

*LIGO Laboratory / LIGO Scientific Collaboration*LIGO- [E1100300](#)*LIGO*May 16th, 2014

**aLIGO BSC-ISI, Pre-integration Testing report,
Unit 7 - Phase I (post-assembly)**

E1100300 – V1

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Distribution of this document:
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Introduction

The BSC-ISI testing is performed in three phases:

- 1) BSC-ISI, Pre-integration Testing, Phase I (post-assembly)
- 2) BSC-ISI, Pre-integration Testing, Phase II: Tests done after Transport (and possible storage), during mating phase with Suspensions, before insertion.
- 3) BSC-ISI, Integration Phase Testing: Procedure and results related to the commissioning in the chamber.

This document presents the series of tests (Phase I) performed on the fourth BSC-ISI assembled at LHO.

The testing procedure document E1000486-v5 was used.

All results are posted on the SVN at:

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/X1/Unit_8/

The following type of document can be found in the SVN:

- Excel spreadsheet (.xls)
- Data location
- Figures location
- Masses distribution scheme (ppt)

II. Tests to be performed during assembly

o Step 1 - Test stand level

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

Test result: Passed: X Failed: ___ Waived :

o Step 2 - Actuators Inventory

The actuators S/N are reported in the table below. Further information can be found in T0900564 and T1100234.

Stage 1		Stage 2	
Actuator	Actuator S/N	Actuator	Actuator S/N
ST1 - H1		ST2 - H1	
ST1 - H2		ST2 - H2	
ST1 - H3		ST2 - H3	
ST1 - V1		ST2 - V1	
ST1 - V2		ST2 - V2	
ST1 - V3		ST2 - V3	

Table 1 - Actuators' inventory

Test result: Passed: X Failed: ___ Waived :

o Step 3 - Sensors Inventory

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

CPS Stage 1	CPS S/N	ADE board serial #
H1		
H2		
H3		
V1		
V2		
V3		

Table 2 - Capacitive position sensors' inventory – Stage 1

CPS Stage 2	CPS S/N	ADE board serial #
H1		
H2		
H3		
V1		
V2		
V3		

Table 3 - Capacitive position sensors' inventory – Stage 2

Geophones GS13	Serial Number	POD
H1		
H2		
H3		
V1		
V2		
V3		

Table 4 - GS13 inventory

Geophones L4C	Serial Number	POD
H1		
H2		
H3		
V1		
V2		
V3		

Table 5 - L4C inventory

Geophones T240	Serial Number	POD
1		
2		
3		

Table 6 - T240 inventory

Test result:

Passed: X

Failed: ___

Waived : ___

o Step 4 - Electronics Inventory

Write down in the table below all serial numbers all the electronic equipment:

Hardware	Ligo reference	S/N
Interface Chassis - Corner 1	D1002432	S110223
Interface Chassis - Corner 2		S1102224
Interface Chassis - Corner 3		S1102218
Anti-Alliasing Chassis - Corner 1	D1002693	S1102693
Anti-Alliasing Chassis - Corner 2		S1102694
Anti-Alliasing Chassis - Corner 3		S1102679
Anti-image Chassis	D070081	S1000250
Binary Input Chassis	D1001726	S1101309
Binary Input Chassis		S11031308
Binary Output Chassis	D1001728	S1101347
T240 Interface - Corner 1	D1002694	S1101040
T240 Interface - Corner 2		S1101838
T240 Interface - Corner 3		S1101839
I/O Chassis	n/a	
Coil driver Pod 1	D0902744	S1000266
Coil driver Pod 2		S1000269
Coil driver Pod 3		S110692

Table 7 - Electronic equipment

Note:

Test result: Passed: X Failed: ___ Waived :

o Step 5 - Check level of Stage 0 after top-bottom plate assembly

Note: This test has not been performed. The test stand was leveled before assembly began.

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

o Step 6 - Check gaps under the blade posts

Test result: Passed: X Failed: ___ Waived :

o **Step 7 - Blade post shim thickness**

This table shows the shims thickness installed under the lockers.

Stage 0-1		Stage 1-2	
Lockers	Shim thickness (mil)	Lockers	Shim thickness (mil)
Corner 1		Corner 1	
Corner 2		Corner 2	
Corner 3		Corner 3	

Table 8 - Shims thickness

Acceptance criteria: Both D0901805 Stage 0-1 Locker Shims & D0902551 Stage 1-2 Locker Shims goes from .110” up to .130” with an increment of .001”.

Test result: Passed: X Failed: ___ Waived :

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

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

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

Test result: Passed: X Failed: ___ Waived :

o Step 10 - Mass budget

Note: The second version of the blade spacers was used. Consequently, the additional payload is expected to be close from design.

Six vibration absorbers were installed on stage 1. Masses on stage 2 are resting on Viton pads.

Stage 1:

The stage 1 payload is reported in the table below:

Corner 1
Corner 2
Corner 3

Stage 1	
Location	Weight (lb)
Corner 1	
Corner 2	
Corner 3	
Total	

Table 9 - Payload Stage 1

Nominal payload on stage 1: 109Kg - 240lb

Additional payload on stage 1 is 48 kg (107lb) less than expected but good enough.

Nominal mass of stage 1=916Kg - 2019lb

Stage 2:

The stage 2 payload is reported in the table below:

Mass Budget	Quantity	Weight	Unit	Weight (lb)
	3	610	lb	1830
	2	233	lb	466
type 0			lb	
type 1			lb	
type 2			lb	
type 3			lb	
type 4			lb	
type 5			lb	
type 6			lb	

Table 10 - Payload Stage 2

Nominal payload: 1183.4Kg – 2609lb

Total nominal mass of Stage 2: 2913.9Kg – 6424lb

Additional stage 2 payload is 30lb lighter than the design.

Error mass on stage 0-1 blades: $-(30+107)/(6424+2019) = -1.6\%$

The Overall error on the weight of the payload is really low.

Test result: Passed: X Failed: ___ Waived :

o Step 12 – Cables inventory – E1100822

The final Class A cables have been used for the testing of this Unit.

DCC Number	Description	Serial Number	Location	Inventory date	Tested
D1100154	25-pin M-to-two 9-pin F straight		L4C corner2		YES
D1100155	25-pin M-to-two 9-pin F straight		GS-13 corner2		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 V3		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 V2		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 H3		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 H2		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 H2		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 H3		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 V3		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 V2		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 V1		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 H2		YES
D1100150	2-wire, 14awg 2 pins to 3-pin F		Act St1 H1		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 H2		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 V2		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 H3		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 V3		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St2 V1		YES
D1100151	2-wire, 14awg 2 pins to 3-pin F		Act St H1		YES
D1100152	25-pin F-to-25-pin F		T240 corner3		YES
D1100152	25-pin F-to-25-pin F		T240 corner1		YES
D1100152	25-pin F-to-25-pin F		T240 corner2		YES
D1100153	25-pin F-to-25-pin F		L4C corner2		YES
D1100153	25-pin F-to-25-pin F		GS-13 corner3		YES
D1100153	25-pin F-to-25-pin F		L4C corner3		YES
D1100153	25-pin F-to-25-pin F		GS-13 corner2		YES
D1100153	25-pin F-to-25-pin F		L4C corner1		YES
D1100153	25-pin F-to-25-pin F		GS-13 corner1		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 V3 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 H1 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 V1		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 H3 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 H1 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St1 V2 ext		YES
D1100148	2-wire, 14awg 3-pin M to 3-pin F		Act St2 V1 ext		YES
D1100154	25-pin M-to-two 9-pin F straight		L4C corner1 ext		YES
D1100155	25-pin M-to-two 9-pin F straight		GS-13 corner1		YES
D1100155	25-pin M-to-two 9-pin F straight		GS-13 corner3		YES
D1100154	25-pin M-to-two 9-pin F straight		L4C corner3		YES

Test result: Passed: X Failed: ___ Waived:

o 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

o Step 1- Geophones pressure readout

Raw pressure measured by the geophones is reported in the table below:

Sensors	Pressure (kPa)		
	Corner 1	Corner 2	Corner 3
ST1-L4C-P			
ST1-L4C-D			
ST1-GS13-P			
ST1-GS13-D			
ST1-T240-P			

Table 11 - Raw Pressure

A screenshot of the MEDM pressure screen is saved in the Misc directory for Unit 6

Note: The T240's chassis has the old gain for the pressure sensors.

Test result: Passed: X Failed: ___ Waived :

o **Step 4.2 - Test N°2 – Push “locally”**

Sensors	Push in negative direction	Push in positive direction	Mil	Mil	Railing	Actuator Gap Check
ST1 - H1	-18000	17000	-22	21		X
ST1 - H2	-17000	17000	-21	20		X
ST1 - H3	-19000	19000	-20	21		X
ST1 - V1	-22000	21000	-29	29		X
ST1 - V2	-22000	21000	-32	29		X
ST1 - V3	-22000	22000	-32	30		X
ST2 - H1					X	X
ST2 - H2					X	X
ST2 - H3					X	X
ST2 - V1					X	X
ST2 - V2					X	X
ST2 - V3					X	X

Table 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**
 - o Absolute value of all estimated motions must be higher than 15000counts for stage 1 (~0.018”)
 - o Absolute value of all estimated motions must be higher than 32000counts for stage 2 (~0.010”)

Test result:

Passed: X

Failed: ___

Waived :

o Step 5 - Sensors spectra

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

seismic/BSC-ISI/X1/Unit_8/Data/Spectra/Undamped/

- [X1 ISI ITMX ASD m LOC CPS T240 L4C GS13 2014 06 09 015413.mat](#) (Unlocked)
- [X1 ISI ITMX ASD m LOC CPS T240 L4C GS13 2014 06 10 124338.mat](#) (Locked)

seismic/BSC-ISI/X1/Unit_8/Data/Figures/Spectra/Undamped/

- [X1 ISI ITMX ASD m LOC CPS T240 L4C GS13 2014 06 09 015413.fig](#) (Unlocked)
- [X1 ISI ITMX ASD m LOC CPS T240 L4C GS13 2014 06 10 124338.fig](#) (Locked)

Stage locked – unlocked

The spectra are measured in two different configurations:

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

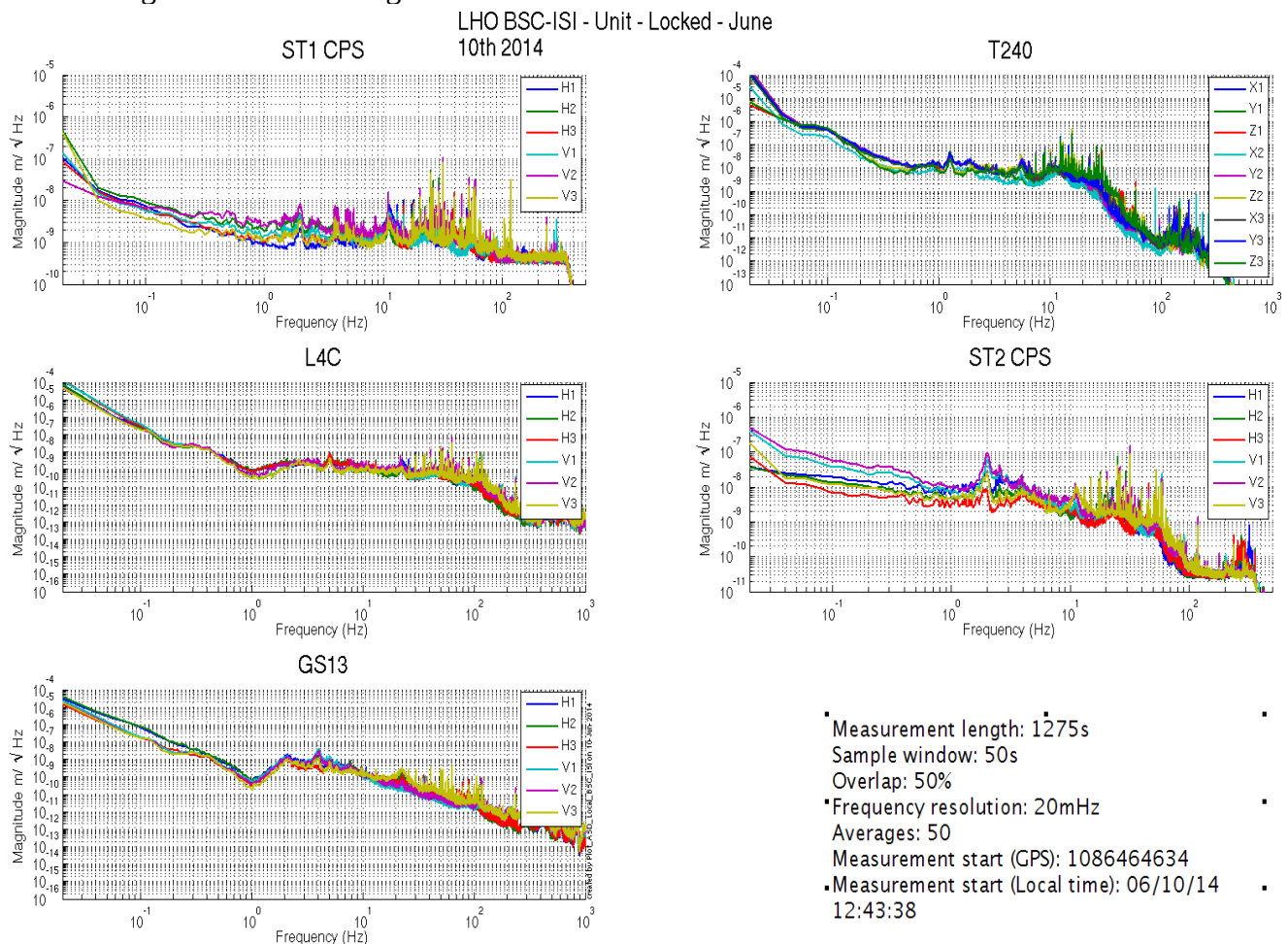
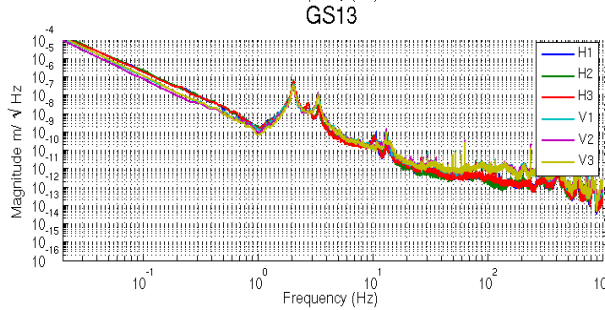
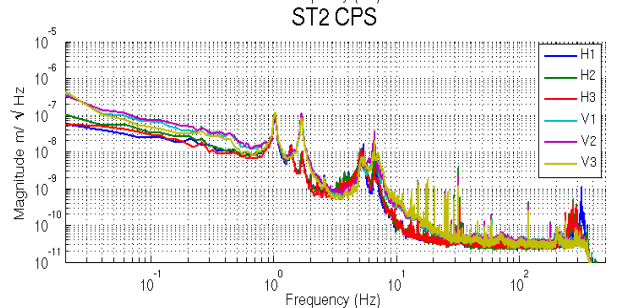
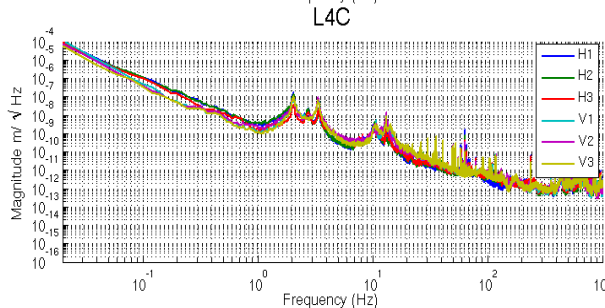
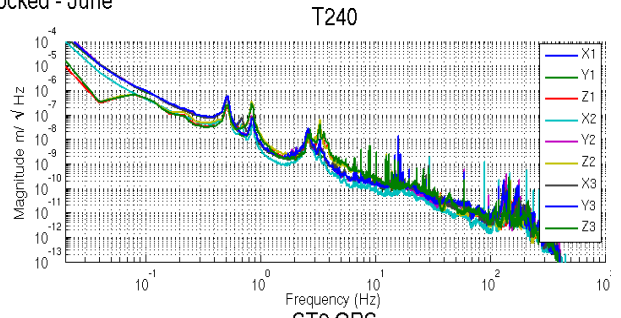
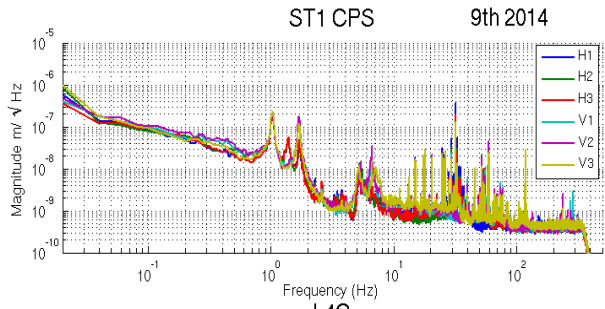


Figure 1: Calibrated Spectra Stage 1 Locked and Stage 2 Locked

LHO BSC-ISI - Unit - unLocked - June
9th 2014



Measurement length: 1275s
Sample window: 50s
Overlap: 50%
Frequency resolution: 20mHz
Averages: 50
Measurement start (GPS): 1086339269
Measurement start (Local time): 06/09/14
01:54:13

Figure 2: Calibrated Spectra Stage 1 Unlocked and Stage 2 Unlocked

Stage Tilted

The Spectra are measured when the ISI is unlocked a mass is placed on stage 2 to tilt Stage 1 and Stage 2.

The six configurations are the following in six different configurations:

- Mass placed in the actuator pocket at corner 1
- Mass placed in the pocket under the blade 0-1 at corner 1
- Mass placed in the actuator pocket at corner 2
- Mass placed in the pocket under the blade 0-1 at corner 2
- Mass placed in the actuator pocket at corner 3
- Mass placed in the pocket under the blade 0-1 at corner 3

/seismic/BSC-ISI/X1/Unit_8/Data/Spectra/Undamped/

- [.mat](#)
- [.mat](#)

seismic/BSC-ISI/X1/Unit_8/Data/Figures/Spectra/Undamped/

- [.fig](#)
- [.fig](#)

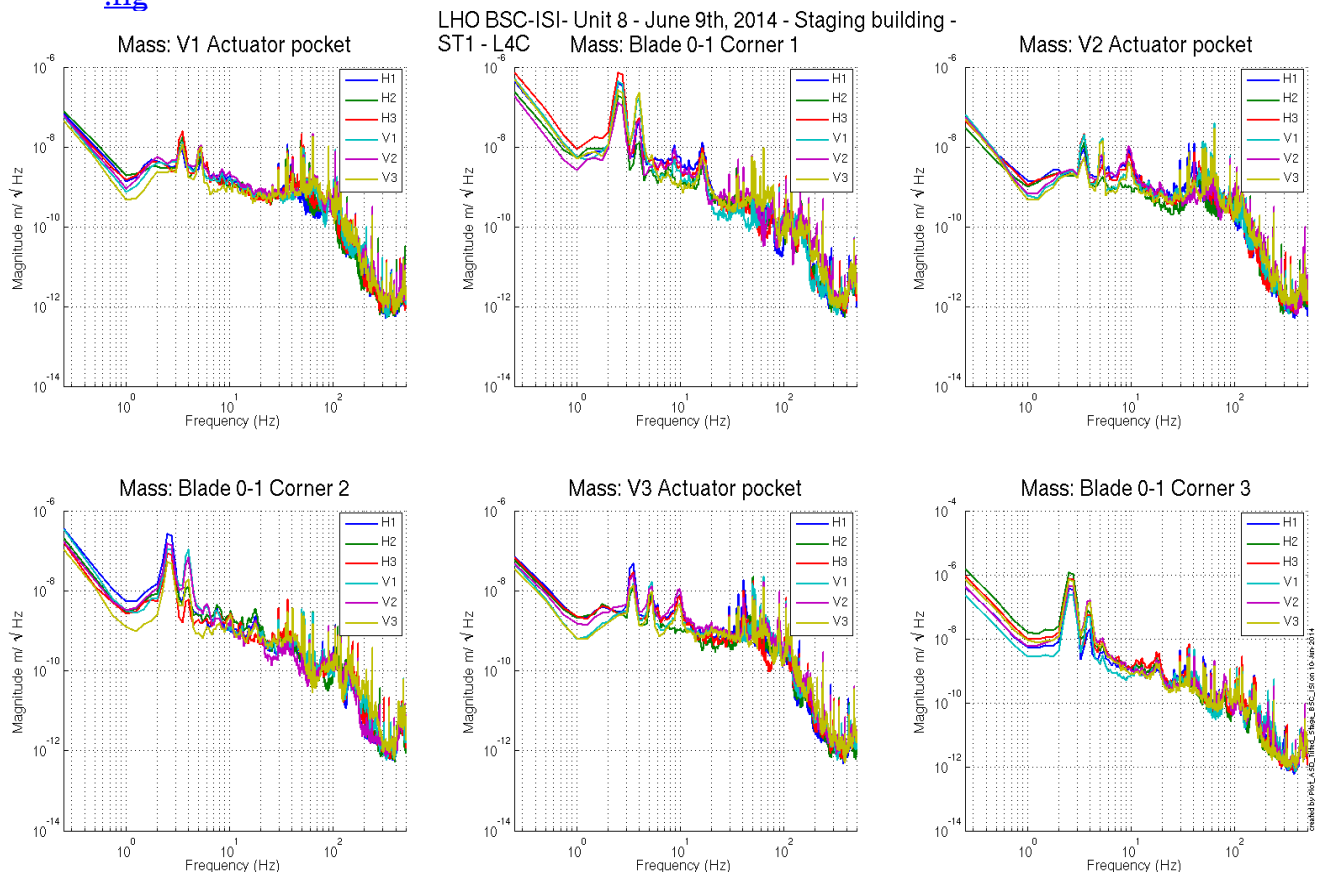


Figure 3 - ST1 L4C – Tilted

LHO BSC-ISI- Unit 8 - June 9th, 2014 - Staging building - ST1 - L4C

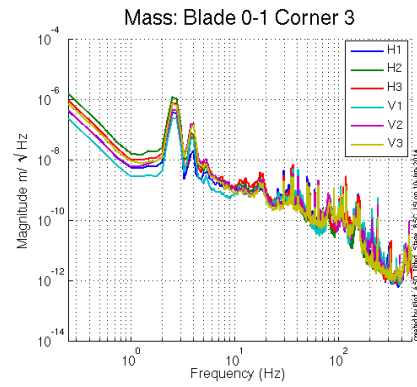
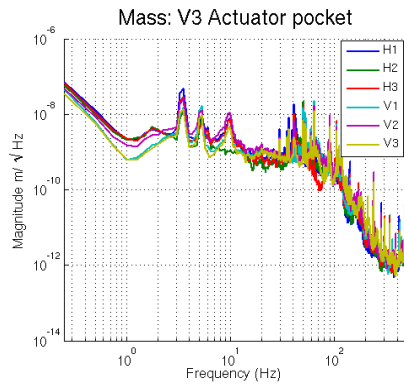
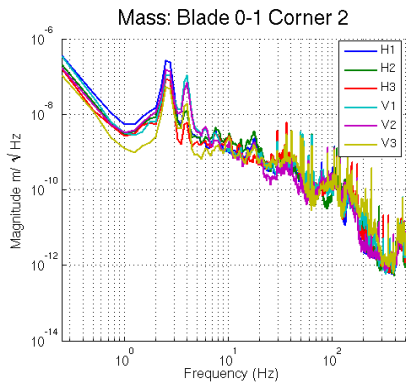
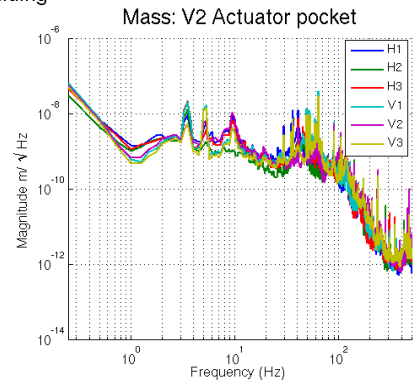
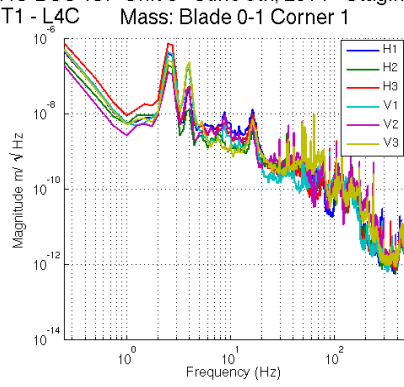
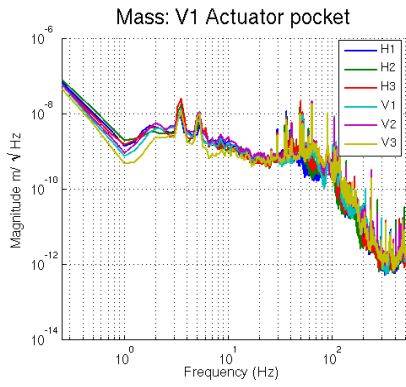


Figure 4 - ST1 GS13 – Tilted

Test result:

Passed: X

Failed:

Waived :

o Step 6 - Coil Driver, cabling and resistance check

Resistances of the couple (actuators + in vacuum cables) were measured using the voltage and current the coil drivers read back. Resistances of the couple actuator + in-vacuum cables are reported in the table below:

Actuator	Resistance (Ω)
ST1 H1	
ST1 H2	
ST1 H3	
ST1 V1	
ST1 V2	
ST1 V3	
ST2 H1	
ST2 H2	
ST2 H3	
ST2 V1	
ST2 V2	
ST2 V3	

Table 14 - Actuator Resistance

Acceptance criteria:

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

Test result:

Passed: X

Failed:

Waived :

Note: The range of motion in the case of a “local drive” is in agreements with the measurements done on the previous units.

Test result: Passed: X Failed: ___ Waived :

o Step 8 - Vertical Sensor Calibration

Not done.

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

o 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 2 is loaded with 3 x 10kg masses and the measurements are repeated three times (by rotating the masses).

	Mean No load	Mean Load	Diff
V1			
V2			
V3			

15028 count
mil
lb/in
%

Blade Stage 1-2

Stage 1 Locked & Stage 2 Unlocked. Stage 2 is loaded with 3 x 5Kg masses and the measurements are repeated three times (by rotating the masses).

	Mean no load	Mean load	Diff 1
V1			
V2			
V3			

count
mil
lb/in
%

Test mitigation: Blades are softer than design.

Test result: Passed: X Failed: ___ Waived :

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

The static tests results are reported in the SVN at :

seismic/BSC-ISI/X1/Unit_8/Data/Static_Tests/

- X1_ISI_ITMX_Offset_Local_Drive_20140610.mat

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

		Sensors					
		ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
Actuators	ST1 - H1	4305	1737	1741	33	12	-9
	ST1 - H2	1708	4199	1699	-7	73	-9
	ST1 - H3	1695	1693	4204	9	10	6
	ST1 - V1	80	-139	121	3464	-601	-608
	ST1 - V2	108	69	-148	-600	3496	-626
	ST1 - V3	-149	98	45	-615	-560	3411

Table 16 - Static test - Local to local - Stage 1

o Step 12 - Linearity test

The “Linearity test” was performed twice (rearranging the cables). The second time, all corners seemed to respond similarly.

The linearity test data can be found in the SVN at:

/seismic/BSC-ISI/X1/Unit_8/Data/Linearity_Test/
[X1 ISI ITMX Linearity test 20140610.mat](#)

The linearity test figures can be found in the SVN at:

/seismic/BSC-ISI/X1/Unit_8/Data/Figures/Linearity_Test/
[X1 ISI ITMX Linearity test 20140610.fig](#)

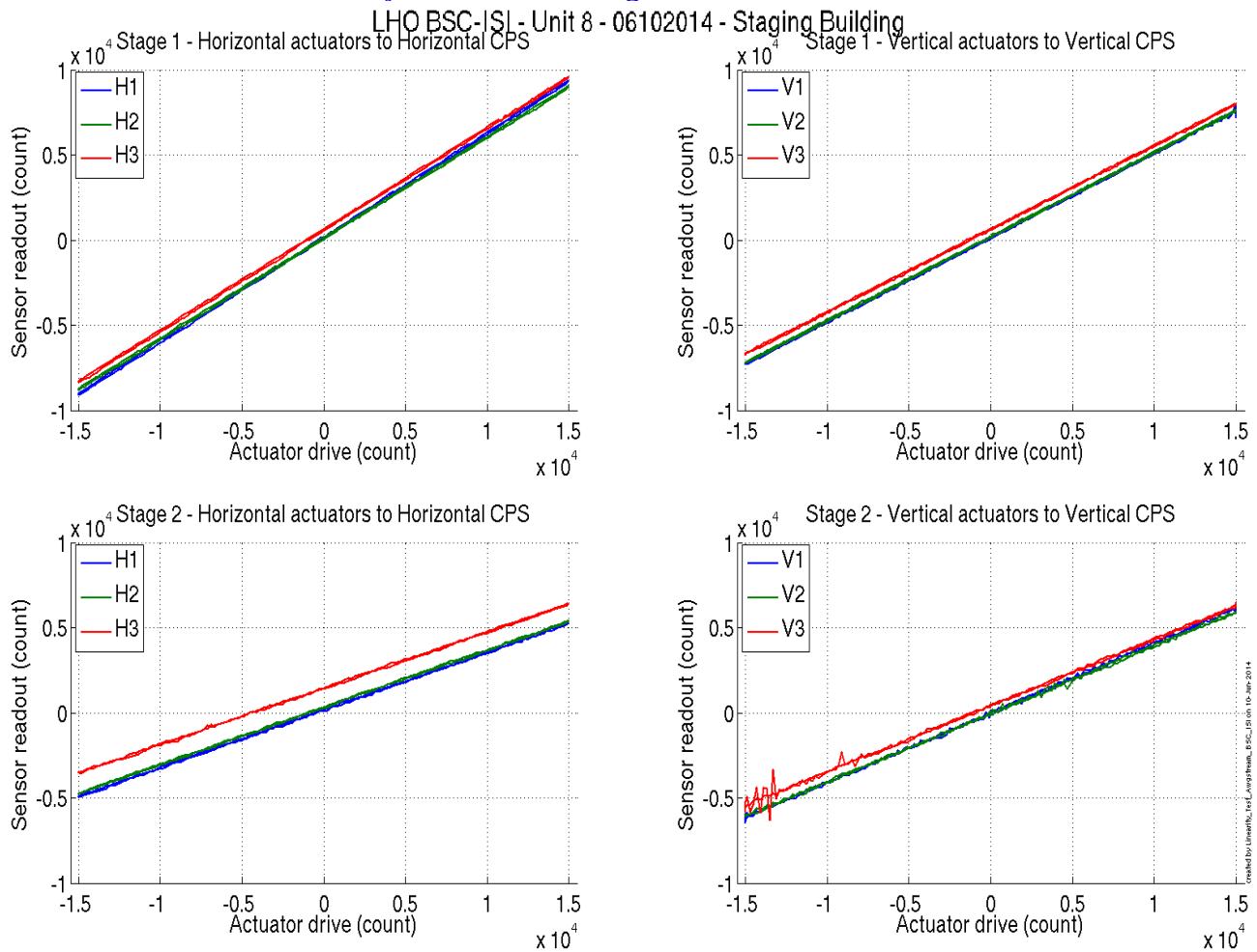


Figure 5 - Linearity Test

Slope – Offset:

		Slope	Offset	Average slope	Variation from average(%)
Stage 1	ST1 - H1	0.61	149	0.6	2.12
	ST1 - H2	0.59	116		-1.4
	ST1 - H3	0.60	614		-0.73
	ST1 - V1	0.50	141	0.49	0.48
	ST1 - V2	0.49	202		0.24
	ST1 - V3	0.49	649		-0.72
Stage 2	ST2 - H1	0.34	150	0.34	1.04
	ST2 - H2	0.34	322		0.4
	ST2 - H3	0.33	1437		-1.44
	ST2 - V1	0.41	-17	0.40	2.56
	ST2 - V2	0.40	-70		-0.03
	ST2 - V3	0.39	418		-2.53

Table 18 - Slopes and offset of the triplet Actuators - BSC-ISI – Sensors

Acceptance criteria:

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

Test result:

Passed: X

Failed: ___

Waived :

o Step 13 – Transfer functions – Local to Local

Note: two vibration absorbers were installed in corner 1 and 2 vibration absorbers were installed in corner 3. No TMDs were installed on the stage 0-1 blades.

Data files measurement of local to local transfer functions in SVN at:

seismic/BSC-ISI/X1/Unit_8/Data/Transfer_Functions/Measurements/Undamped/

- [.mat](#)
- [.mat](#)
- [.mat](#)
- [.mat](#)
- [.mat](#)
- [.mat](#)
- [.mat](#)

Script file for processing and plotting local to local transfer functions in SVN at:

/seisvn/seismic/BSC-ISI/X1/Unit_8/Scripts/Control_Scripts

- Step_1_TF_L2L_Raw_X1_ISI_TST.m

Figures of local to local transfer functions (Main couplings) in SVN at:

/seismic/BSC-ISI/X1/Unit_8/Data/Figures/Transfer_Functions/Measurements/Undamped/

- [.fig](#)
- [.fig](#)
- [.fig](#)
- [.fig](#)
- [.fig](#)
- [.fig](#)
- [.fig](#)

Measured of local to local transfer functions in the SVN at:

/svncommon/seisvn/seismic/BSC-ISI/X1/Unit_8/Data/Transfer_Functions/Simulations/Undamped

- [.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.

BSC-ISI - LHO - Unit 7 - 20130514

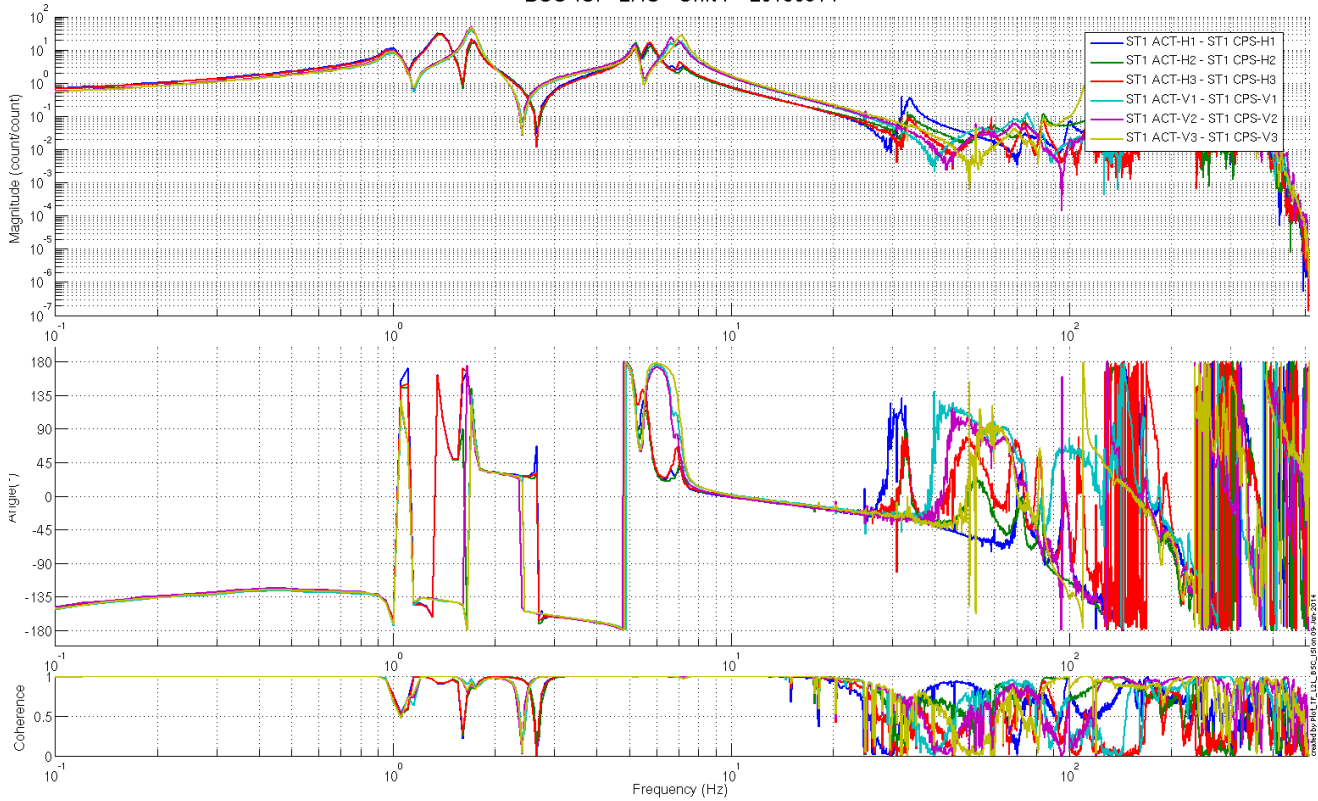


Figure 6: TF L2L Raw - ST1 Act to ST1 CPS

BSC-ISI - LHO - Unit 8 - 20140609

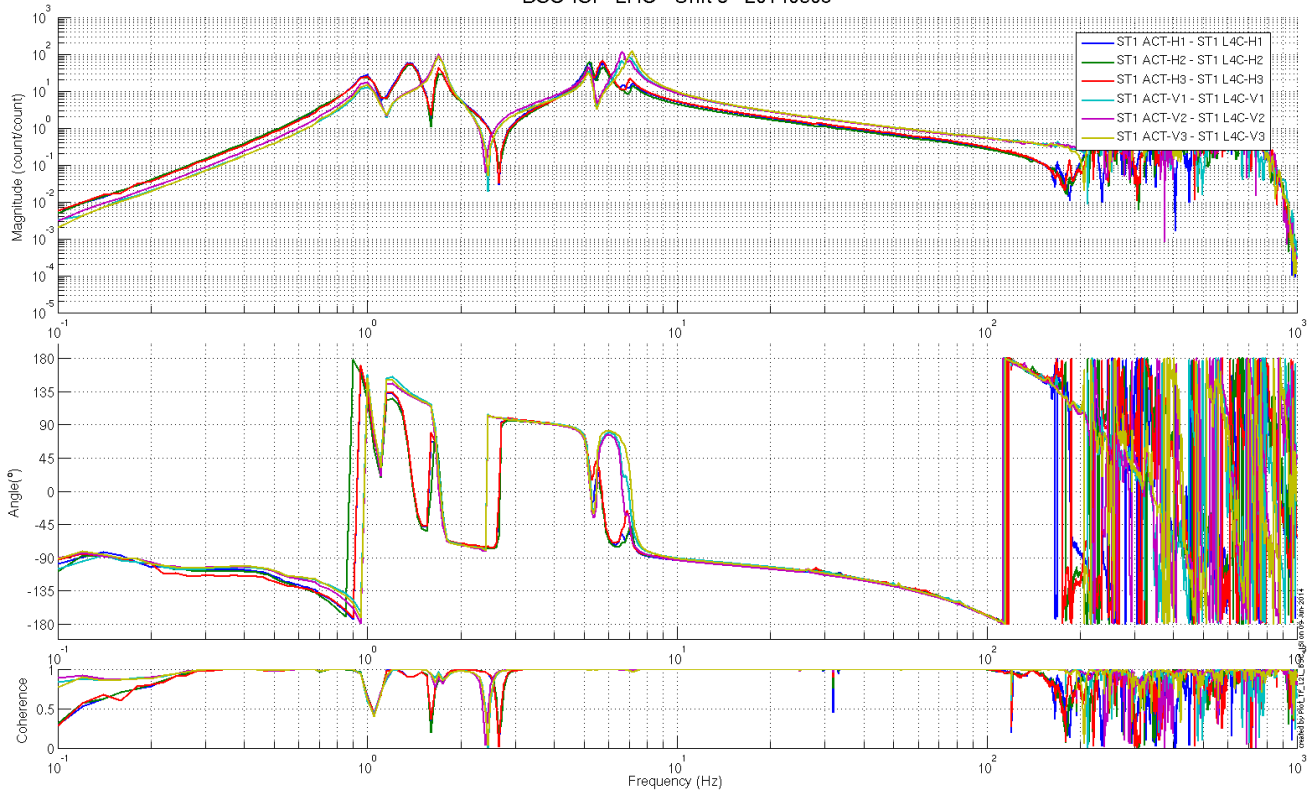


Figure 7: TF L2L Raw - ST1 Act to ST1 L4C

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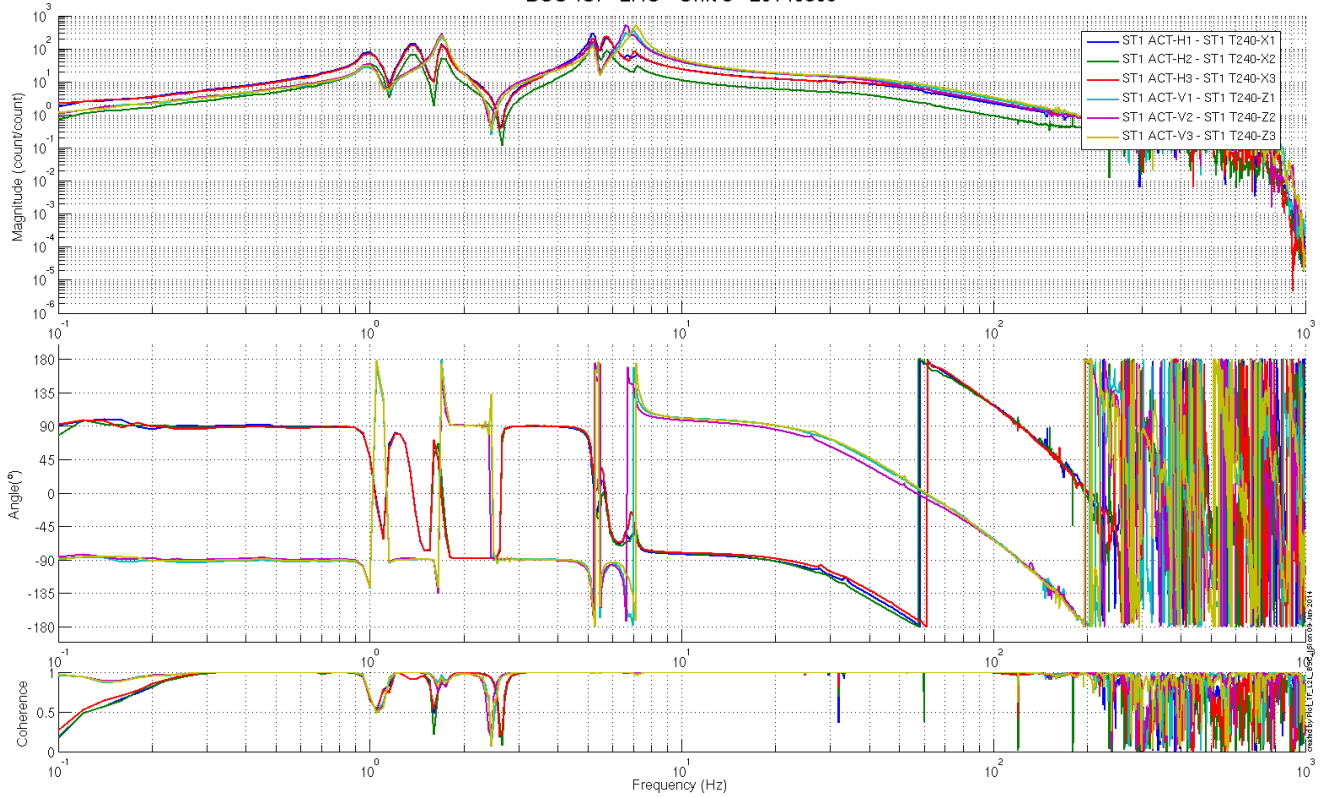


Figure 8 - TF L2L Raw - ST1 Act to ST1 T240

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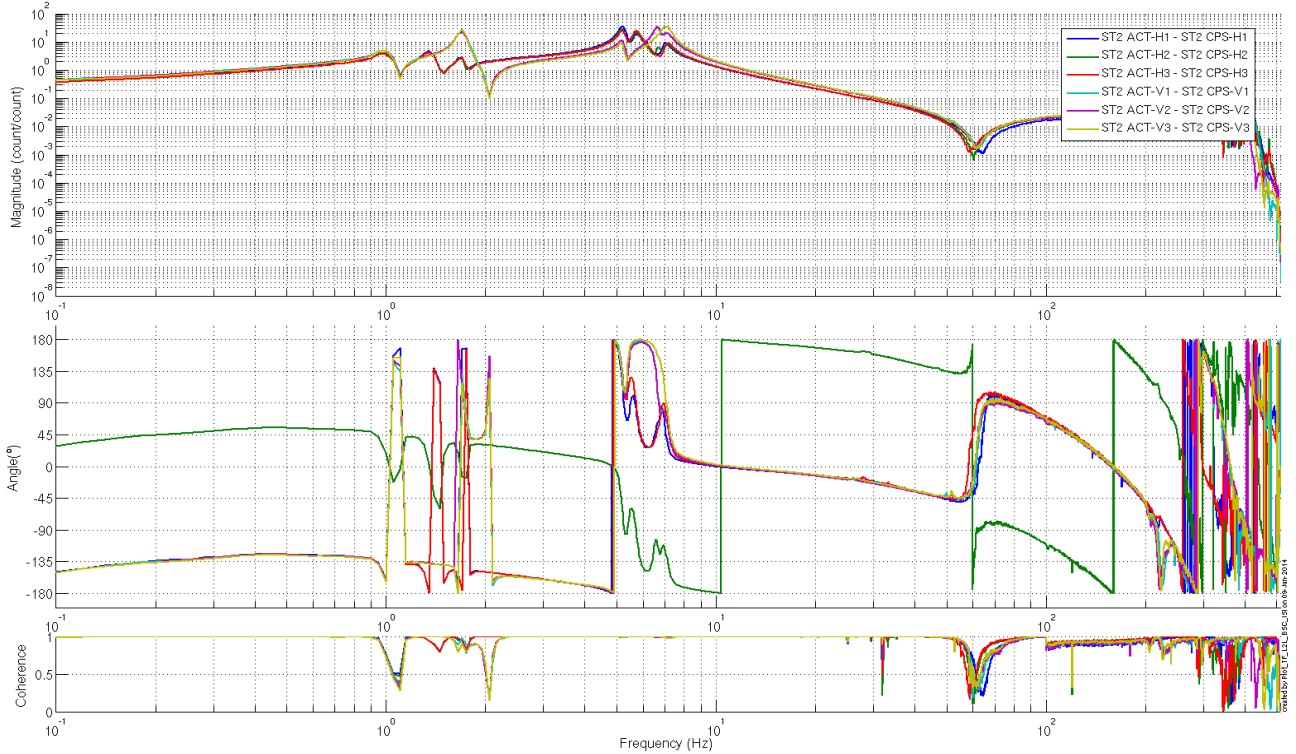


Figure 9: TF L2L Raw - ST2 Act to ST2 CPS

- **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 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.

4- Lists of tests skipped that needs to be done during phase II.

- **Step III.14 – Symmetrization – Calibration**
- **Step III.17 – Lower Zero Moment Plan**
- **Step III.18.1 – Damping Loops – Stage 2**
- **Step III.18.2 – Damping Loops – Stage 1**
- **Step III.20 – Isolation loops**