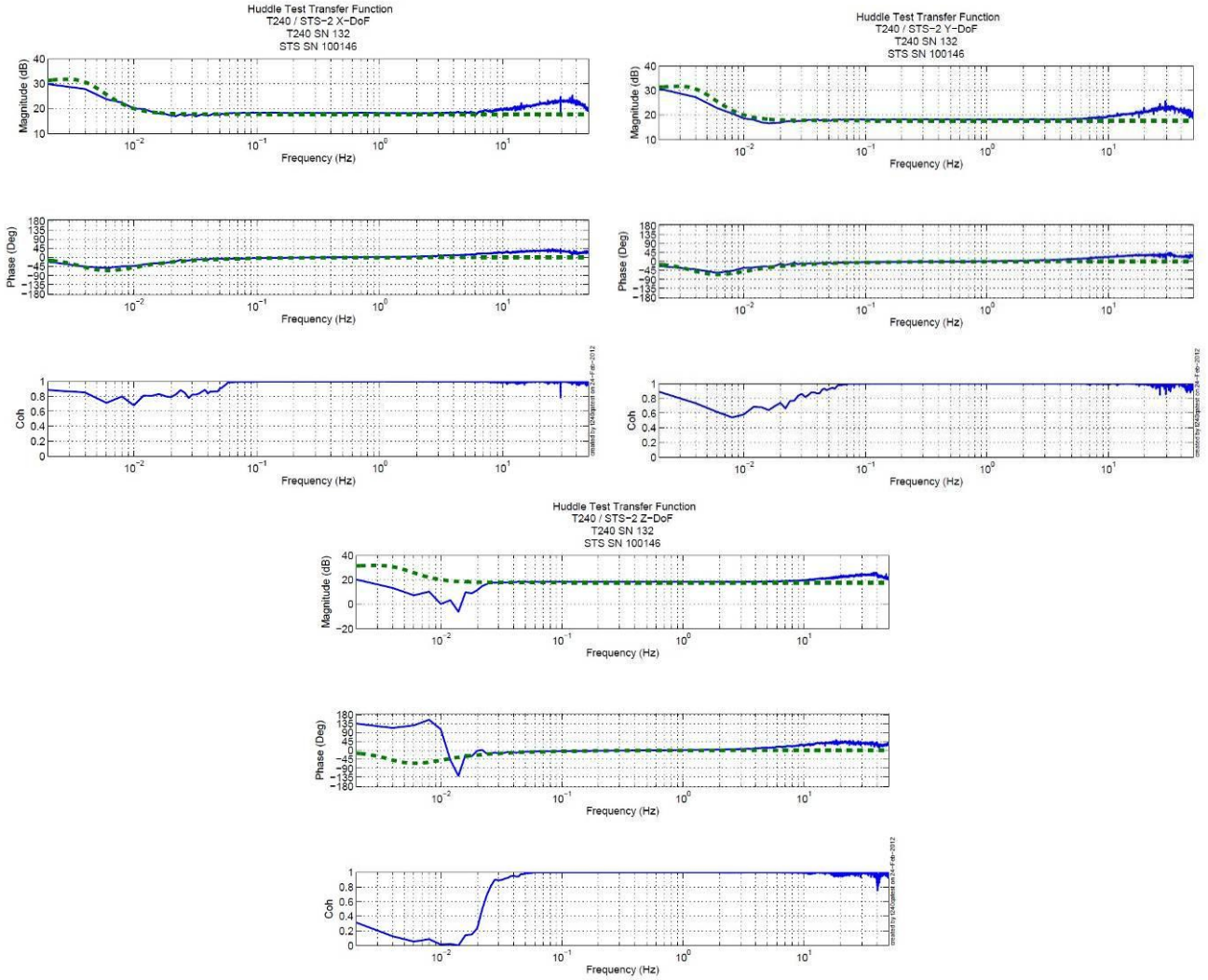


Figure 6: Huddle Test Transfer Function of the X, Y & Z axis of the T240 SN 132

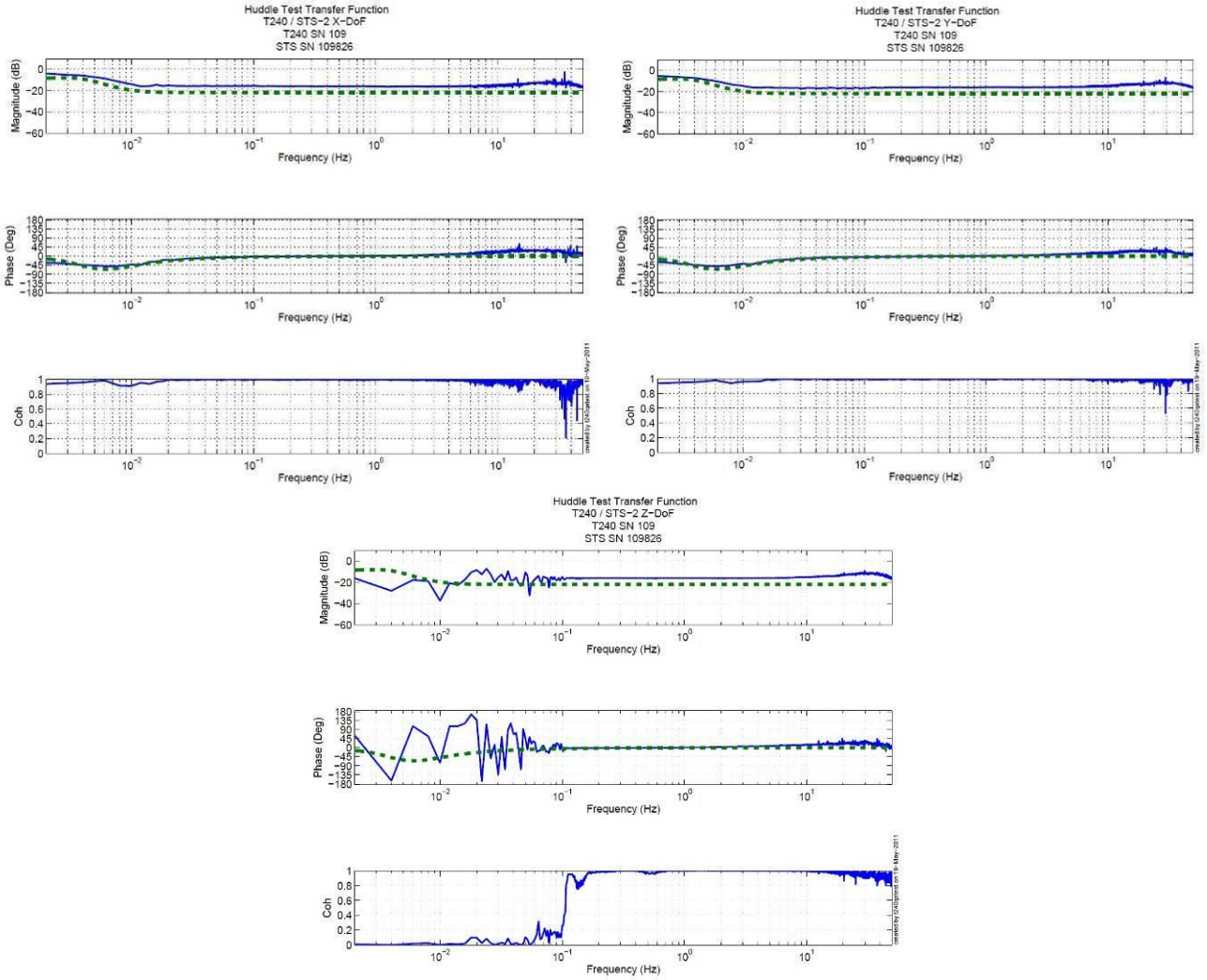


Figure 7: Huddle Test Transfer Function of the X, Y & Z axis of the T240 SN 109

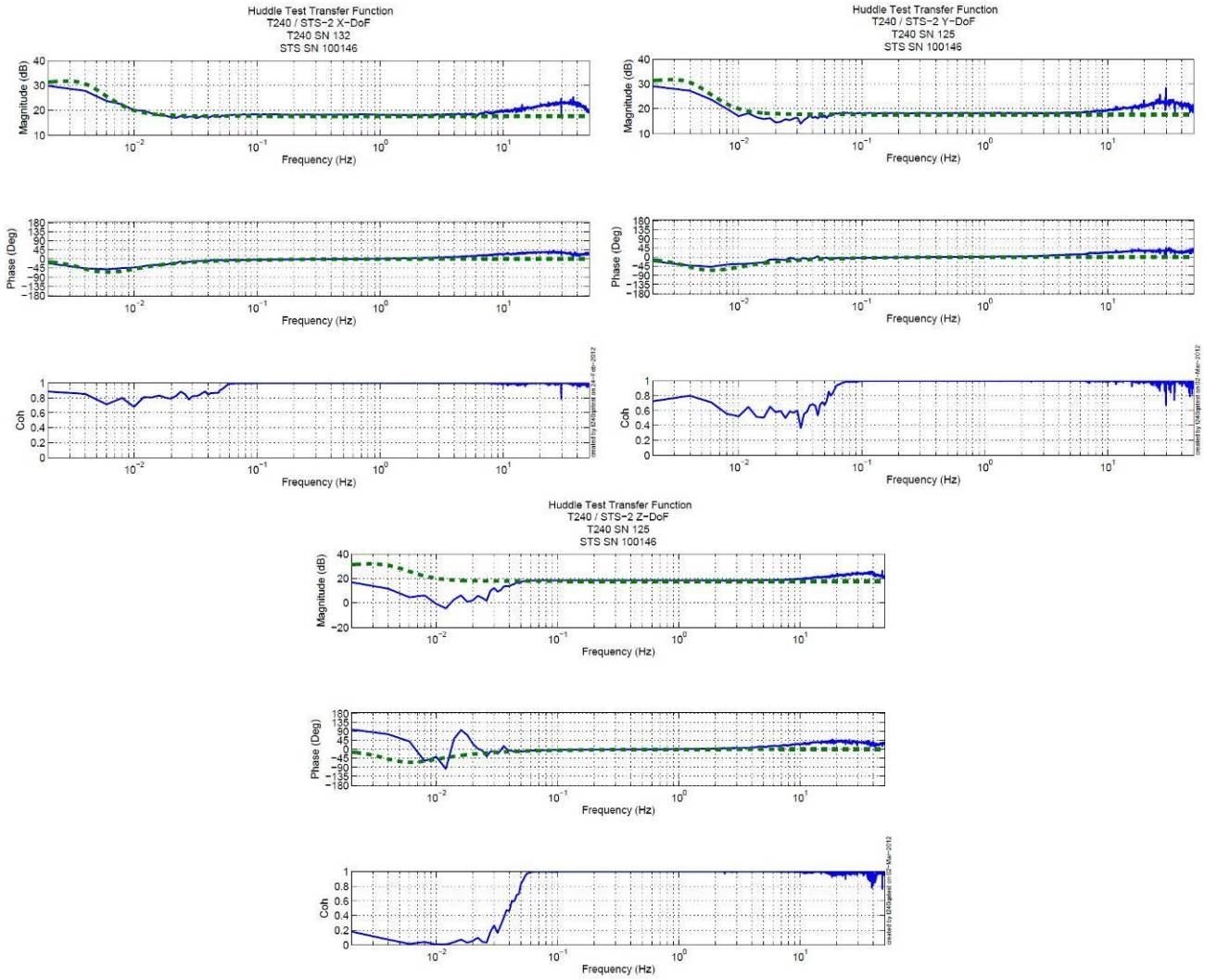


Figure 8: Huddle Test Transfer Function of the X, Y & Z axis of the T240 SN 125

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 #: L0091 Operator Name: Gordon, Matt Date: 11/21/2009 Time: 11:30 AM Actuator Coil Resistance: 6.23 Ohms, PASS Ambient Temperature: 69.5 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.524 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.505	Actuator Serial #: S071 Operator Name: Gordon, Matt Date: 4/13/2011 Time: 9:38 AM Actuator Coil Resistance: 10.29 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.657 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.509
H2	Actuator Serial #: L005 Operator Name: Smith, Lane Date: 8/11/2009 Time: 4:23 PM Actuator Coil Resistance: 6.41 Ohms, PASS Ambient Temperature: 73.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.521 Y Travel Limit (inches): 0.193 Z Travel Limit (inches): 0.479	Actuator Serial #: S100 Operator Name: Gordon, Matt Date: 4/14/2011 Time: 2:56 PM Actuator Coil Resistance: 10.57 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.683 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.513
H3	Actuator Serial #: L136 Operator Name: Gordon, Matt Date: 4/12/2010 Time: 4:01 PM Actuator Coil Resistance: 6.32 Ohms, PASS Ambient Temperature: 73.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.535 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.502	Actuator Serial #: S025 Operator Name: Gordon, Matt Date: 7/28/2010 Time: 3:15 PM Actuator Coil Resistance: 10.40 Ohms, PASS Ambient Temperature: 78.8 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.634 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.504
V1	Actuator Serial #: L012 Operator Name: Smith, Lane Date: 8/12/2009 Time: 11:18 AM Actuator Coil Resistance: 6.39 Ohms, PASS Ambient Temperature: 70.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.523 Y Travel Limit (inches): 0.204 Z Travel Limit (inches): 0.506	Actuator Serial #: S078 Operator Name: Gordon, Matt Date: 4/13/2011 Time: 1:53 PM Actuator Coil Resistance: 10.22 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.654 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.515
V2	Actuator Serial #: L032 Operator Name: Smith, Lane Date: 8/12/2009 Time: 4:18 PM Actuator Coil Resistance: 6.38 Ohms, PASS Ambient Temperature: 71.8 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.520 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.503	Actuator Serial #: S035 Operator Name: Gordon, Matt Date: 7/28/2010 Time: 4:13 PM Actuator Coil Resistance: 10.32 Ohms, PASS Ambient Temperature: 79.0 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.642 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.506
V3	Actuator Serial #: L085 Operator Name: Gordon, Matt Date: 11/21/2009 Time: 4:32 PM Actuator Coil Resistance: 6.26 Ohms, PASS Ambient Temperature: 70.0 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.532 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.506	Actuator Serial #: S096 Operator Name: Gordon, Matt Date: 4/14/2011 Time: 1:47 PM Actuator Coil Resistance: 10.45 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.668 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.513

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

II. Tests to be performed during assembly

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

The HAM-ISI Teststand 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	L091	**H1**	S071
H2	L005	**H2**	S100
H3	L136	**H3**	S025
V1	L012	**V1**	S078
V2	L032	**V2**	S035
V3	L085	**V3**	S096

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	13681	15892
H2	12954	12431
H3	13625	15872
V1	13456	15911
V2	13522	15688
V3	13447	12434

Table 2 - Capacitive position sensors' inventory – Stage 1

CPS Stage 1-2	CPS S/N	ADE board serial #
H1	13581	16052
H2	13445	12568
H3	13644	15906
V1	13448	15909
V2	13463	12578
V3	13636	15901

Geophones GS13	Serial Number	POD
H1	872	38
H2	826	53
H3	837	61
V1	723	60
V2	718	22
V3	730	23

Table 3 - GS13 inventory

Geophones L4C	Serial Number	POD
H1	959	10
H2	817	124
H3	1097	34
V1	1074	32
V2	931	78
V3	1084	138

Table 4 - L4C inventory

Geophones T240	Serial Number	POD
1	132	29
2	109	36
3	125	7

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	S1000251
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	Xp005
Coil driver Pod 1	D0902744	S1000317
Coil driver Pod 2		S1000316
Coil driver Pod 3		S1103313

Table 6 - Electronic equipment

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	.129"	**A**	.118"
B	.122"/.124" (See Note)	**B**	.117"
C	.128"	**C**	.116"

Table 7 - Shims thickness

Note: For Stage 0-1 Locker B, we used two shims with different (.122" & .124") because we didn't have the right size shims on site (.123").

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 first Unit):

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

The values of this LLO 2nd 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.

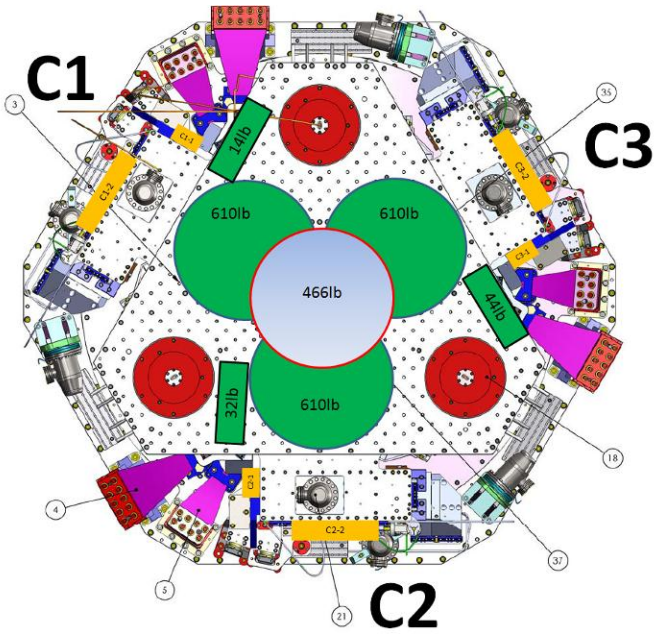


Figure 9: Masses distribution

Stage 1:

Stage 1		
Location	**Weight (lb)**	**Weight (Kg)**
C1-1	12	5.44
C1-2	15	6.80
C1-3	29.9	13.56
C2-1	0	0.00
C2-2	15	6.80
C2-3	17.5	7.94
C3-1	12	5.44
C3-2	15	6.80
C3-3	16	7.26
Total	**132.4**	**60.06**

Table 8 - Payload Stage 1

Nominal payload: 108.9Kg – 240lb
Added masses are 48.8Kg – 107.6lb lighter than expected.
Total mass of stage 1=936.2Kg - 2064lb

Stage 2:

Original	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							1		1		20.1	9.12
F2								3			23.7	10.75
F3					2					1	29.4	13.34
Stage 2	3	2	0	0	2	0	1	3	1	1	2363.2	1071.93

Table 9 - Payload Stage 2

Nominal payload: 1183.4Kg – 2609lb
The added masses is 111.5Kg lighter than expected.

Total nominal mass of Stage 2: 2824.5Kg – 6227lb
Error on the nominal overall mass of stage 2: 111.5/2824.5=3.9%

Summary:

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 1 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

After noticing a small gap between Stage 0-1 Blades and their spacers, we repositioned the Blades and decided to torque the bolts to a higher value. We also decided to better the consistency in the torque value to Silver plate these bolts and thus better the friction coefficient. LLO Unit 3 will be the first one to use these Silver Plated Bolts!

This step gave us the results from the 3/1/2012. From there, we decided to do the same work on Stage 1-2 Blades which gave us the final results from the 3/9/2012.

Previous Units Results:

	Plan	LHO Unit 1	LHO Unit 2	LLO Unit 1	Avg (3 1st Units)	STD	**LLO Unit 2**
Stage 1	108.86	35.6	58.6	36.29	43.50	10.68	**60.06**
Stage 2	1183.42	1082.4	1059.5	1096.83	1079.58	15.37	**1071.93**
Stage 1	81.3	-40.7	-2.4	-39.6	-0.28	% of Diff/LLO Unit 2	
Stage 2	10.4	1	-1.2	2.3	0.01		

Note: This Unit is the last one with regular Eastwood Bolts for the Blades. Like the 1st Unit built here at LLO, we used a high torque value of 150 ft.lbs (instead of the regular 110 ft.lbs) to overcome the bad friction coefficient of Stainless (Eastwoood Bolts) in Nitronic 60 (Barrel Nuts) and get a good contact between the Blades and its Angled Spacer. All the Units built after this one, will take Silver Plated Bolts for the following reasons:

- Stainless Steel Eastwood Bolts threaded in Nitronic 60 Barrel Nuts → Risk of galling
- Silver Plating for a better friction coefficient and so a better consistency on the torque value

Even if the mass budget on Stage 1 is a ~80% away from 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:

- not even 1% away from the average Mass Budget of the first 3 Units for both Stage 1 & Stage 2!
- Stage 1 Mass Budget is the closest one to the Plan built to date.
- Stage 2 Mass Budget is really close to the average of the first three Units.

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

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

No value has been recorded during the locker adjustments. The Twist values have not been recorded because it was good enough that we can put on the Lock Pins on both Stages so it means that the value of the Twist is less than the Locker gap (~.002"). Measurements using the CPS sensors when the stages are locked and unlocked have been done Step III.2.

	Stage 1		Stage 2	
D.I at Lockers	Dial indicators V	Dial indicators H	Dial indicators V	Dial indicators H
A				
B				
C				

Table 10 - Dial indicators read-out (stage locked-unlocked independently)

Test failure mitigation:
Step III.2 passed. Consequently, this test can be waived.

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

- ***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 – S1107138	D1100150 – S1107070	D1100151 – S1107150
	Extension	D1100148 – S1106924	D1100148 – S1106966	D1100148 – S1106921
St 0-1 H Actuators	Pigtail	D1100150 – S1107127	D1100150 – S1107068	D1100151 – S1107155
	Extension	D1100148 – S1106970	D1100148 – S1106951	D1100148 – S1106902
St 1-2 V Actuators	Pigtail	D1100150 – S1107136	D1100150 – S1107073	D1100151 – S1107143
	Extension	D1100148 – S1106965	D1100148 – S1106962	D1100148 – S1106940
St 1-2 H Actuators	Pigtail	D1100150 – S1107135	D1100150 – S1107071	D1100151 – S1107144
	Extension	D1100148 – S1106931	D1100148 – S1106955	D1100148 – S1104035
L4C	Pigtail	D1100154 – S1104263	D1100154 – S1107338	D1100155 – S1104251
	Extension	D1100152 – S1107235	D1100153 – S1107336	D1100153 – S1107290
GS-13	Pigtail	D1100154 – S1107337	D1100154 – S1107343	D1100155 – S1107386
	Extension	D1100153 – S1107266	D1100153 – S1107299	D1100153 – S1107311
T240		D1100152 – S1107237	D1100153 – S1104567	D1100152 – S1107232

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	100.9	100.8	100.0
ST1-L4C-D	0.1	-0.4	0.7
ST1-GS13-P	100.4	77.9	76.8
ST1-GS13-D	-0.6	-0.6	0.1
ST1-T240-P	154.8	154.2	154.6

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 Corner 2 & 3.

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!).

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.

May-2012

	Table locked		Table unlocked		Difference locked - unlocked	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**mil**
ST1 - H1	1.6	15.0	-318.3	93.9	320.0	0.38
ST1 - H2	-16.2	10.0	-110.8	126.7	94.6	0.11
ST1 - H3	-142.4	14.3	-554.9	101.9	412.6	0.49
ST1 - V1	-182.0	20.0	122.1	95.3	-304.1	-0.36
ST1 - V2	-39.6	14.4	704.7	134.8	-744.2	-0.89
ST1 - V3	-442.8	15.6	276.6	207.8	-719.3	-0.86
ST2 - H1	584.6	32.9	-242.9	99.4	827.5	0.99
ST2 - H2	303.7	52.3	1124.3	141.3	-820.6	-0.98
ST2 - H3	-319.7	31.9	1201.5	116.1	-1521.2	-1.81
ST2 - V1	-223.5	48.3	-4939.3	263.1	4715.8	5.61
ST2 - V2	-203.6	66.7	-1593.9	362.5	1390.4	1.66
ST2 - V3	-8.4	66.7	-4751.1	473.4	4742.7	5.65

Table 11 - 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")

Note: Even if Stage 1 V3 CPS is a little bit over the acceptable value when the table is in the Locked Position, we did the testing with these values, knowing that the CPS will have to be re-centered before Install.

On this Unit, we had a very hard time setting the CPS probe parallel to its target!Plus it seems that the minimal gap on the Stage 2 CPS is very, very small ~ 0.002" (or smaller) when Stage 1 and Stage 2 are as close as they can be!

This very tiny gap makes those CPS really difficult to set (parallelism, adjustments...) and in some case (when the head of the screw attaching the probe onto its mount, is sticking out a little bit) it can cause contact between the Sensor Target and the probe!

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

- ***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	-14896.0	8105.1	-17.7	9.6
ST1 - V2 - ST2 LCK	-18722.0	19044.0	-22.3	22.7
ST1 - V3 - ST2 LCK	-16056.0	12337.0	-19.1	14.7
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	15524.0	-15766.0	18.5	-18.8
ST1 - H2 - ST2 LCK	16115.0	-15838.0	19.2	-18.9
ST1 - H3 - ST2 LCK	15537.0	-15790.0	18.5	-18.8
ST2 - H1 - ST1 LCK	-22716.0	26727.0	-6.8	8.0
ST2 - H2 - ST1 LCK	-13831.0	29327.0	-4.1	8.7
ST2 - H3 - ST1 LCK	-32767.0	25897	-9.8	7.7

Test result: **Passed: ___** **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	20514	-22617	-26.9	24.4		OK
ST1 - H2	17078	-18814	-22.4	20.3		OK
ST1 - H3	16237	-19451	-23.2	19.3		OK
ST1 - V1	25657	-22436	-26.7	30.5		OK
ST1 - V2	25461	-20803	-24.8	30.3		OK
ST1 - V3	26781	-22685	-27.0	31.9		OK
ST2 - H1	32767	-32768	-9.8	9.8	X	OK
ST2 - H2	32767	-32768	-9.8	9.8	X	OK
ST2 - H3	32767	-32768	-9.8	9.8	X	OK
ST2 - V1	32767	-32768	-9.8	9.8	X	OK
ST2 - V2	32767	-32768	-9.8	9.8	X	OK
ST2 - V3	32767	-32768	-9.8	9.8	X	OK

Table 12 - Stages range of motion – "Push locally"

Acceptance criteria:

- The vertical sensor readout must be positive when the optic table is pushed in the +Z direction
- The horizontal sensor readout 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***

Some of the powerspectra have been measured with a non-working capacitive positive sensor (ST1-V2 - CPS)
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_05_23.fig
- LLO_ISI_BSC3_Powerspectra_ct_ST1_Locked_ST2_Locked_2012_05_23.fig
- LLO_ISI_BSC3_Powerspectra_ct_ST1_Locked_ST2_Unlocked_2012_05_23.fig
- LLO_ISI_BSC3_Powerspectra_ct_ST1_Unlocked_ST2_Locked_2012_05_23.fig
- LLO_ISI_BSC3_Tilted_ASD_CT_LOC_ST1_L4C_2012_05_25.fig
- LLO_ISI_BSC3_Tilted_ASD_CT_LOC_ST2_GS13_2012_05_25.fig

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

- LLO_ISI_BSC3_Calibrated_PSD_CPS_T240_L4C_GS13_Locked_vs_Unlocked2012_05_23
- LLO_ISI_BSC3_ASD_m_L4C_GS13_Stage_Tilted_2012_05_25.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

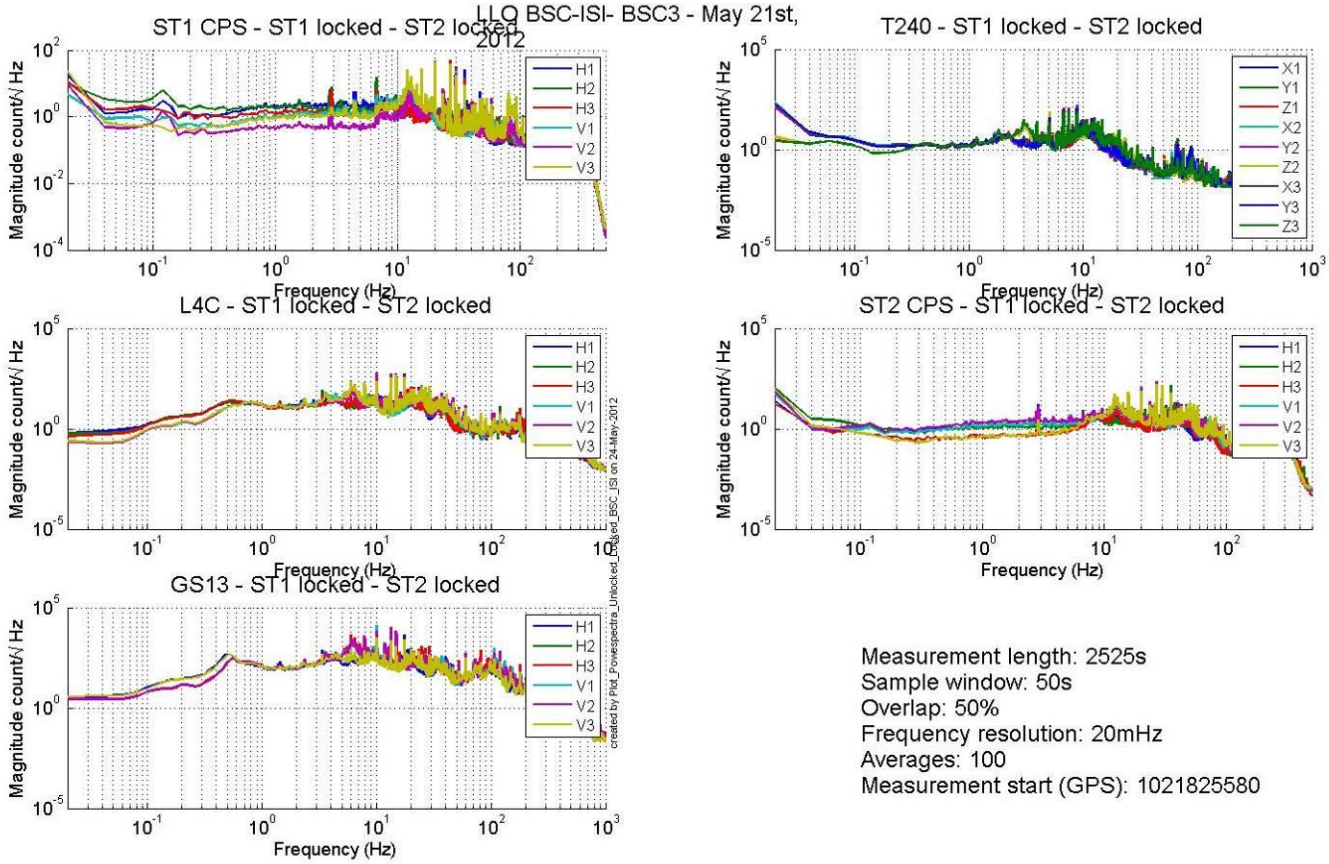


Figure 10: Spectra Stage 1 Locked Stage 2 Locked

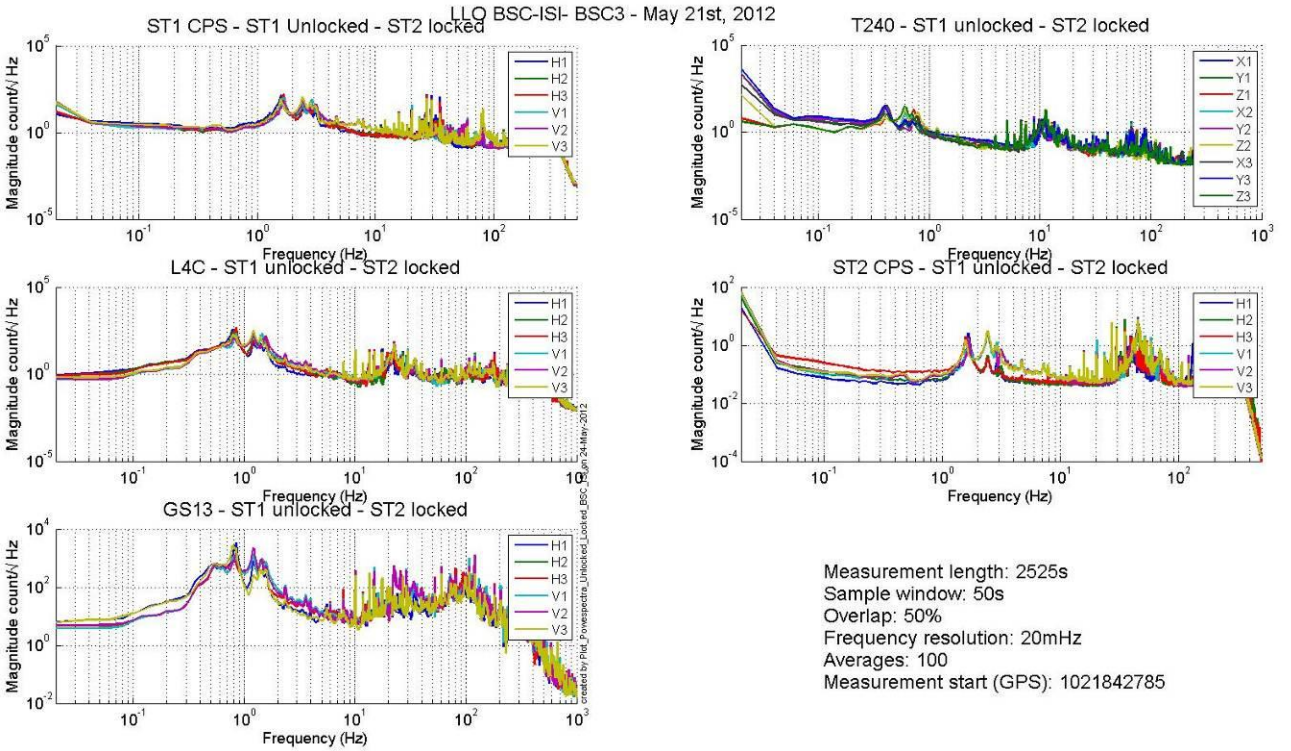


Figure 11: Spectra Stage 1 Unlocked Stage 2 Locked

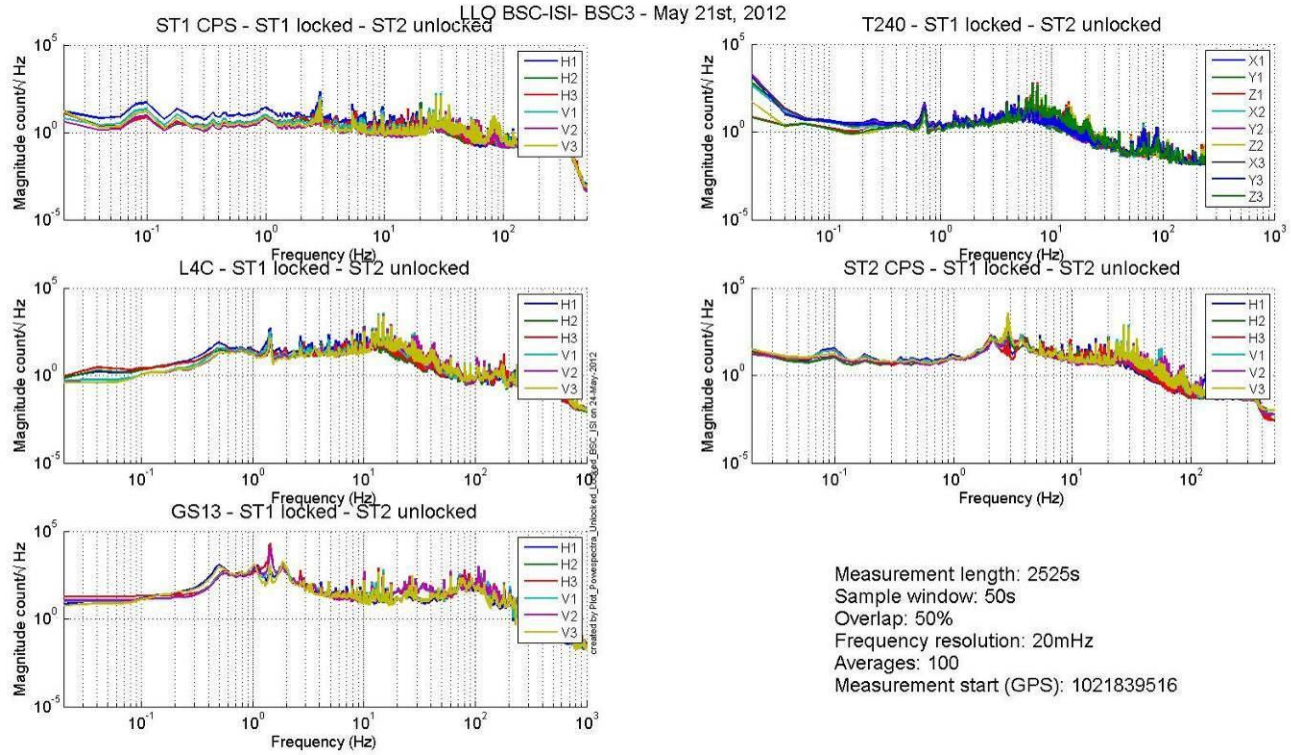


Figure 12: Spectra Stage 1 Locked Stage 2 Unlocked

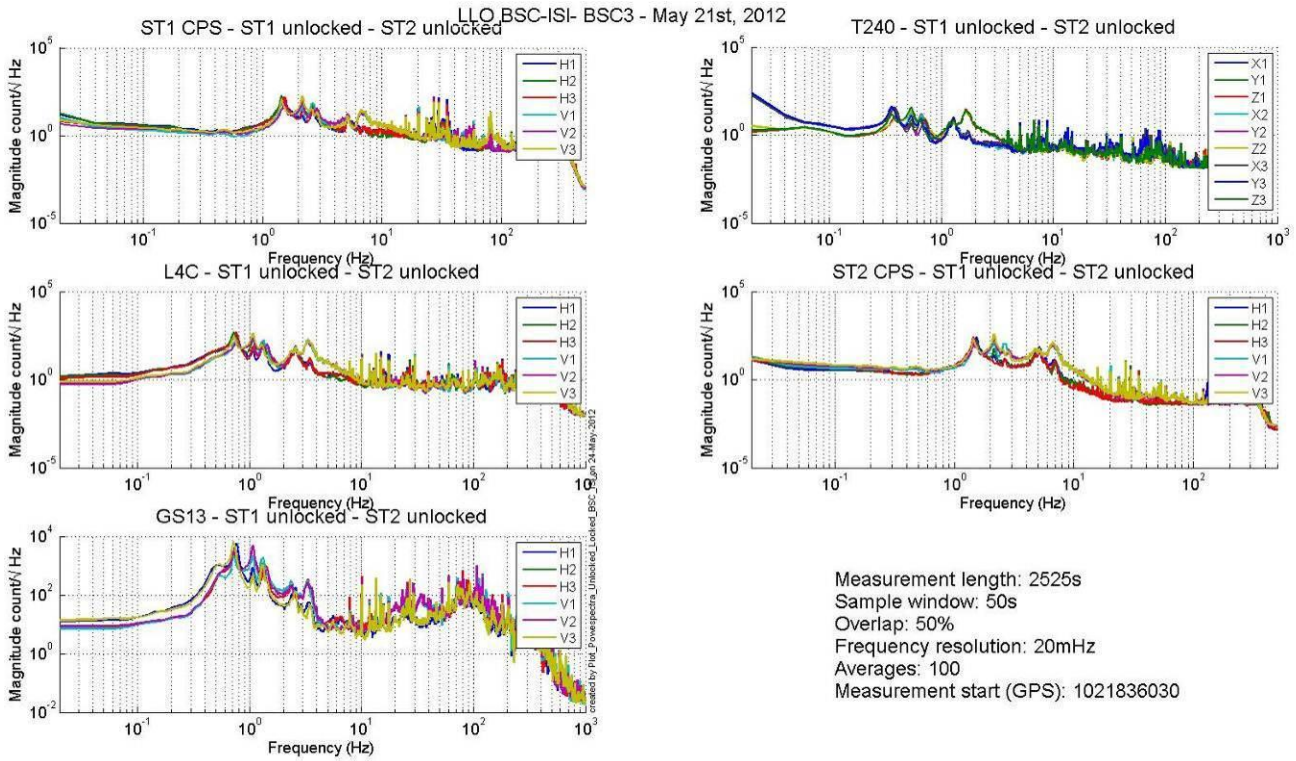


Figure 13: Spectra Stage 1 Unlocked Stage 2 Unlocked

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

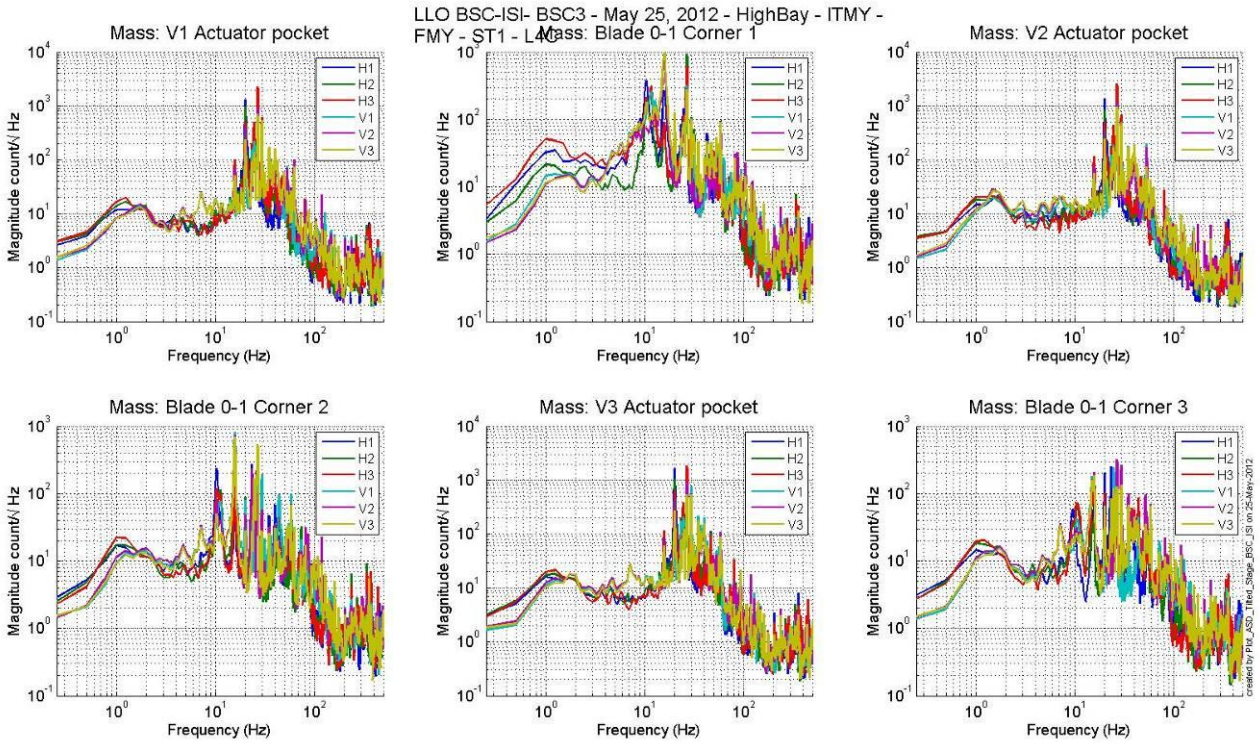


Figure 14 - ST1 L4C – Tilted

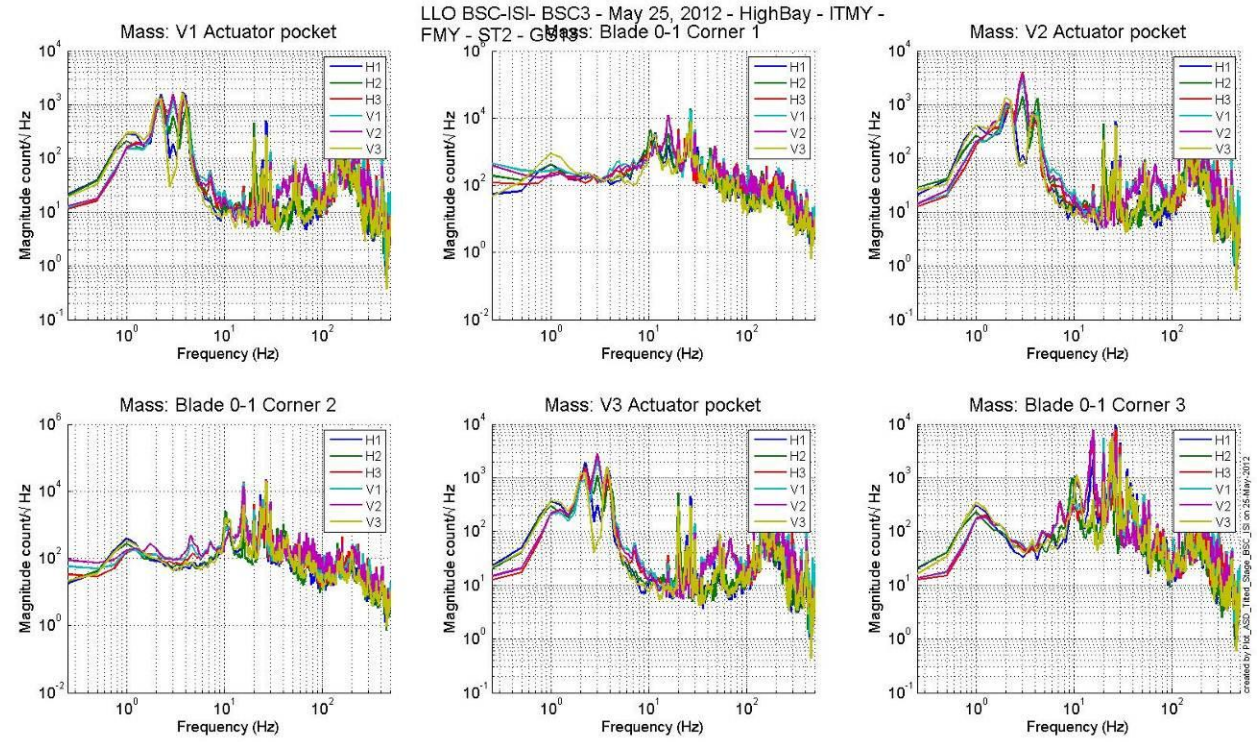


Figure 15 - ST1 GS13 – Tilted

- ***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	6.5
ST2 H1	Coil 1 Fine 1	10.5
ST2 V1	Coil 1 Fine 2	10.5
ST1 V1	Coil 1 Coarse 2	6.6
ST1 H2	Coil 2 Coarse 1	6.7
ST2 H2	Coil 2 Fine 1	10.7
ST2 V2	Coil 2 Fine 2	10.4
ST1 V2	Coil 2 Coarse 2	6.6
ST1 H3	Coil 3 Coarse 1	6.6
ST2 H3	Coil 3 Fine 1	10.7
ST2 V3	Coil 3 Fine 2	10.6
ST1 V3	Coil 3 Coarse 2	6.6

Acceptance criteria:

- For the actuators of stage 1, the measured resistance between the middle pin and one side pin must be 6.3 +/-0.5 ohms
- For the actuators of stage 2, the measured resistance between the middle pin and one side pin must be 10.3 +/-0.5 ohms
- Actuator neutral pins must be connected on pin #1 (left side pin of the plug)
- Actuator drive pins must be connected on pin #2 (middle pin of the plug)
- Actuator ground shield pins must be connected on pin #3 (right pin of the plug)
- All LEDs on the coil driver front panel must be green the binary input bit must be in the upper state.

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

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

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

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

In this step, range of motion of the two stages is checked when applying a local drive (30000 counts) on actuators.

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-16203	-482	16375.1	32578.6	39
ST1 - H2	-16496	-251	16791.5	33287.6	40
ST1 - H3	-16157	-770	16300.0	32456.9	39
ST1 - V1	-15197	-358	14589.1	29786.2	35
ST1 - V2	-14396	645	15664.6	30060.5	36
ST1 - V3	-14223	800	15936.3	30159.7	36
ST2 - H1	-7610	2565	12811.7	20421.5	6
ST2 - H2	-9513	626	10814.3	20327.7	6
ST2 - H3	-9160	1027	11194.5	20354.9	6
ST2 - V1	-17480	-5008	7570.9	25050.9	7
ST2 - V2	-14239	-1810	10509.9	24749.0	7
ST2 - V3	-17022	-4898	7244.8	24266.6	7

Table 13 - 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 20000 counts (+/-0.02") for H Stage 2 CPS
- Amplitude must be at least 24000 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 5Kg masses and the measurements are repeated three times (by rotating the masses).

	No load	Load 15 Kg	Load 30Kg	Diff 1	Diff 2
V1	26.64	-7800.03	-15201.67	-7826.68	-15228.31
V2	766.59	-6988.70	-14349.67	-7755.29	-15116.26
V3	586.59	-7171.40	-14548.33	-7757.99	-15134.92

-15159.82956	count
-18.04741614	mil
-1220.475638	lb/in
1.653856758	**%**

The blades from stage 0 to stage 1 are too soft by 1.65%.

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	-5147.60	-31972.33	26824.73
V2	-963.37	-27613.67	26650.30
V3	-4104.40	-30929.33	26824.93

26766.65	count
7.97	mil
1370.407452	lb/in
6.456829236	%

The blades from stage 1 to stage 2 are too soft by 6.46%.

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

On this second Unit built at LLO, after noticing a small gap between the Blade and its Spacer on the 1st Unit built here at LLO, all the Blades have been untorqued, put in the same position (using oversized .5015" dowel pins, with the Blade brought as far back as possible) and retorqued to a higher value (150 ft. lbs instead of the initial 110) without using methanol. After that, the gap was barely noticeable.

Facts:

- Nominal load on Stage 0-1 blades is 8240 lb (per initial design estimation)
- -1.65% of 8240 lb is -136 lbs.
- +253 lb are compensated per ST1 - launch angle correction (E1100284, line 9)
- So we should be at +253-136= 117 lb over nominal (53kg).

But in reality, we are 160 kg too light, so we have 160 + 53 = 213 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_20120611.mat

Actuators \ Sensors	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - H1	4386.0	1770.0	1744.7	13.9	-18.5	17.5
ST1 - H2	1752.4	4393.3	1786.2	-15.5	46.2	-8.7
ST1 - H3	1748.5	1759.7	4352.7	-1.1	-5.3	65.4
ST1 - V1	66.8	-184.6	75.4	3501.5	-616.5	-607.9
ST1 - V2	91.0	40.1	-178.3	-597.3	3560.3	-664.8
ST1 - V3	-159.1	94.2	63.1	-648.9	-636.0	3604.1

Table 14 - 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	1756.0	1794.0	-15.0	29.0	-23.2	-7.0	14.0	19.8
ST1 - H2	1715.0	1770.8	4224.0	4388.5	1705.0	1765.5	-10.0	8.5	-22.5	18.0	-2.8	7.0
ST1 - H3	1734.0	1747.8	1716.0	1755.1	4246.0	4363.1	-17.8	2.0	1.0	3.8	8.8	30.0
ST1 - V1	33.3	79.0	-164.0	-161.6	80.8	109.0	3481.0	3587.0	-665.0	-664.6	-602.3	-588.0
ST1 - V2	94.0	132.0	34.0	87.0	-167.8	-135.0	-614.8	-609.0	3385.0	3514.8	-648.1	-615.0
ST1 - V3	-153.7	-102.0	93.0	128.0	31.0	76.0	-637.5	-591.0	-623.4	-570.0	3347.0	3539.6

Table 15: 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	2439.3	349.5	354.8	1.7	50.1	28.4
ST2 - H2	366.4	2454.7	362.7	7.5	62.3	51.4
ST2 - H3	406.5	411.4	2390.7	31.0	59.4	53.9
ST2 - V1	107.4	142.3	-215.0	3018.1	346.2	59.5
ST2 - V2	-153.0	180.9	103.9	15.1	2933.3	400.9
ST2 - V3	163.2	-202.1	59.2	306.7	-27.4	2918.0

Table 16 - 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	2425.0	351.0	383.5	337.0	371.0	8.0	18.0	-77.9	8.0	-10.4	36.0
ST1 - H2	324.0	363.0	2338.0	2401.0	336.3	373.0	-65.8	27.0	-85.9	10.0	-12.0	-4.8
ST1 - H3	311.0	364.0	341.5	375.0	2332.0	2379.2	-77.1	3.0	-79.7	27.0	-134.8	18.0
ST1 - V1	65.0	79.0	122.0	136.0	-220.0	-203.1	2773.0	3013.0	213.4	349.0	-62.2	-28.0
ST1 - V2	-244.0	-233.3	68.7	101.0	94.0	127.0	-161.4	-12.0	2891.9	2937.0	242.7	333.0
ST1 - V3	78.5	135.0	-167.0	-152.6	41.0	97.0	266.3	349.0	-140.0	-31.0	2830.1	2960.0

Table 17: 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: X** **Failed: ___** **Waived : ___**

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

The 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_20120612.mat

Actuators	Sensors					
	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - X	1733.6	-868.3	-859.8	-10.4	-3	32.5
ST1 - Y	12.3	1527.9	-1463.8	-15.6	55.2	-46.6
ST1 - Z	-8.7	-13.6	16	728.5	755.6	784.6
ST1 - RX	-7.3	165.3	-148.8	-2904.6	2465.9	422.2
ST1 - RY	-183.9	109.4	120	-1185.9	-1953.9	3182.3
ST1 - RZ	3165.1	3229	3200.1	-18.4	20.7	43.6

Table 18 - 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	1752.0	1803.0	-848.2	-839.0	-846.7	-812.0	-26.0	23.0	0.0	0.4	-26.1	-8.0
ST1 - Y	-32.0	2.4	1493.0	1522.0	-1505.1	-1469.0	6.0	14.3	-11.4	18.0	-18.1	-14.0
ST1 - Z	-33.0	-3.0	-14.0	0.6	-27.5	3.0	744.6	772.0	709.0	758.3	711.0	727.0
ST1 - RX	6.2	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	86.0	-1178.1	-1119.0	-1955.6	-1871.0	2959.0	3089.3
ST1 - RZ	3162.0	3230.0	3124.0	3211.9	3166.0	3213.3	-20.5	18.0	-32.9	23.0	-27.0	27.0

Table 19 - 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	687.7	-1389.8	656.2	-28.5	-13	-77.7
ST2 - Y	1179.2	-52.5	-1188	-27.2	-15.9	11.2
ST2 - Z	19.9	12.1	-21.4	1063.6	1075.6	1062.3
ST2 - RX	-294.5	45.5	243.5	-2526.7	2463.7	-62.5
ST2 - RY	153.3	-405.4	156	-1595	-1513.4	2762.7
ST2 - RZ	1763.2	1775.9	1791.3	-29	-41.1	47.5

Table 20 - 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	-1346.8	-1312.0	653.0	676.0	-34.4	31.0	-79.0	15.0	-72.9	44.0
ST2 - Y	1144.0	1198.0	-20.0	18.0	-1193.9	-1153.0	-33.0	42.0	-136.0	10.0	-62.0	15.0
ST2 - Z	-3.0	17.0	-15.5	6.0	-33.0	14.0	1017.9	1133.0	939.0	1135.0	982.4	1104.0
ST2 - RX	-312.0	-277.0	-3.0	20.3	250.1	288.0	-2572.0	-2469.1	2352.0	2574.0	-153.7	-49.0
ST2 - RY	116.6	200.0	-313.0	-303.0	116.0	189.0	-1558.0	-1499.7	-1486.0	-1123.3	2792.0	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	37.0

Table 21 - 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 22 - 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 23 - 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_BSC2_Offset_Cartesian_Drive_20120612.mat

		Sensors					
		ST1 - X	ST1 - Y	ST1 - Z	ST1 - RX	ST1 - RY	ST1 - RZ
Actuators	ST1 - X	1734.2	-6.4	10.9	-13.5	-10.3	-2
	ST1 - Y	-9.1	1732.2	-12.4	31.2	-54.3	24.4
	ST1 - Z	-13.9	-2.9	747.2	5.2	1.1	-6.4
	ST1 - RX	2.4	361.4	-8.2	3021.9	-23.5	-1.1
	ST1 - RY	-384.6	-5.6	-5.3	0.3	3068.7	9.8
	ST1 - RZ	-12.9	4.1	1.3	19.5	4.4	3331.9

Table 24 - Static Test - Cartesian to Cartesian – Stage 1

		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)	
Actuators	ST1 - X	1715.0	1772.1	-12.4	9.0	4.1	6.0	-11.0	6.0	-20.6	1.0	32.8	59.0
	ST1 - Y	-2.0	8.7	1720.0	1734.4	-3.0	11.0	-10.0	10.0	-15.0	3.0	-4.0	16.0
	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	-9.5	7.0	-9.0	29.0
	ST1 - RY	-380.0	-342.0	4.0	16.0	-19.7	5.0	-5.0	17.0	2901.0	3033.3	-5.1	6.0
	ST1 - RZ	2.0	24.0	-4.0	2.6	-21.0	16.0	-6.0	7.3	-2.0	20.0	3276.0	3346.1

Table 25 - Static Test - Cartesian to Cartesian – Stage 1 Results (min & max) from the previous BSC Units

		Sensors					
		ST2 - X	ST2 - Y	ST2 - Z	ST2 - RX	ST2 - RY	ST2 - RZ
Actuators	ST2 - X	1377.4	7.3	-53.4	55.5	-16.9	-9.4
	ST2 - Y	4.5	1342	-9.9	59	-41.6	-26.2
	ST2 - Z	5.1	2	1022.5	52.7	-73	8.4
	ST2 - RX	-62.3	-8.5	-47.8	4356.2	-39.3	26.2
	ST2 - RY	40.3	0	-127.1	151.4	4180.6	-39.2
	ST2 - RZ	-9.5	7.5	-71.6	73.9	-28.9	2586.8

Table 26 - 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	1356.0	-16.2	25.0	-42.5	29.0	-22.0	-5.0	-18.6	24.0	-10.1	24.0
ST2 - Y	-10.0	13.0	1331.0	1358.0	-53.2	20.0	-53.0	2.7	-35.1	55.0	-25.1	34.0
ST2 - Z	-6.0	24.9	-17.2	2.0	1030.0	1114.0	-91.0	6.5	-33.0	28.0	-18.0	14.0
ST2 - RX	-9.0	8.0	-31.1	-14.0	-98.0	22.0	4223.0	4325.8	-105.3	58.0	-18.0	13.0
ST2 - RY	-8.0	27.0	-17.8	30.0	-44.0	56.9	15.0	241.5	4055.2	4319.0	-32.7	24.0
ST2 - RZ	-1.0	21.0	-7.2	9.0	-67.0	29.0	-35.0	11.3	-17.0	52.0	2509.0	2602.0

Table 27 - 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_20120605.fig
- LLO_ISI_BSC3_Linearity_test_20120605.pdf

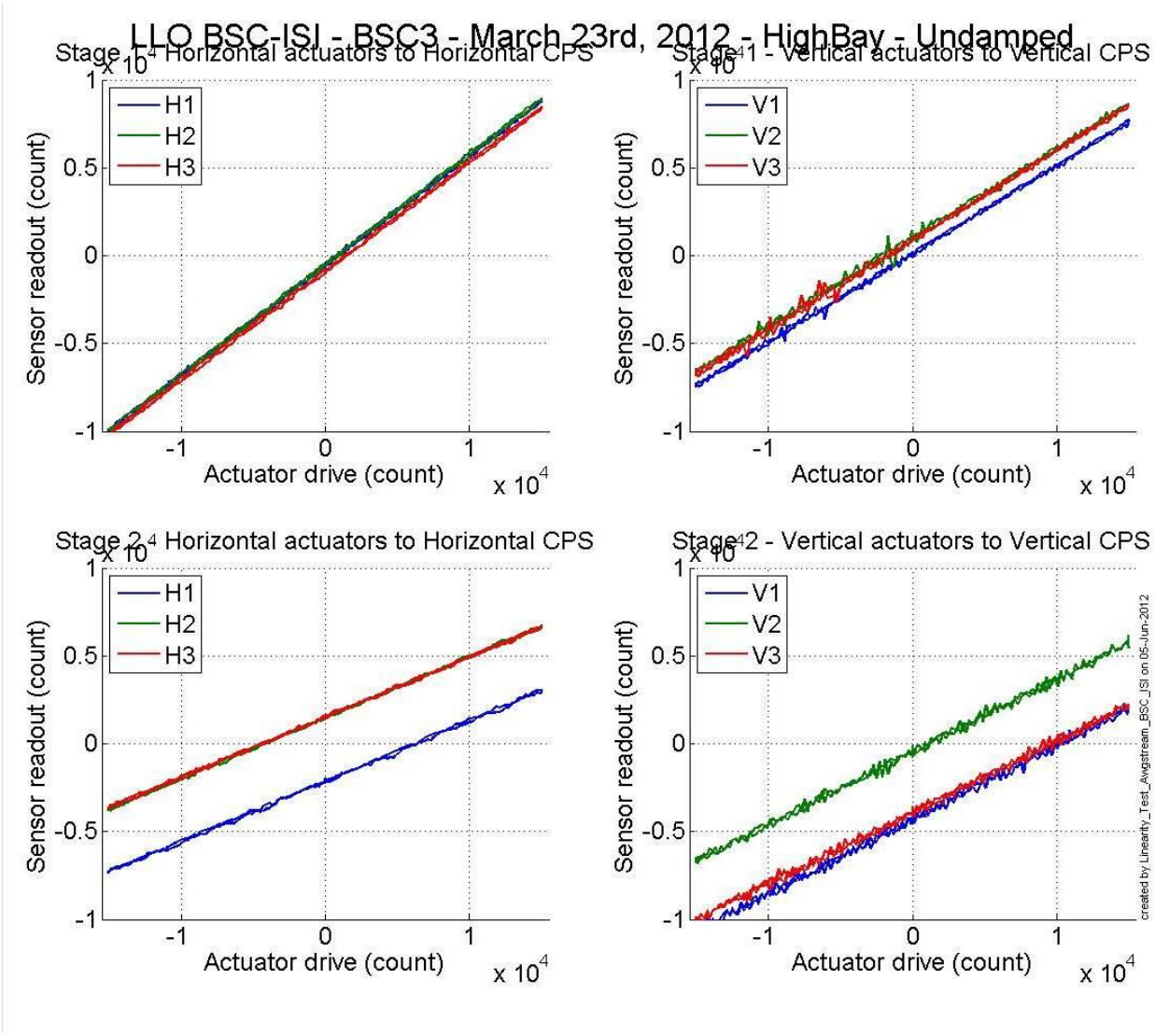


Figure 16 - Linearity Test

Slope – Offset:

		Slope	Offset	Average slope	Variation from average (%)
Stage 1	ST1 - H1	0.625	-545.663	0.6243	0.11
	ST1 - H2	0.629	-505.057		0.75
	ST1 - H3	0.619	-869.126		-0.85
	ST1 - V1	0.500	110.081	0.5050	-0.99
	ST1 - V2	0.505	1027.266		0.00
	ST1 - V3	0.510	883.994		0.99
Stage 2	ST2 - H1	0.344	-2130.726	0.3443	-0.10
	ST2 - H2	0.347	1480.327		0.77
	ST2 - H3	0.342	1513.962		-0.68
	ST2 - V1	0.423	-4312.523	0.4137	2.26
	ST2 - V2	0.413	-460.412		-0.16
	ST2 - V3	0.405	-3912.741		-2.10

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

Previous Results:

		Averages (LHO Unit 1 & 2, LLO Unit 1)				Comparisons with LLO Unit 2	
		Slope	Offset	Average slope	Standard Deviation to Average Slope	% Slope Previous Units/ LLO Unit 2 Slope	% Average Slope of Previous Units / LLO Unit 2 Average Slope
Stage 1	ST1 - H1	0.631	36.584	0.624	0.002	-0.920	0.09
	ST1 - H2	0.622	-130.014			1.073	
	ST1 - H3	0.618	60.969			0.121	
	ST1 - V1	0.503	292.270	0.501	0.003	-0.600	0.73
	ST1 - V2	0.501	693.317			0.743	
	ST1 - V3	0.500	268.249			2.059	
Stage 2	ST2 - H1	0.345	899.569	0.343	0.002	-0.291	0.46
	ST2 - H2	0.343	1702.082			1.153	
	ST2 - H3	0.341	2331.741			0.439	
	ST2 - V1	0.423	-878.881	0.419	0.003	0.000	-1.27
	ST2 - V2	0.418	365.397			-1.271	
	ST2 - V3	0.415	-111.935			-2.469	

Looking at the average Slopes from the Previous BSC-ISI Units, we can see that this Unit follows the general trend (within 1.3%).

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 2 V1 and V3 is a little bit high but still satisfies our criteria and looking the comparisons with averages from the Previous Units, we can conclude that it is more than acceptable.

Test result: **Passed: X** **Failed: ___** **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_20120605-193428.mat
- LLO_ISI_BSC3_Data_L2L_100mHz_700mHz_ST1_ST2_20120605-230119.mat
- LLO_ISI_BSC3_Data_L2L_700mHz_10Hz_ST1_ST2_20120606-082709.mat
- LLO_ISI_BSC2_Data_L2L_10Hz_100Hz_ST1_ST2_20120326-192909.mat
- LLO_ISI_BSC3_Data_L2L_100Hz_500Hz_ST1_ST2_20120605-174928.mat
- LLO_ISI_BSC3_Data_L2L_500Hz_1000Hz_ST1_ST2_20120605-162459.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_06_06.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST1_L4C_2012_06_06.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_CPS_2012_06_06.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_GS13_2012_06_06.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 207Hz. The next resonance is observed at 232Hz. 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 162Hz.

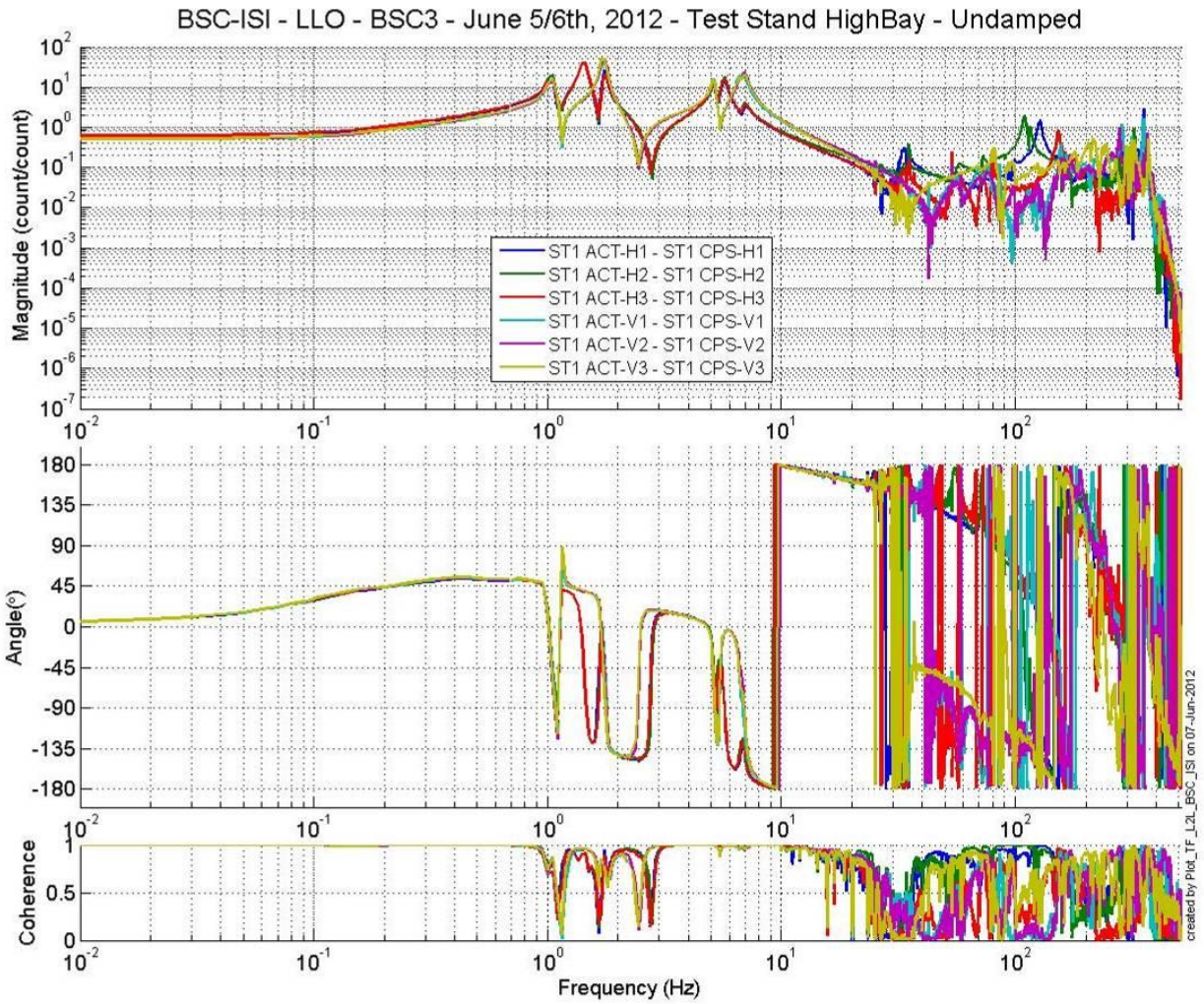


Figure 17 - TF L2L Raw - ST1 Act to ST1 CPS

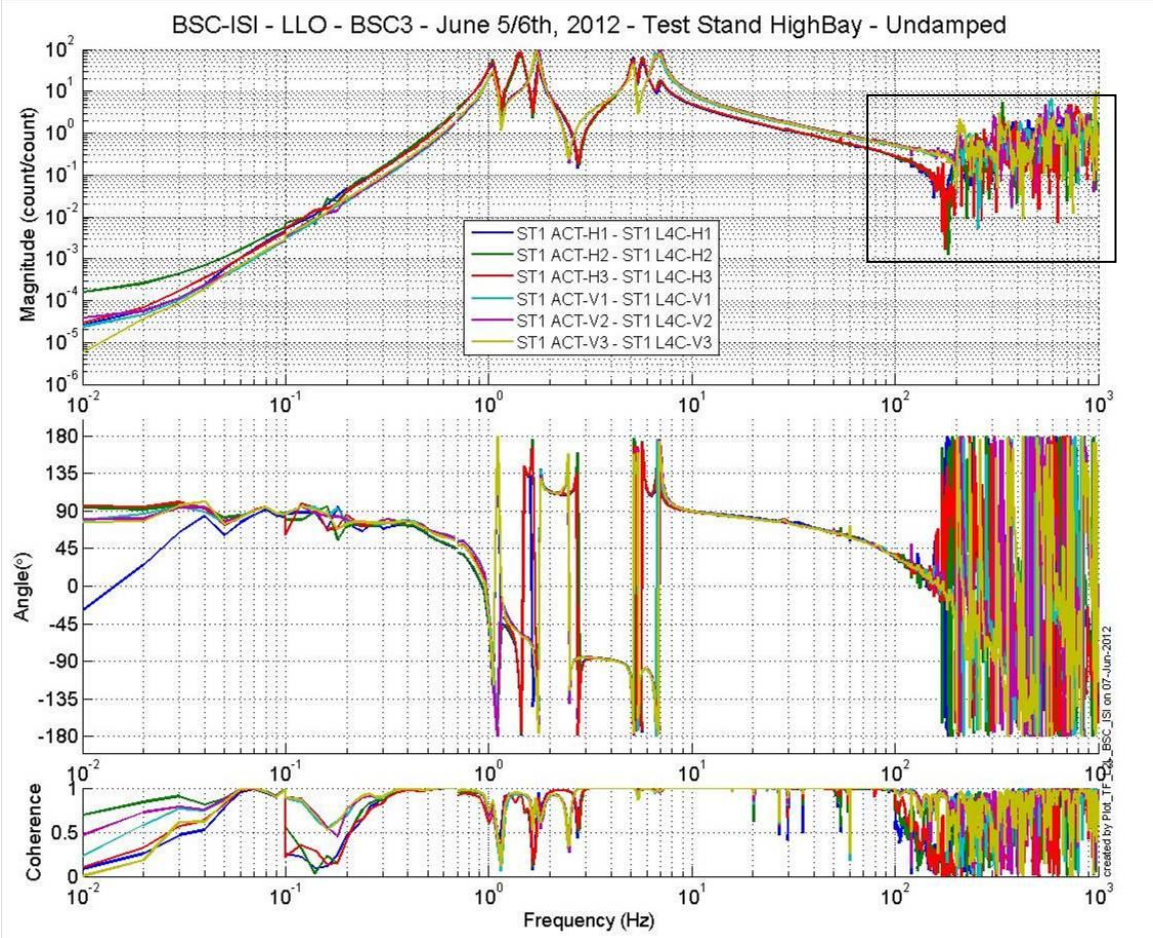
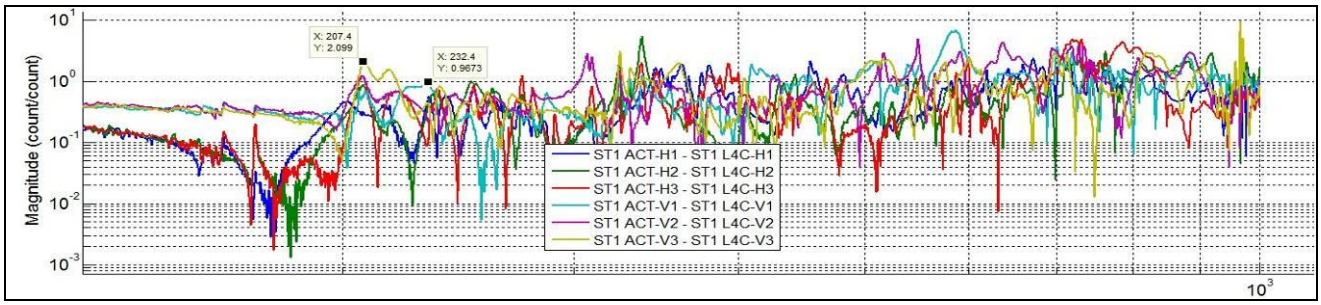


Figure 18 - TF L2L Raw - ST1 Act to ST1 L4C



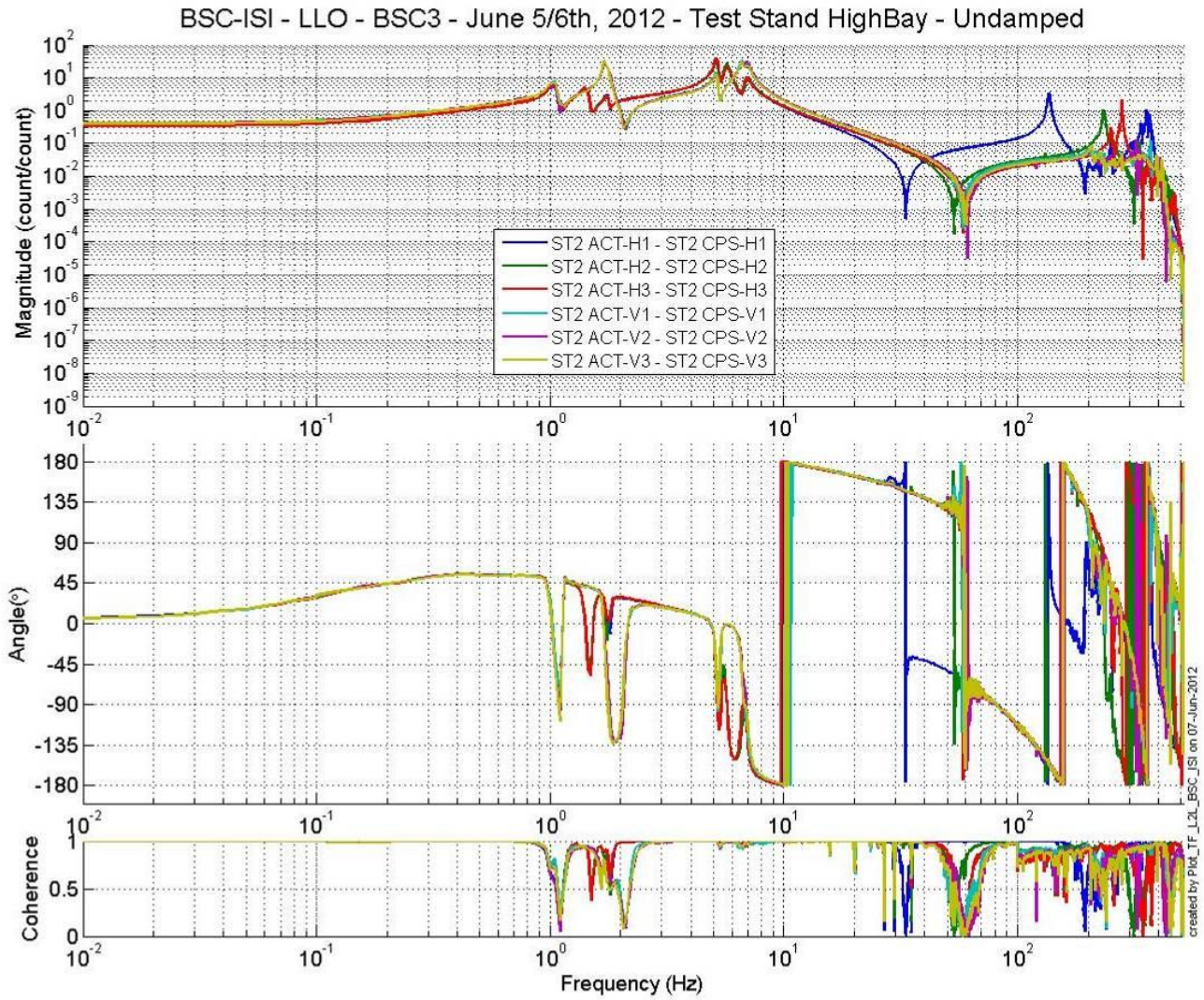


Figure 19 - TF L2L Raw - ST2 Act to ST2 CPS

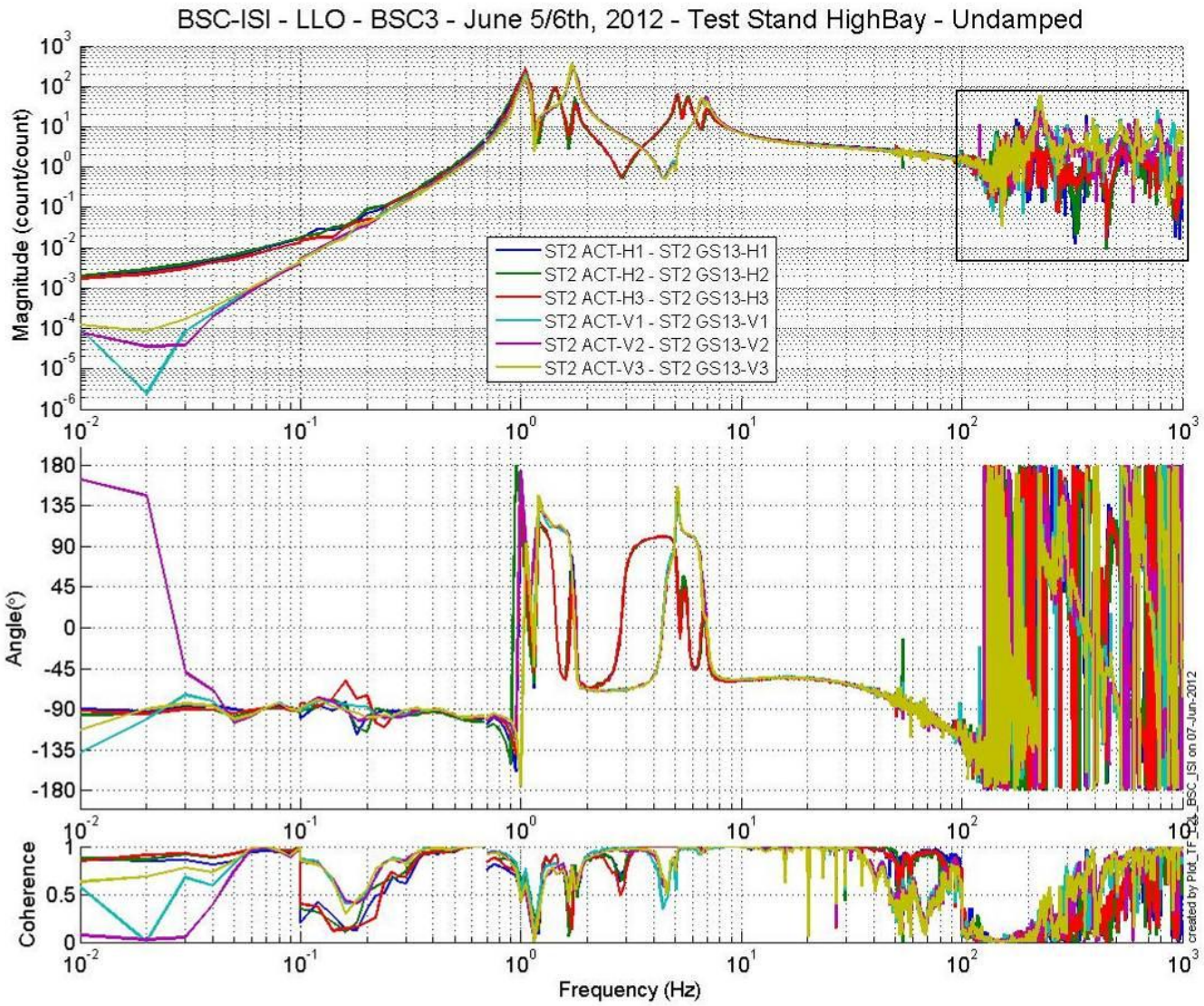
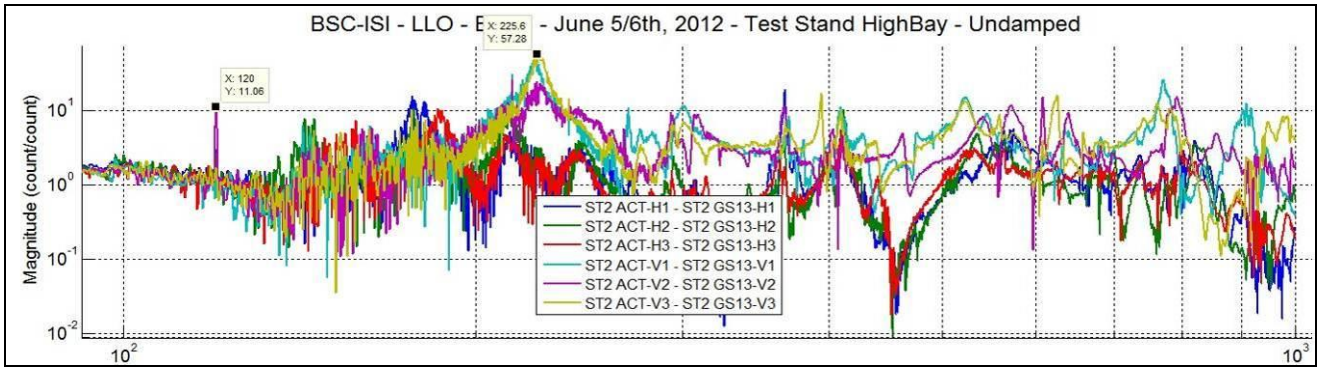


Figure 20 - TF L2L Raw - ST2 Act to ST2 GS13



After taking these Transfer Functions, we tried to increase the number of averages in order to have a better coherence. We used :

- 100 instead of the usual 75 averages for 500 Hz – 1000 Hz
- 100 instead of the usual 75 averages for 100 Hz - 500 Hz
- 100 instead of the usual 75 averages for 10 Hz – 100 Hz
- The usual 75 averages for 700 mHz – 10 Hz
- The usual 30 averages for 100mHz – 700 mHz
- 10 instead of the usual 5 averages for 10 mHz – 100 mHz

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_20120629-202956.mat
- LLO_ISI_BSC3_Data_L2L_100mHz_700mHz_ST1_ST2_20120630-004647.mat
- LLO_ISI_BSC3_Data_L2L_700mHz_10Hz_ST1_ST2_20120630-165237.mat
- LLO_ISI_BSC3_Data_L2L_10Hz_100Hz_ST1_ST2_20120629-202956.mat
- LLO_ISI_BSC3_Data_L2L_100Hz_500Hz_ST1_ST2_20120629-175505.mat
- LLO_ISI_BSC3_Data_L2L_500Hz_1000Hz_ST1_ST2_20120629-155037.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_06_29.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST1_ACT_to_ST1_L4C_2012_06_29.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_CPS_2012_06_29.fig
- LLO_ISI_BSC3_TF_L2L_Raw_from_ST2_ACT_to_ST2_GS13_2012_06_29.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_Data_L2L_10Hz_100Hz_ST1_ST2_20120629-202956.mat

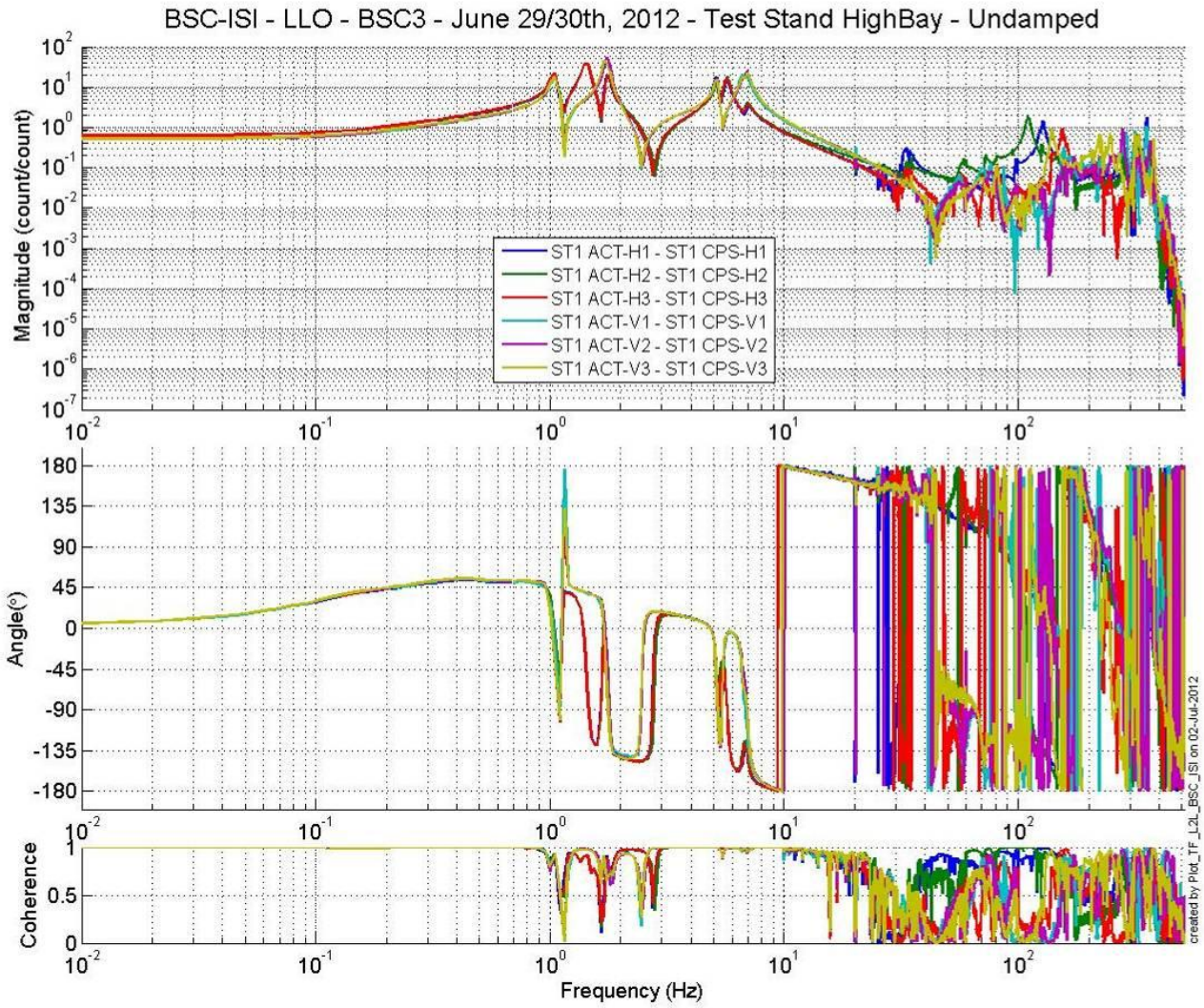


Figure 21: TF L2L Raw - ST1 Act to ST1 CPS

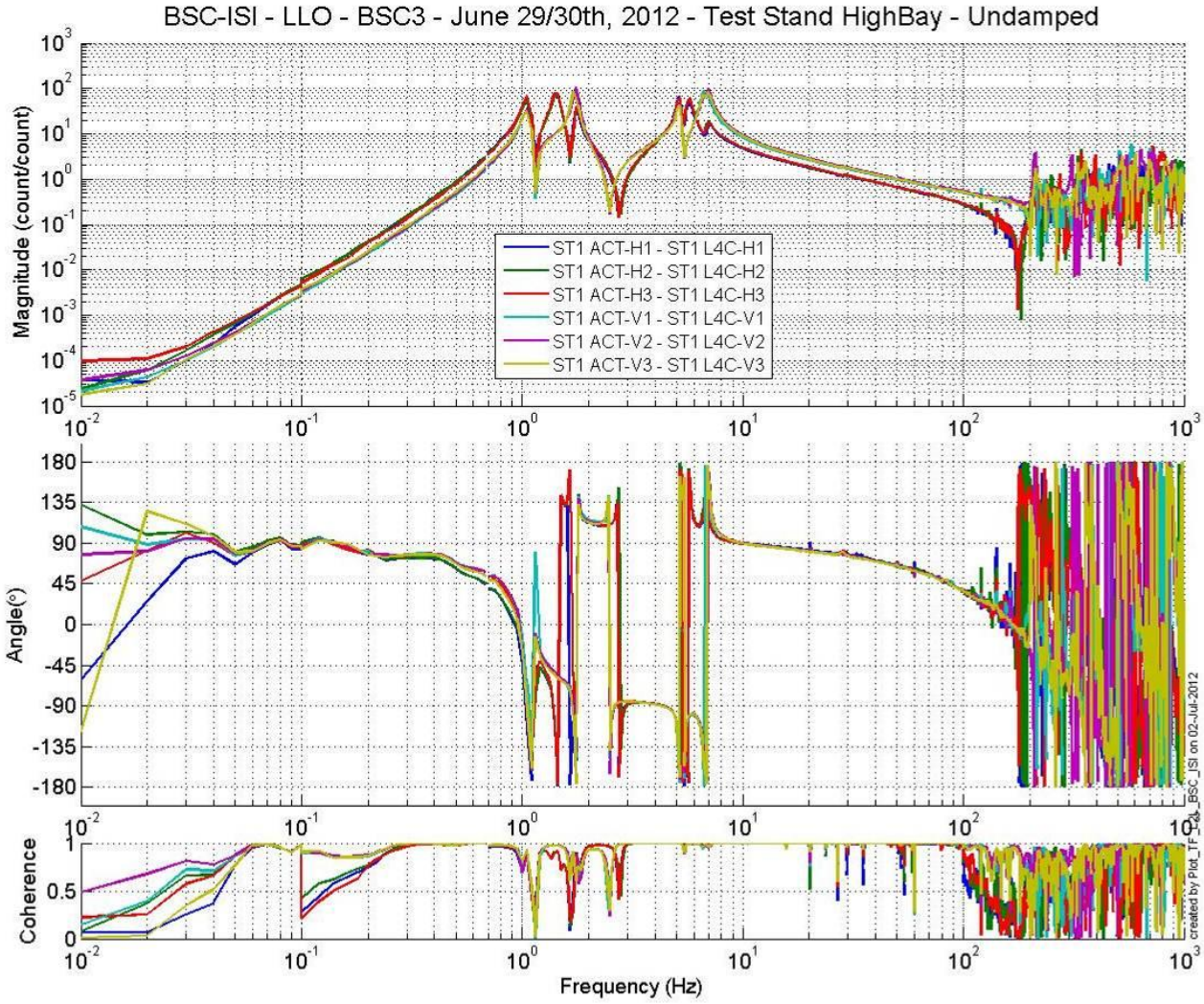


Figure 22: TF L2L Raw - ST1 Act to ST1 L4C

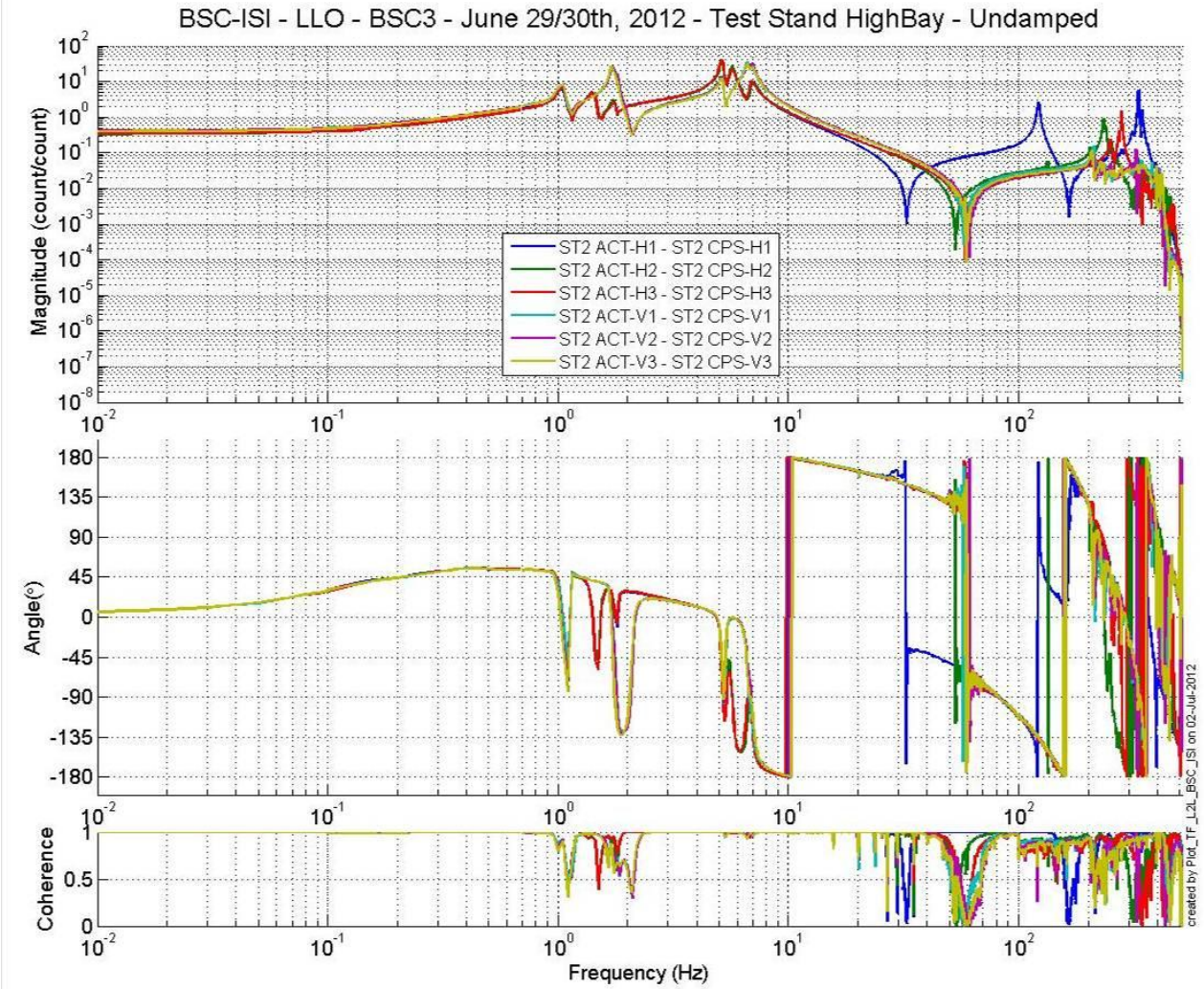


Figure 23: TF L2L Raw - ST2 Act to ST2 CPS

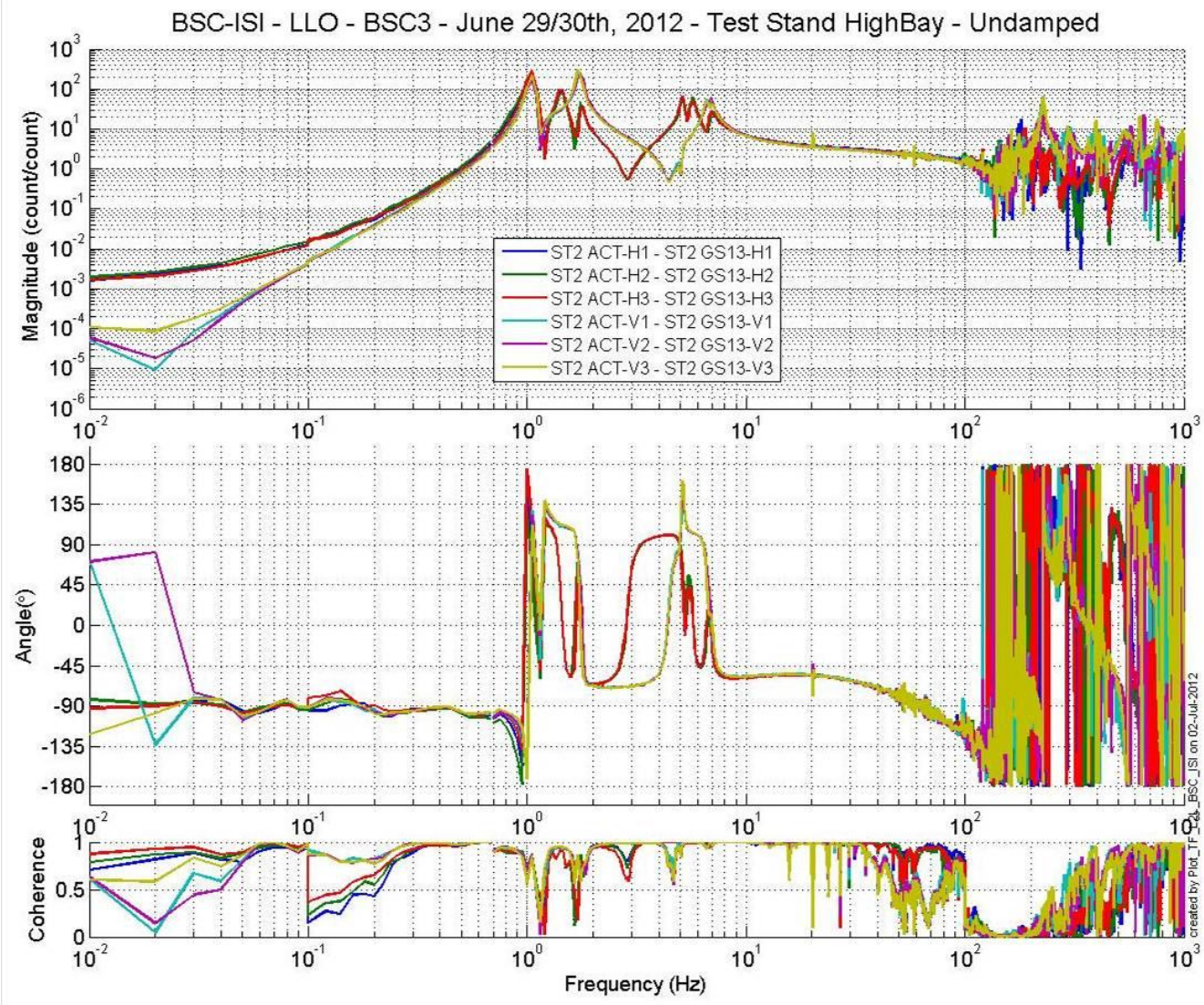


Figure 24: TF L2L Raw - ST2 Act to ST2 GS13

With more averages we can see that we have a better coherence.

We then also decided to compare these results with previous Units (LLO BSC 2 and LHO BSC8).

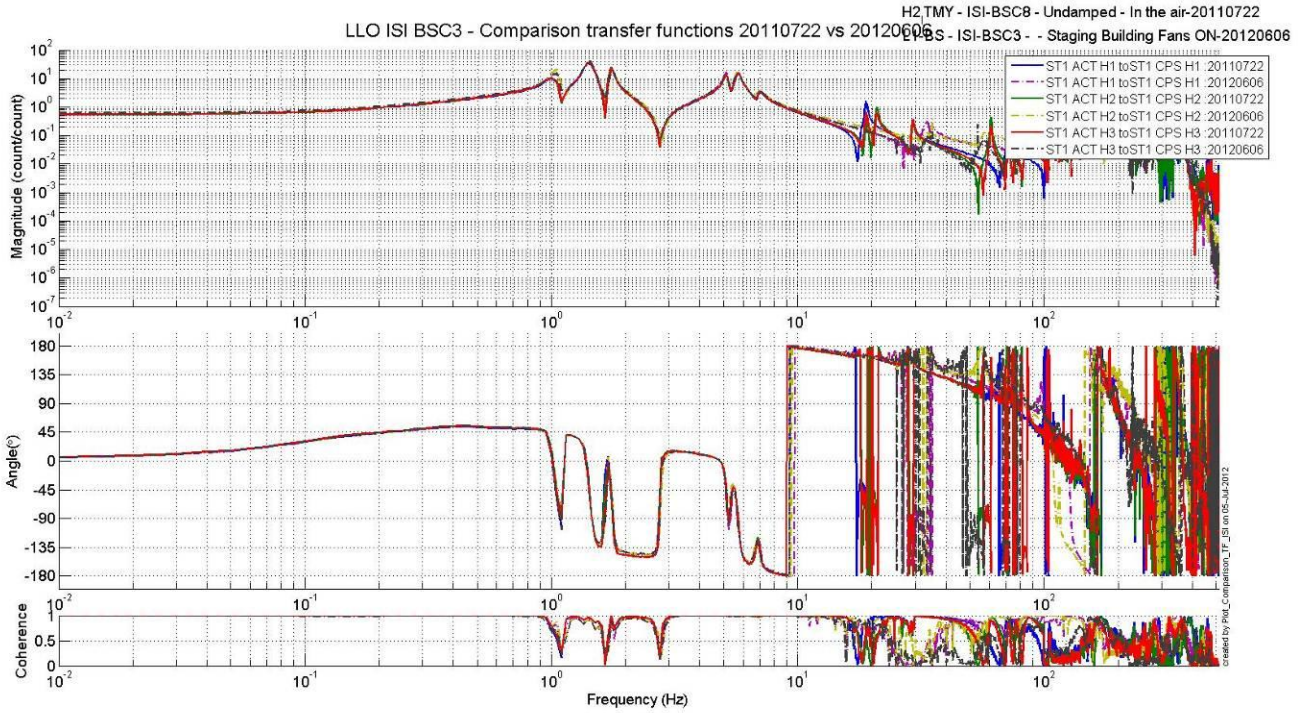


Figure 25: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 – H ST1 Actuator to ST1 CPS

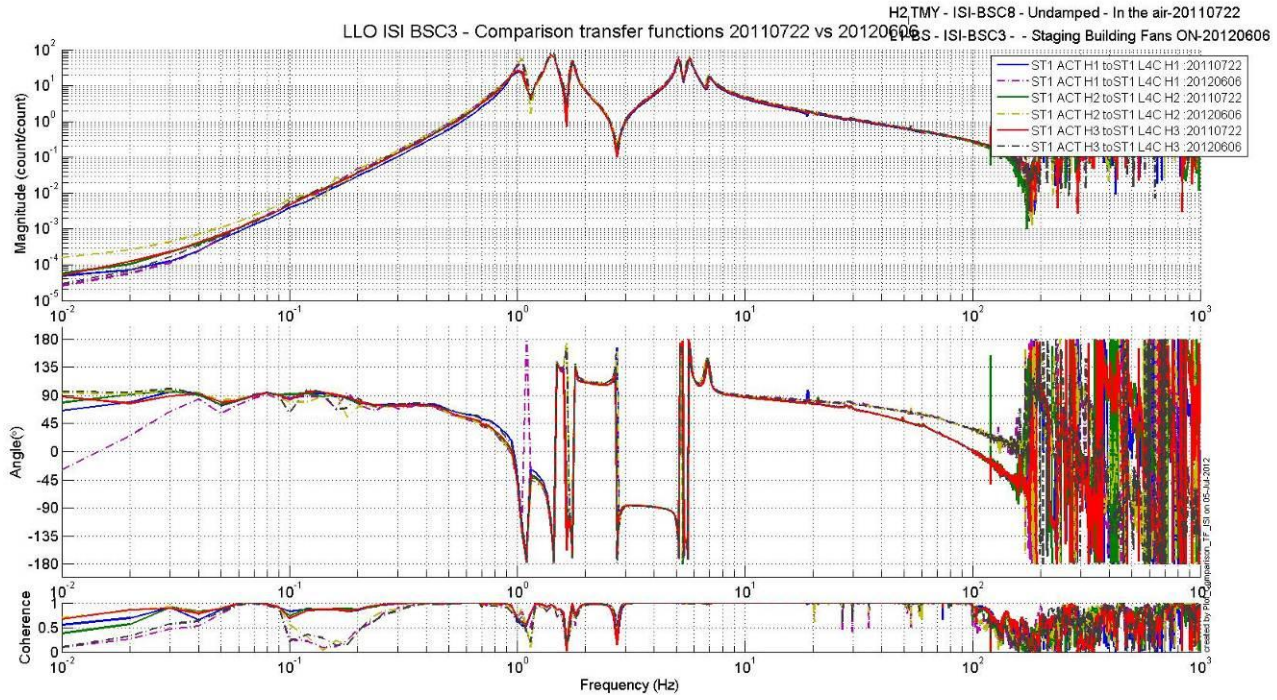


Figure 26: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 – H ST1 Actuator to ST1 L4C

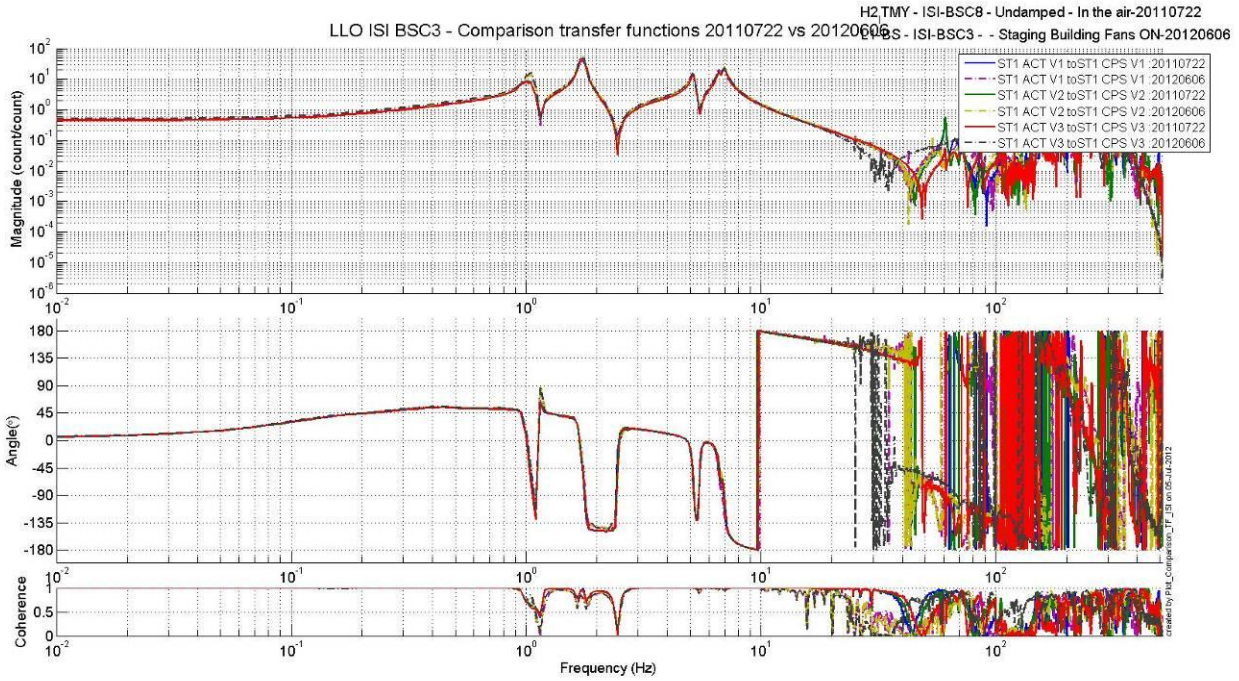


Figure 27: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 – V ST1 Actuator to ST1 CPS

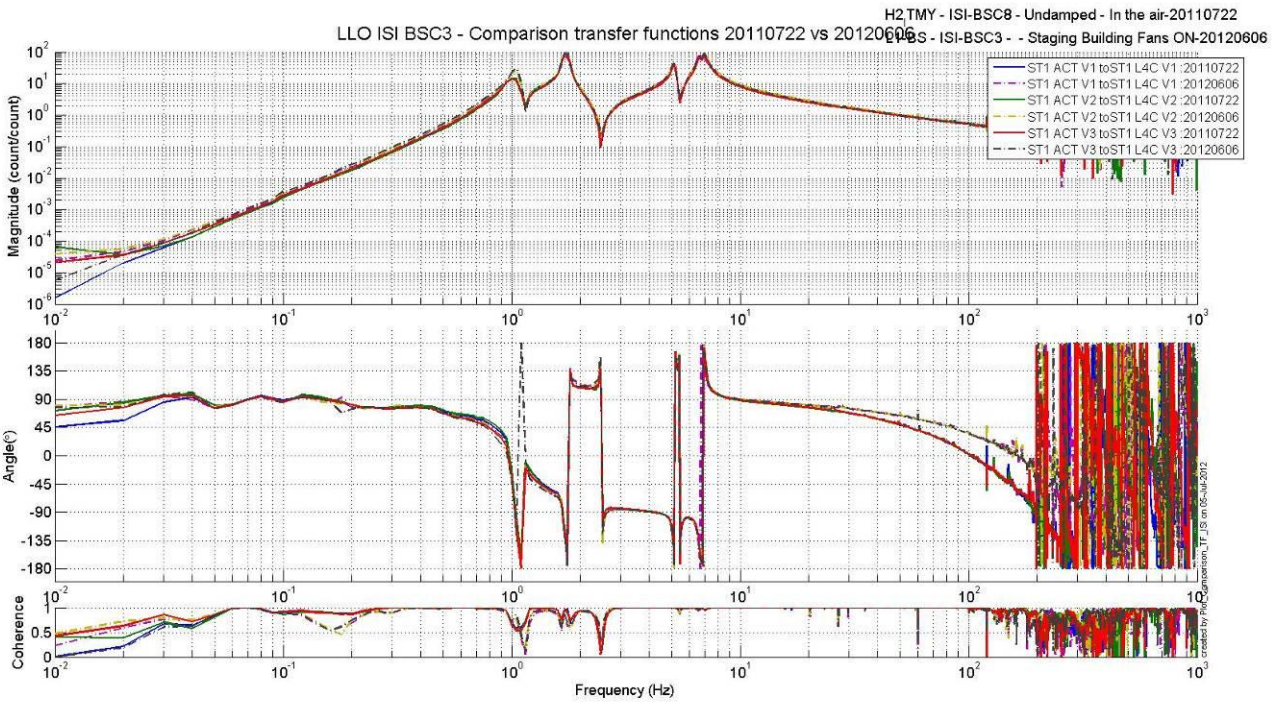


Figure 28: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 – V ST1 Actuator to ST1 L4C

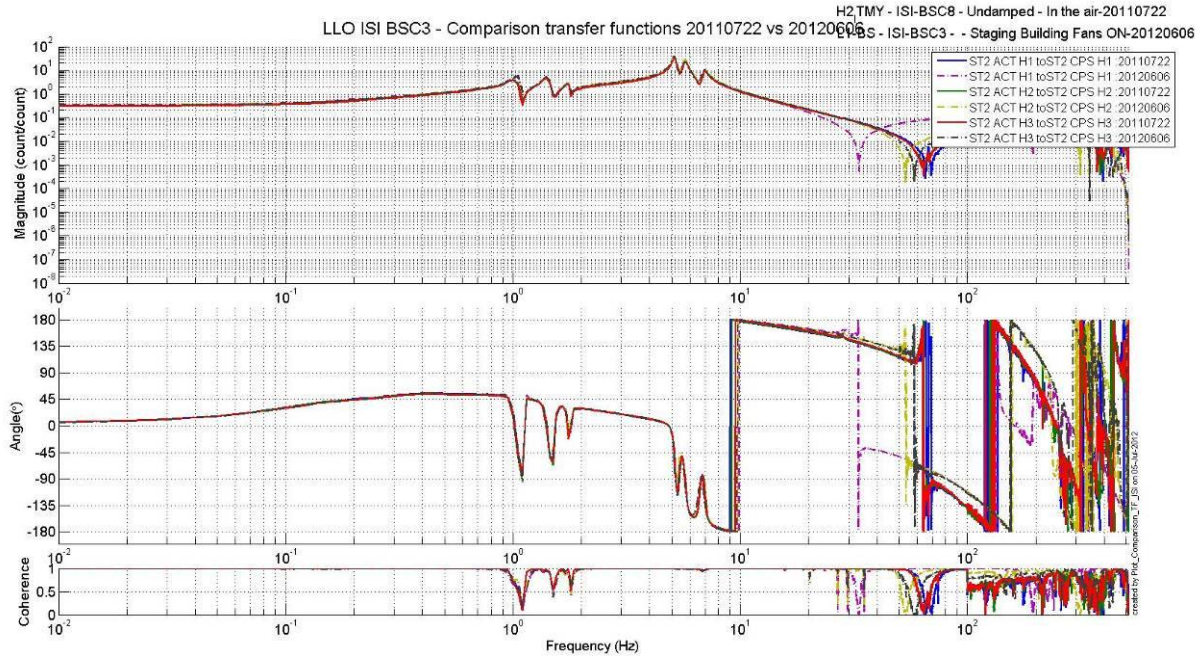


Figure 29: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 – H ST2 Actuator to ST2 CPS

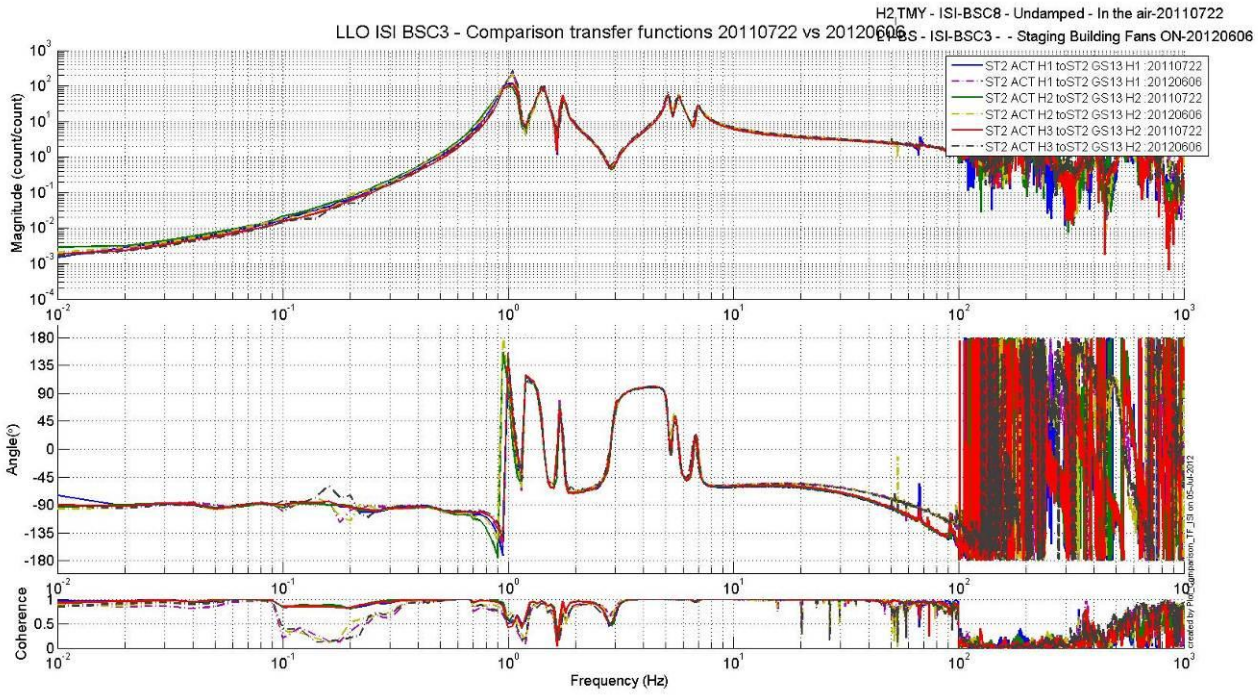


Figure 30: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 – H ST2 Actuator to ST2 GS13

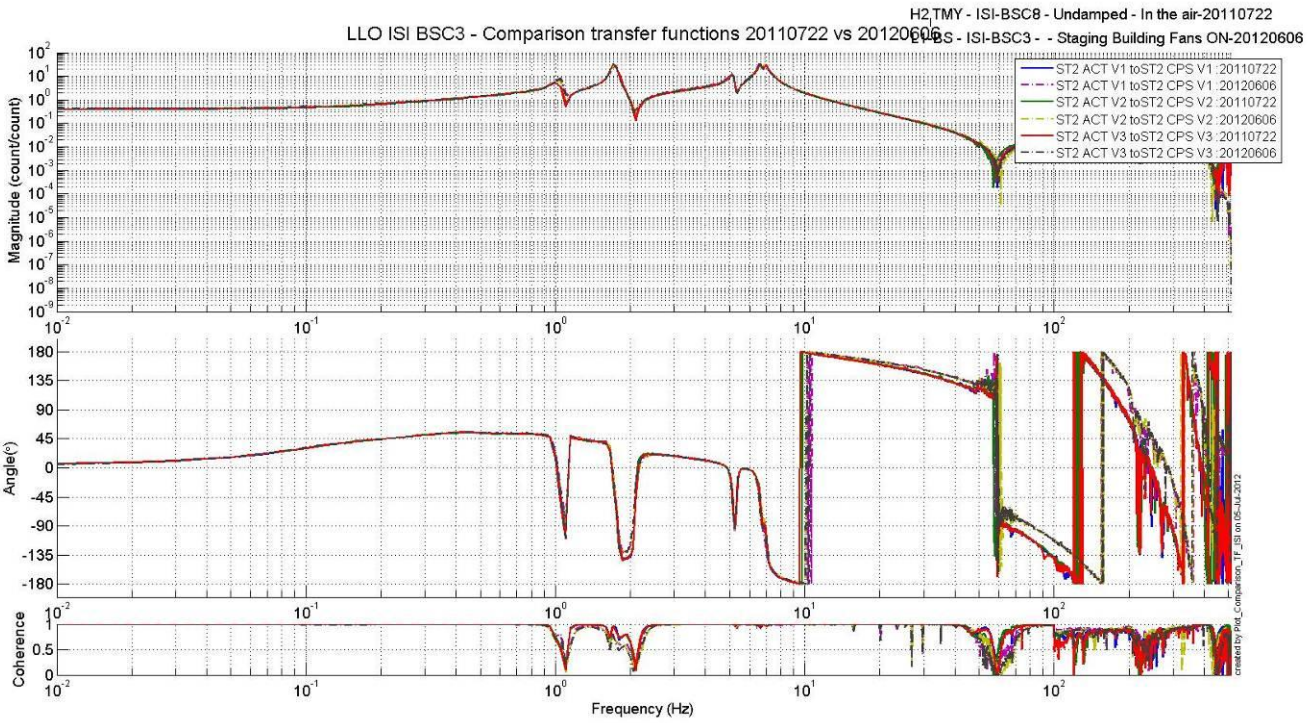


Figure 31: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 – V ST2 Actuator to ST2 CPS

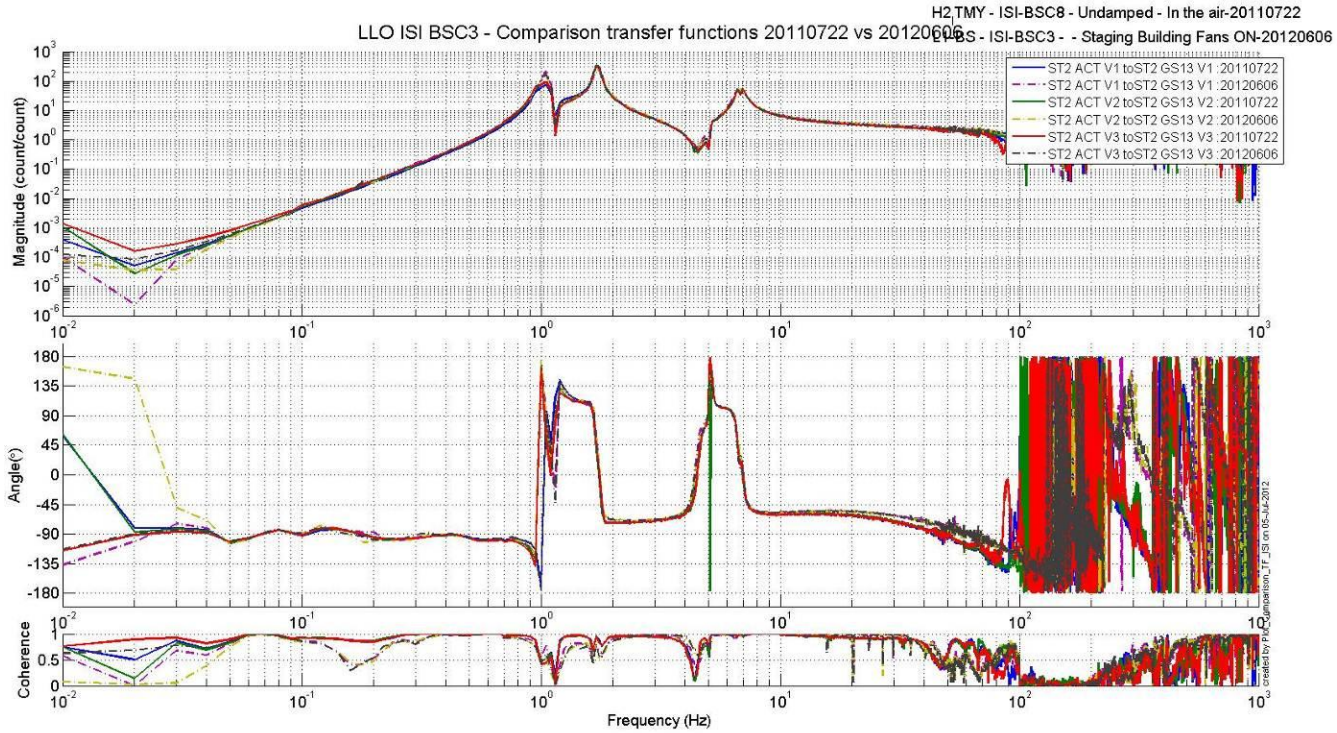


Figure 32: TF L2L Comparison between LLO BSC 3 & LHO BSC 8 – V ST2 Actuator to ST2 GS13

By comparing it to BSC 8, 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_06_25_112515.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_06_25_112515.fig
- LLO_ISI_BSC3_ASD_CT_CART_ST2_GS13_Undamped_vs_Damping_2012_06_25_112515.fig
- LLO_ISI_BSC3_ASD_m_CART_ST1_L4C_Undamped_vs_Damping_2012_06_25_112515.fig
- LLO_ISI_BSC3_ASD_m_CART_ST2_GS13_Undamped_vs_Damping_2012_06_25_112515.fig

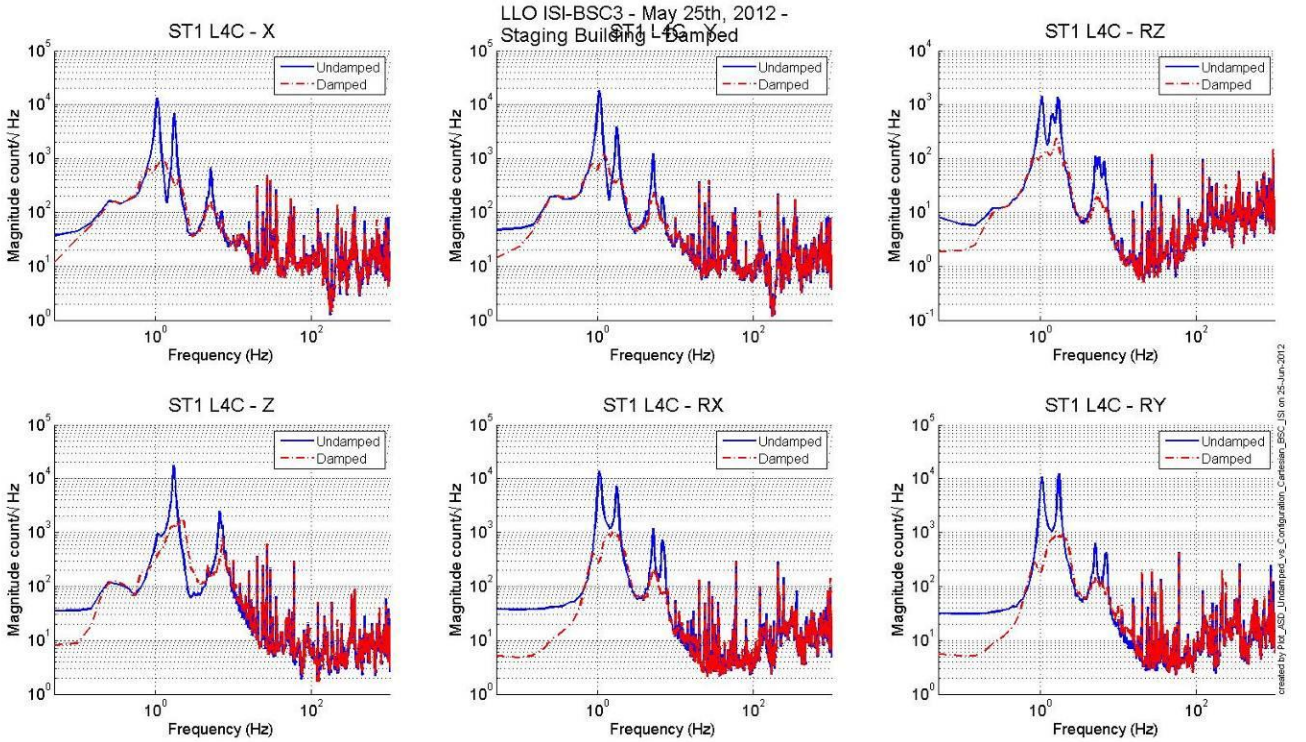


Figure 33: LLO ISI BSC3 ASD CT CART Stage 1 L4C Undamped vs Damping

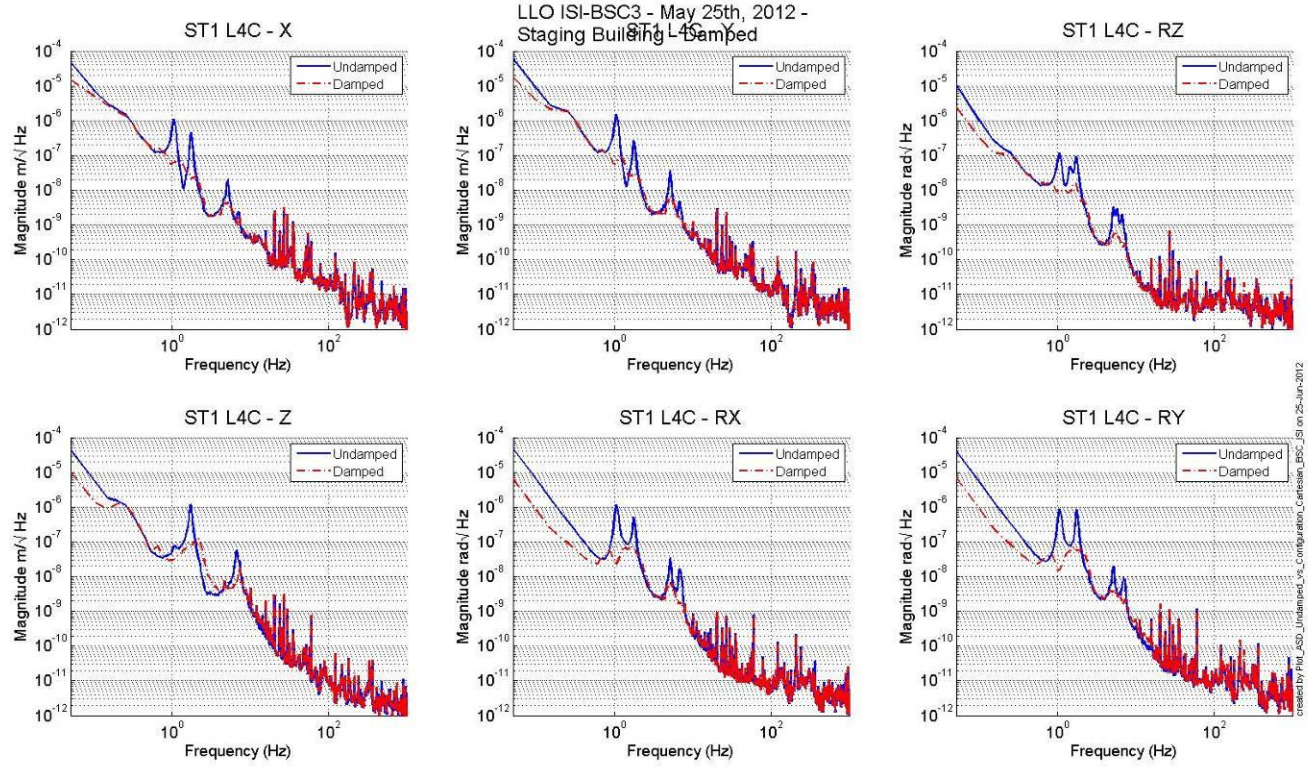


Figure 34: LLO ISI BSC2 ASD m CART Stage 1 L4C Undamped vs Damping

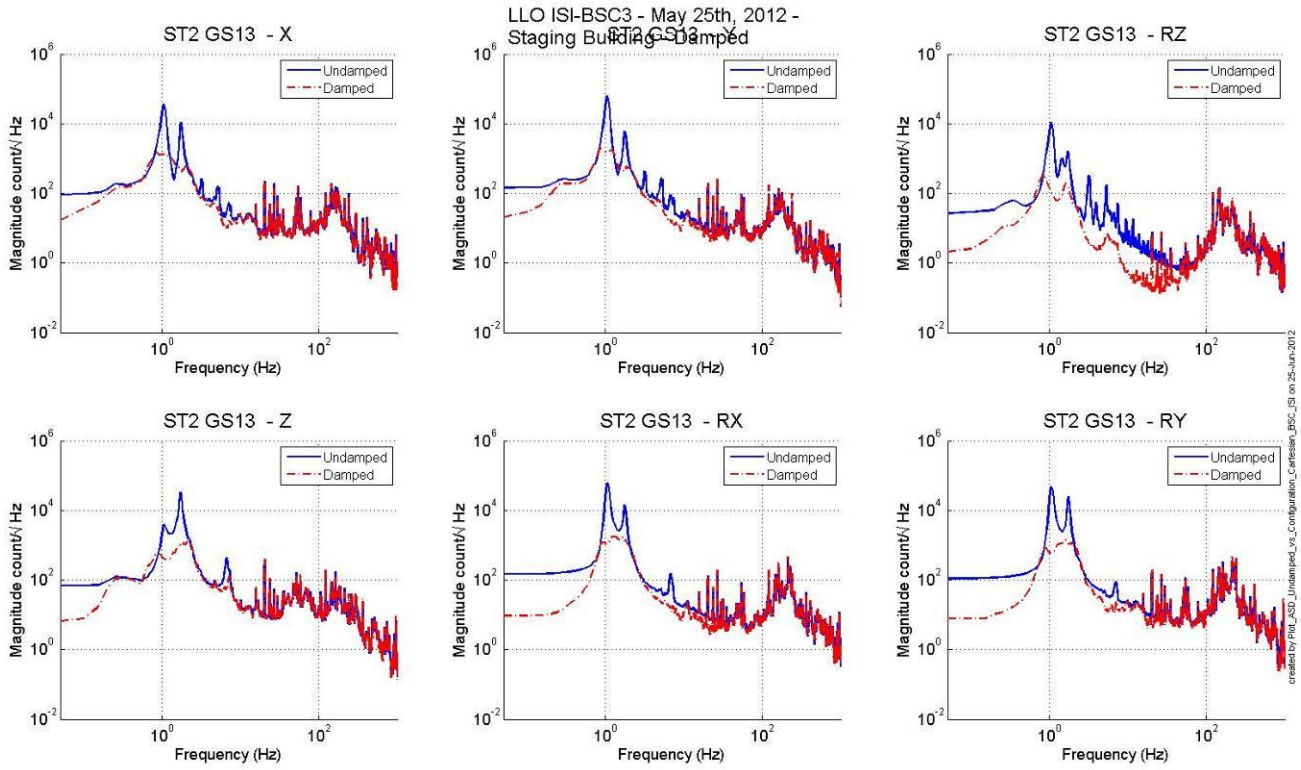


Figure 35: LLO ISI BSC3 ASD CT CART Stage 2 GS 13 Undamped vs Damping

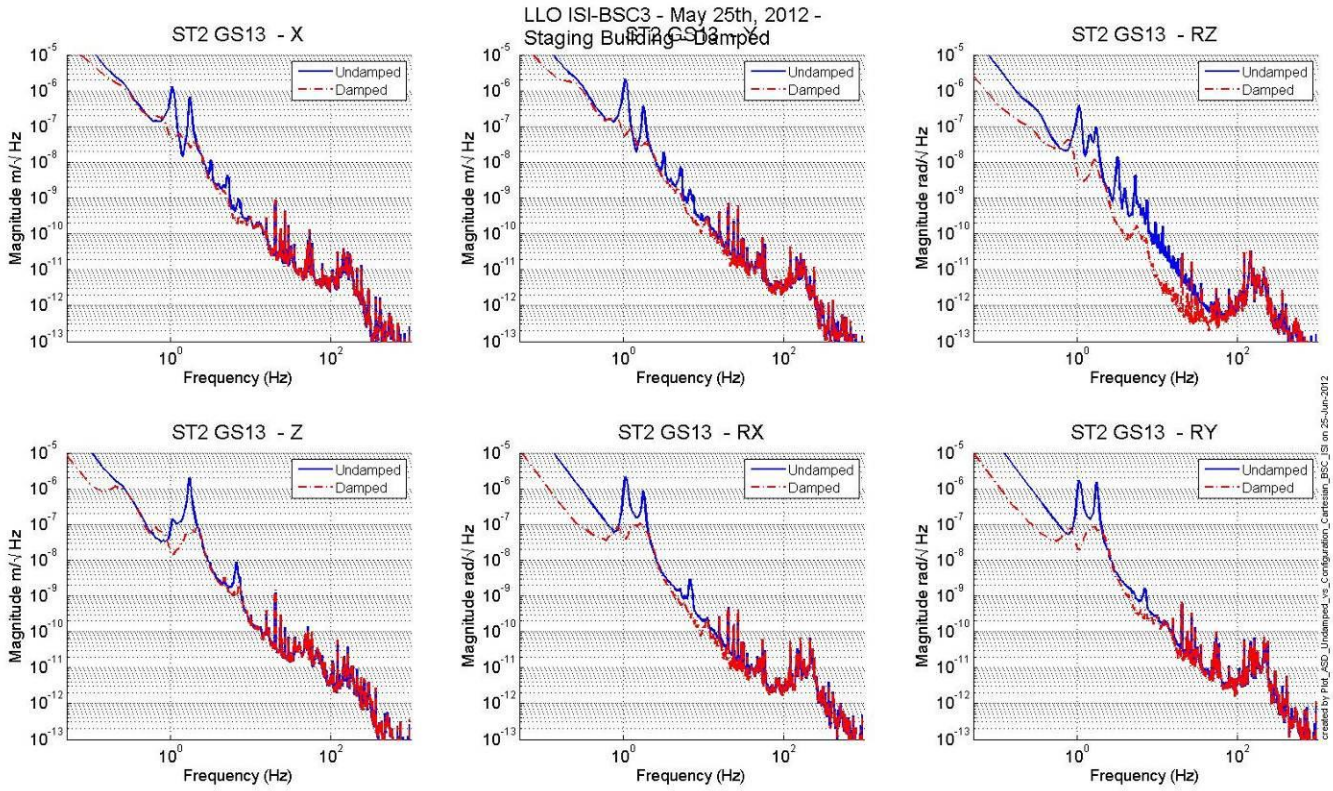


Figure 36: LLO ISI BSC3 ASD m CART Stage 2 GS 13 Undamped vs Damping

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 May & June 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

- **Step II.11 – Lockers adjustment –** No value has been recorded during the locker adjustments. The Twist values have not been recorded because it was good enough that we can put on the Lock Pins on both Stages so it means that the value of the Twist is less than the Locker gap (~.002"). Measurements using the CPS sensors when the stages are locked and unlocked have been done Step III.2.

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

- **Step III.2 – Set up Sensors Gap – Locked vs Unlocked Positions -** Even if Stage 1 V3 CPS is a little bit over the acceptable value (by 40 counts on a 400 counts criteria which is 10%) when the table is in the Locked Position, we did all the testing with these values, knowing that the CPS will have to be re-centered before Install.
- **Step III. 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.

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).
- **Step II.11** – Lockers Adjustment – The Lockers have already been adjusted with the dial indicators, we just didn't record the value, but they are well adjusted (see all passed tests).

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.