LIGO Laboratory / LIGO Scientific Collaboration

LIGO- E1200105 *LIGO* March 22nd 2012

aLIGO HAM-ISI, Installation Test Report, Phase II, LLO HAM-ISI 2

E1200105-v4

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Distribution of this document:
Advanced LIGO Project

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Introduction

This unit was first assembled in the early fall of 2010, and tested until October 2010. Following the discovery of un-authorized repairs while building this unit, the testing was interrupted. Testing done until interruption can be seen under v1 of this document. The unit was subsequently disassembled in Spring 2011 and immediately re-assembled.

The unit was pulled from storage in February 2012, and the assembly was then completed (3 new horizontal GS-13s, Tuned Mass Dampers and final cabling were installed).
Testing was completed on March 3rd 2012 and had been fairly in-depth due to worries about transfer functions response around the system resonance, which were finally identified as results of the GS-13s behavior themselves. Actual install took place on March 6th.

Initial in-chamber testing was conducted between March 7th and March 22nd. The testing was extended due to actuator ground loops, which seemingly impacted the slopes of the actuators linearity tests.

I. SIDE CHAMBER TESTING

- *Step 1: GS13*

All data related to GS-13 post podding testing can be found in the SVN at : SeismicSVN\seismic\Common\Data\aLIGO_GS13_TestData\PostMod_TestResults_PDFs. E1000058 spreadsheet provides the status of each individual GS-13 at LLO site during aLIGO HAM assembly

Data files in SVN at:
/opt/svncommon/seisvn/seismic/Common/Data/aLIGO_GS13_TestData/PostMod_TestResults_Raw ASCII

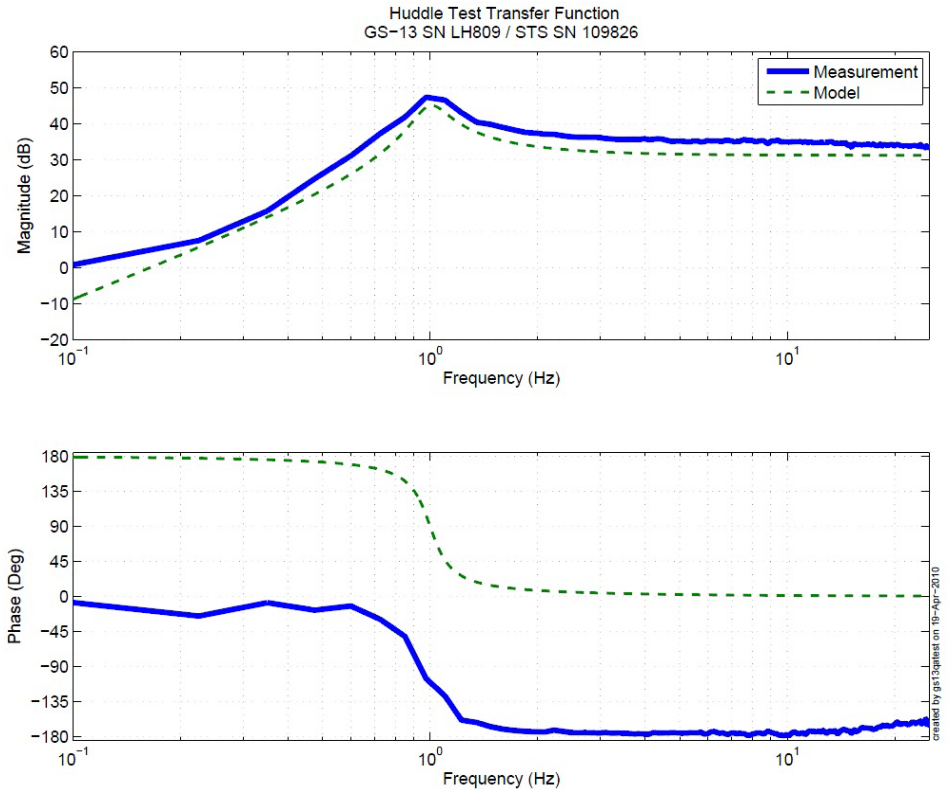
Scripts files for processing and plotting in SVN at: seismic/Common/MatlabTools

- gs13qatest.m

Figures in SVN at:
/opt/svncommon/seisvn/seismic/Common/Data/aLIGO_GS13_TestData/PostMod_TestResults_PDFs

- *Step 1.1 – Horizontal GS-13s*

Huddle testing



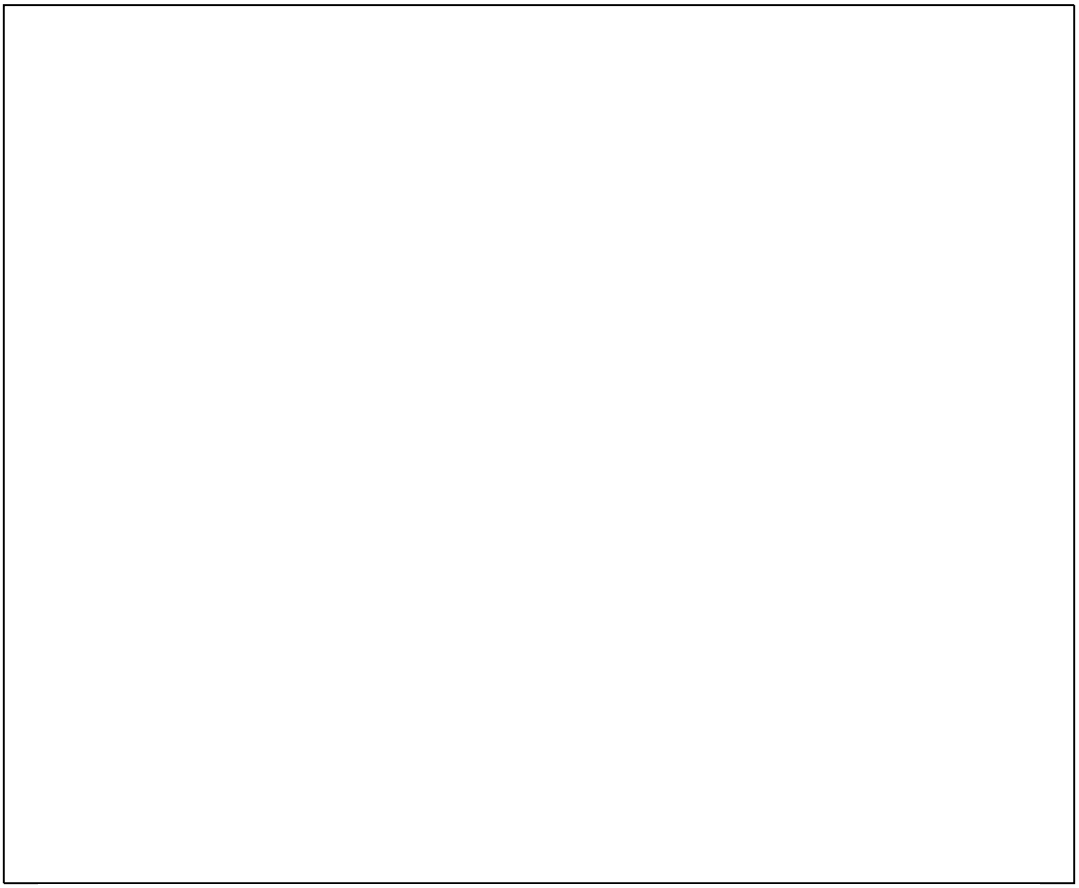


Figure - Huddle testing of Horiz GS-13 809, 787 and 706 after aLIGO modifications

We can notice that both 787 and 776 appear to have their resonances slightly off from 1Hz.

Acceptance Criteria:

- GS13 should have been already modified and tested. GS-13 Inspection/Pod Assembly (D047810). Checklist is defined in F090070-v6
- Resonant frequency at 1 Hz (huddle testing)
- No spring resonance on vertical driven tests

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

- *Step 2: Inventory (E1000052)*

DCC/Vendor number	Part name	Configuration	S/N	S/N	S/N
D071001	Stage 0 base		002		
D071050	Stage 1 base		001		
D071051	Optical table		002		
D071002	Spring Post		007	005	015
D071100	Spring		34	17	39
D071102	Flexure		42	21	45
ADE	Position sensor	Horizontal	11981	12079	12071
		Vertical	12078	12080	12069
D047812	GS-13 pod	Horizontal	**46**	**39**	**73**
		Vertical	32	19	51
D047823	L4C pod	Horizontal	N/A	N/A	N/A
		Vertical	N/A	N/A	N/A
D0902749	Actuator	Horizontal	L139	L081	L086
		Vertical	L084	L089	L092

- *Step 3: Blade spring profile*

Re-measured because we had to change shims to meet the platform level requirements.

Blade #	Base (")	Tip(")	Flatness (mils)
1	.484	.473	+11
2	.486	.470	+16
3	.484	.473	+11

Table 1 - Blade profile

Issues/difficulties/comments regarding this test:
Those were re-measured because we adjusted the shims to get the table within level requirements.

Acceptance Criteria:

- Blades must be flat within 0.015" inches.

Test result: **Passed: __** **Failed: X__**

- *Step 4: Gap checks on actuators-after installation on Stage 1*

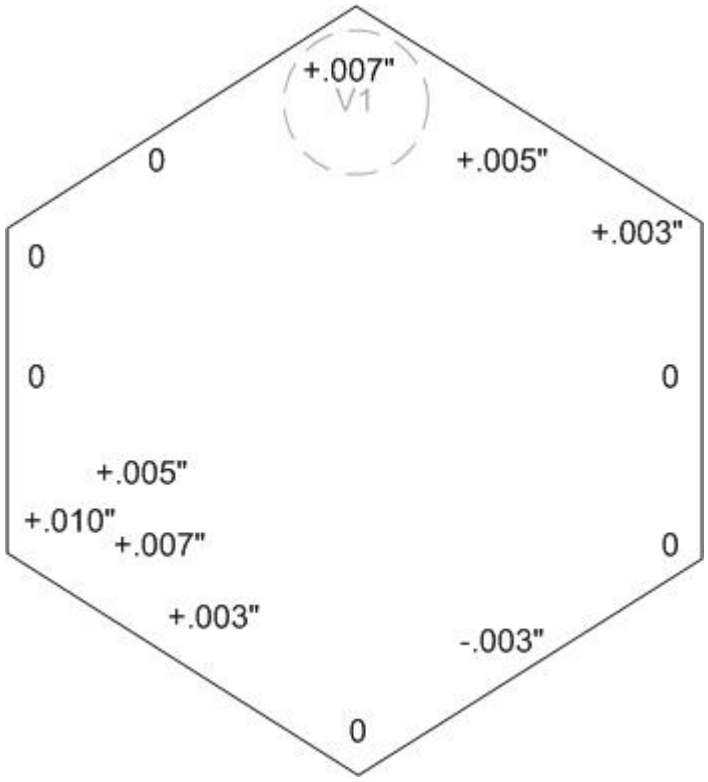
Not recorded but checked and within requirements.

Acceptance Criteria

- Gaps must be within 0.010” of design value (0.080”)

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

- *Step 5: Check level of Stage 1 Optical Table*



Acceptance Criteria

- The maximum angle of the table with the horizontal mustn't exceed ~100µrad

This table appears to have local deformation but no excessive tilt

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

- *Step 6: Mass budget*

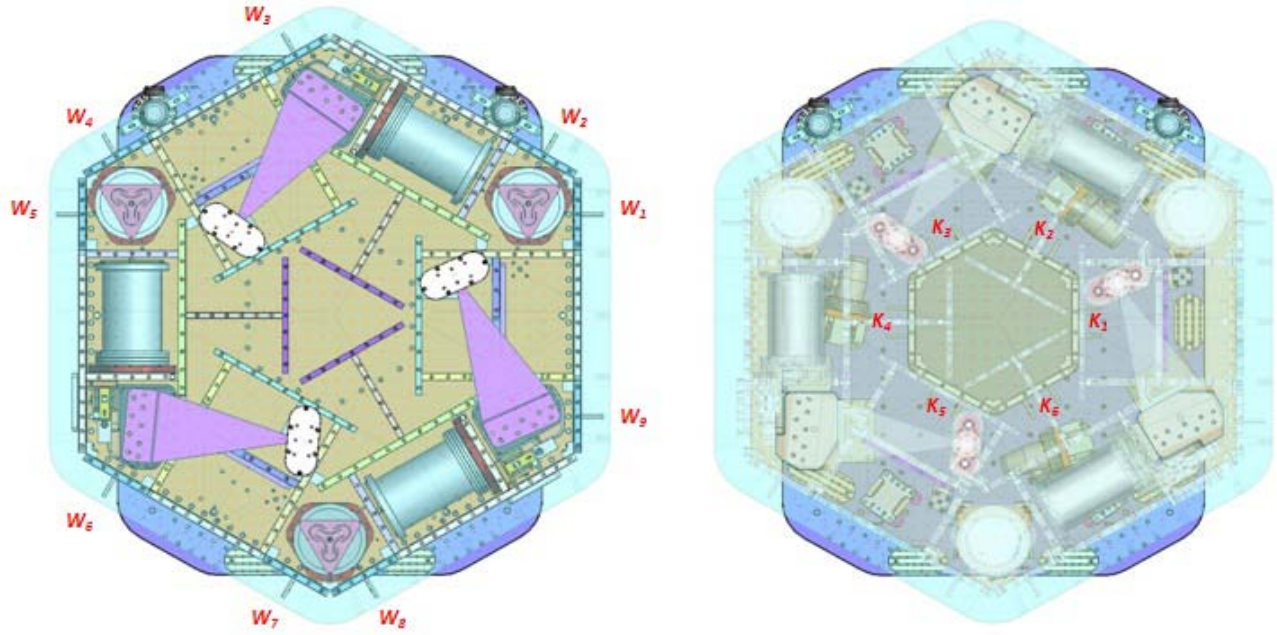


Figure – Keel Masses and Wall masses location

	00	01	02	03	04	05	06		
	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
k1					1		1	35.1	15.92
k2	1	1	1				1	31.1	14.11
k3					1		1	35.1	15.92
k4	1	1	1				1	31.1	14.11
k5					1		1	35.1	15.92
k6	1	1	1				1	31.1	14.11
	3	3	3	0	3	0	6	198.6	90.08

Table- Keel masses

	00	01	02	03	04	05	06		
	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
w9	1	1	1	1		1		24	10.89
w1	2	1	1	1		1		24.6	11.16
w2	3		2	1		1		26.3	11.93
w3	2		1	1		1		23.5	10.66
w4	3		1	1		1		24.1	10.93
w5			1	1		1		22.3	10.12
w6	2	1	1	1		1		24.6	11.16
w7	1			1		1		20.7	9.39
w8	3		2	1		1		26.3	11.93
Side Masses Total	17	3	10	9	0	9	0	216.4	98.16

Table- Side masses

	D972213	D972214	D972215	D0901075				
				2.5 kg	5 kg	10 kg		
	610	375	230	5.5	11	22	lbs	kgs
Top Masses	0	2	0	0	3	3	849	385.10

Table- Optical table masses

	Side	Keel	Top	Total
Weigh (kg)	98.16	90.08	385.10	573.34

Table - Masses distribution (computed using T1100261)

Acceptance Criteria

The Mass budget must be

- 579.1 Kg (cf E1100427)+/-25Kg (5%)

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

- *Step 7: Shim thickness*

Lockers	Shim thickness (mil)
A	130
B	123
C	122
D	120

Table – Shims Thickness

Issues/difficulties/comments regarding this test:
Those shims were changed in order to correct initial tilt found on the optical table.

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

- *Step 8: Lockers adjustment*

Not recorded but within requirements-cf CPS results later.

Acceptance Criteria

- Vertical and horizontal displacement near the lockers must be lower than 2 mils (0.002”)

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

- *Step 9 - Electronics Inventory*

Hardware	LIGO reference	S/N
Coil driver	D0902744	S1103308
		S1103332
Anti Image filter	D070081	S1104572
Anti aliasing filter	D1000269	S1104621
		S1104638
Interface chassis	D1000067	S1107434
		S1104638

Table - Inventory electronics

Acceptance Criteria

- Inventory is complete

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

- *Step 10 – Cables inventory – E1100822*

Cable Connects		Cable S/N		
Part Name	**Configuration**	**Corner 1**	**Corner 2**	**Corner 3**
GS13	Horizontal	S1104670-S114694	S1104663-S1104606	S1104667-S1104592
GS13	Vertical			
L4C	Horizontal	N/A	N/A	N/A
L4C	Vertical	N/A	N/A	N/A
Actuator	Horizontal	S1106907	S1104751	S1104499
	Vertical	S1106674	S1104606	S1104479

Table – Cables inventory

Acceptance Criteria

- Cable inventory completed
- E110082 spreadsheet updated

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

- *Step 10 - Set up sensors gap*

	No mass	
Table locked	**ADE boxes on**	
Sensors	**Offset (Mean)**	**Std deviation**
H1	113.73	9.7958
H2	38.192	12.716

H3	-151.86	6.5609
V1	418.12	15.454
V2	-638.13	35.608
V3	318.67	7.7891

Table – Capacitive position sensor readout after gap set-up

Acceptance criteria:

- All mean values must be lower than 400 cts (a bit less than .0005").
- All standard deviations below 5 counts.
- No cross talk

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

- *Step 11 - Check Sensor gaps after the platform release*

	Table locked		Table unlocked	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Difference**
H1	113.73	9.7958	-611.01	724.74
H2	38.192	12.716	-85.507	123.699
H3	-151.86	6.5609	-178.95	27.09
V1	418.12	15.454	-723.53	1141.65
V2	-638.13	35.608	-1311.8	673.67
`V3	318.67	7.7891	-416.11	734.78

Table – Sensor gaps after platform release

Acceptance criteria:

- Absolute values of the difference between the unlocked and the locked table must be below:
  - 1600 cts for horizontal sensors (~0.002")
  - 1600 cts for vertical sensors (~0.002")
- Considering the acceptance criteria of step 4, all mean values must be lower than
  - 2000 cts for horizontal sensors (~0.0025")
  - 2000 cts for vertical sensors (~0.0025")

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

- *Step 12 - Position Sensors unlocked/locked Power Spectrum*

Data files in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_2/Powerspectra/Undamped
LLO_HAM_ISI_Unit_2_Calibrated_PSD_CPS_GS13_Unlocked_Locked_2011_06_09.mat
Scripts files for processing and plotting in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_2/Powerspectra/Undamped

- Powerspectra_Measurement_HAM_ISI_Locked_Unlocked.m

Figures in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_2/Figures/Powerspectra/Undamped

LLO_HAM_Unit_2_Calibrated_PSD_CPS_Unlocked_Locked_2011_06_09.pdf

CPS calibration:

The CPS power spectrums are calibrated by using a sensitivity of 30.2 nm/count.

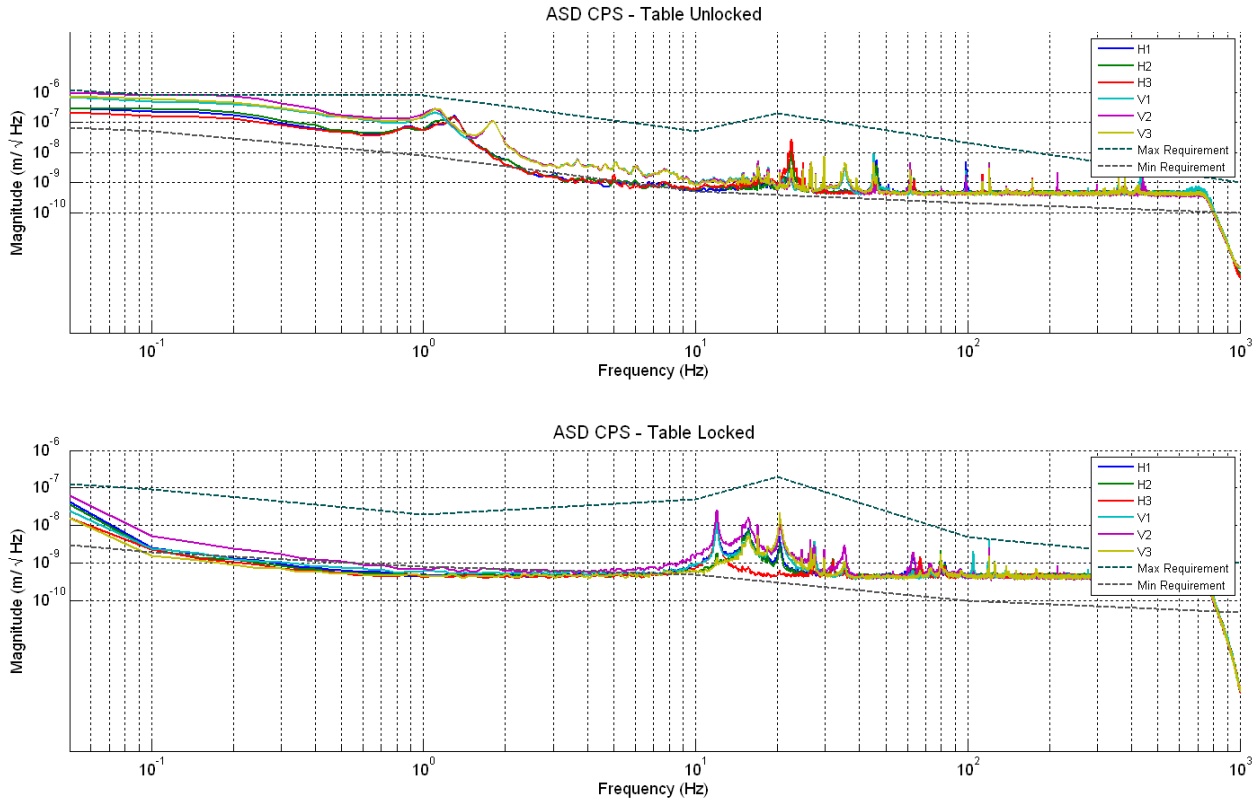


Figure - Calibrated CPS power spectrum

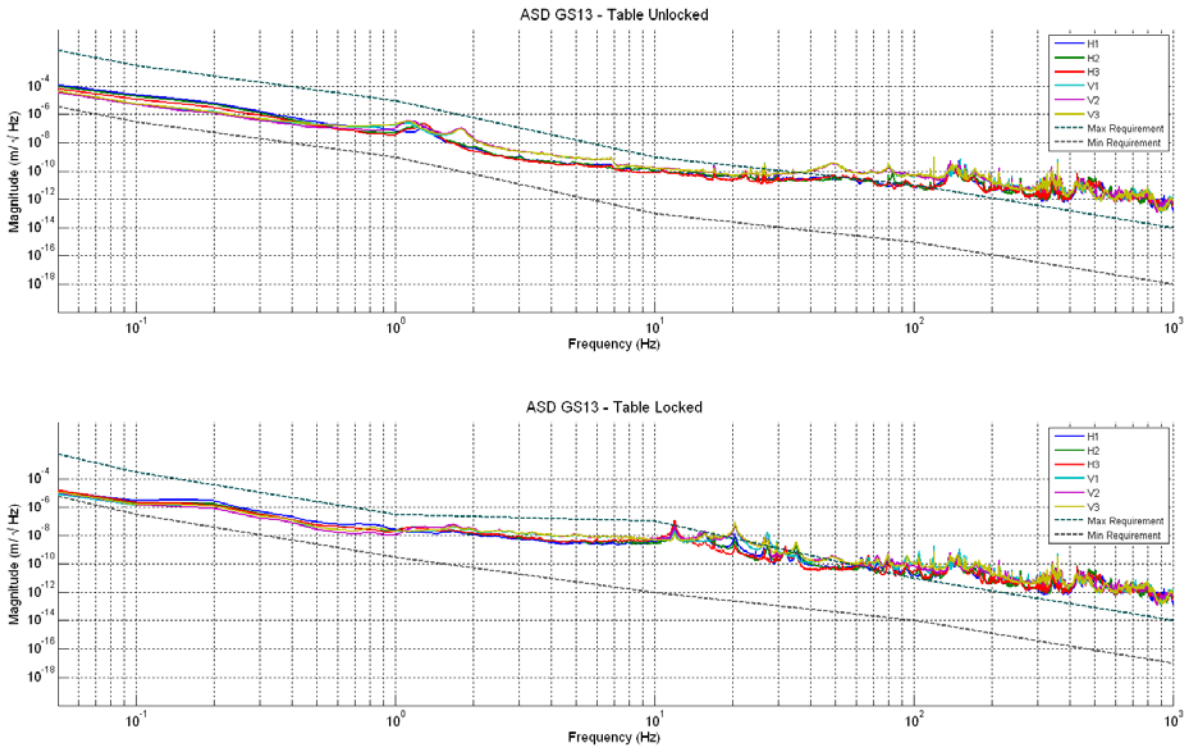


Figure – Power spectrum Calibrated GS13

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Spectra/Undamped/

- LLO_ISI_HAM2_ASD_m_CPS_T240_L4C_GS13_Locked_vs_Unlocked_2012_03_02.mat

Issues/difficulties/comments regarding this test:
H3 CPS seems to have a lower response between 10 and 13 Hz (locked config), this was the only time this was observed, and response appears normal in other configuration.

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- Plot_ASD_Unlocked_Locked_HAM_ISI.m
- Plot_ASD_Unlocked_Locked_Group_HAM_ISI.m

Figures in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Figures/Spectra/Undamped/

- LLO_ISI_HAM2_ASD_m_GS13_Requirements_Locked_vs_Unlocked_2012_03_02.pdf
- LLO_ISI_HAM2_ASD_m_CPS_Requirements_Locked_vs_Unlocked_2012_03_02.pdf

Acceptance criteria:

- No cross talk (peaks at low frequencies + harmonics on measurements)
- Magnitudes of power spectra must be between requirement curves such as in the following figures (dashed lines)

Sensors	ISI state	Frequency (Hz)	$2x10^{-2}$	$1x10^{-1}$	1	10	20	100	1000
GS-13	Table locked	Max	$3x10^{-1}$	$3x10^{-4}$	$3x10^{-7}$	10^{-7}		10^{-11}	10^{-14}
		Min	$3x10^{-4}$	$3x10^{-7}$	$3x10^{-10}$	10^{-12}		10^{-14}	10^{-17}

	Table unlocked	Max	1	$3x10^{-3}$	10^{-5}	10^{-9}		10^{-11}	10^{-14}
		Min	10^{-4}	$3x10^{-7}$	10^{-9}	10^{-13}		10^{-15}	10^{-18}
CPS	Table locked	Max	$2*10^{-7}$	$2x10^{-8}$	10^{-8}	$5x10^{-8}$	$2x10^{-7}$	$5x10^{-9}$	10^{-9}
		Min	$5x10^{-9}$	$2x10^{-9}$	$8x10^{-10}$	$5x10^{-10}$		10^{-10}	$5x10^{-11}$
	Table unlocked	Max	$2x10^{-6}$	$8x10^{-7}$	$8x10^{-7}$	$5x10^{-8}$	$2x10^{-7}$	$2x10^{-8}$	10^{-9}
		Min	10^{-7}	$5x10^{-8}$	$8x10^{-9}$	$5x10^{-10}$		$2x10^{-10}$	10^{-10}

Table - Step 6 -Normal conditions-Sensors powerspectra requirements

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

- *Step 13- GS13 power spectrum -tabled tilted*

The figure below presents the GS13 power spectrum when the table is unlocked and loaded with a 20Kg mass at one of its corner.

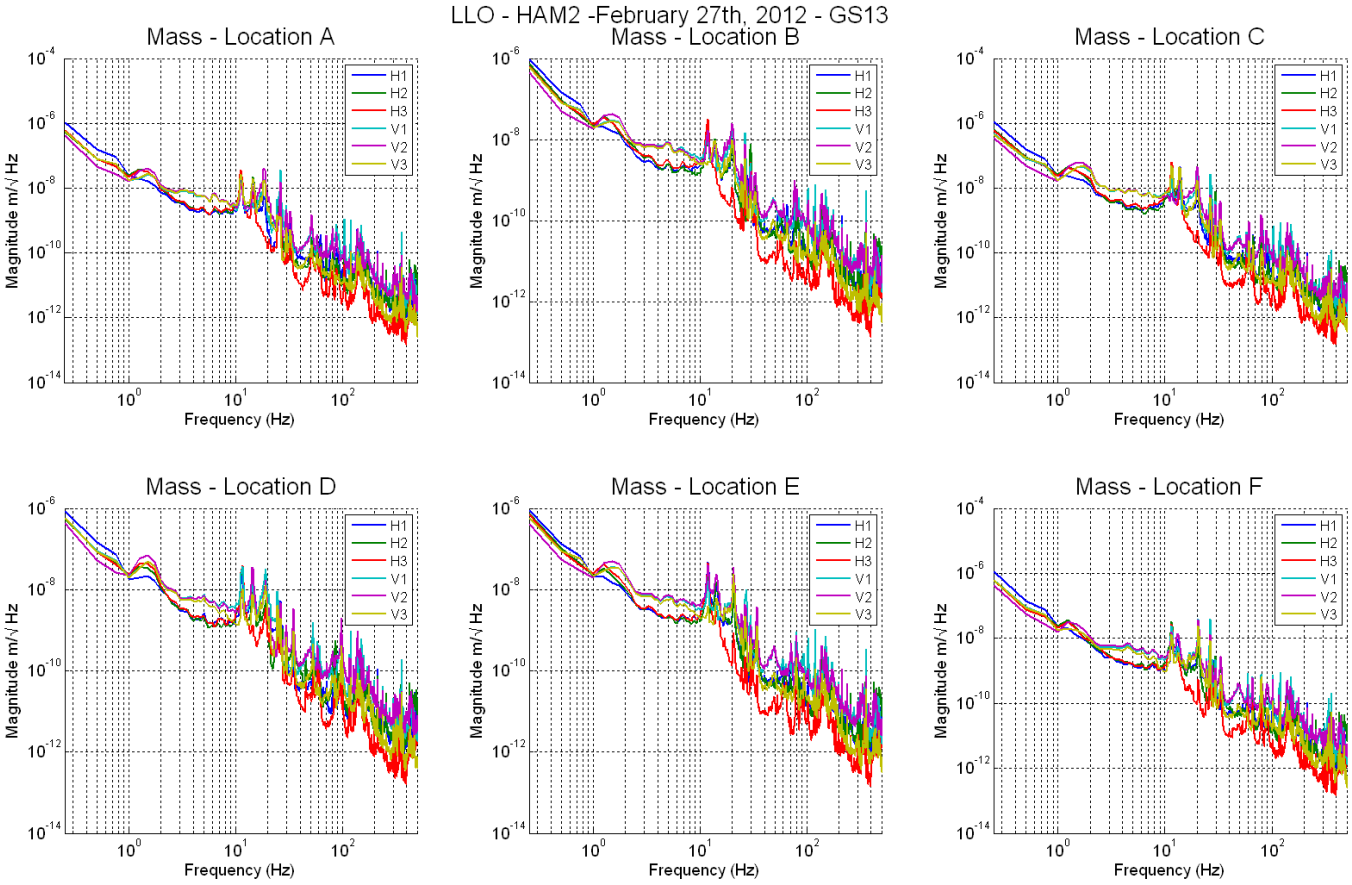


Figure – Power spectrum Calibrated GS13 with mass at corner

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Spectra/Undamped/

- LLO_ISI_HAM2_ASD_m_GS13_Stage_Tilted_2012_02_27.mat

Scripts files for taking and processing the data, and plotting it in SVN at:

seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Plot_ASD_Tilted_Stage_HAM_ISI.m

Figures in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Figures/Spectra/Undamped/
- LLO_ISI_HAM2LLO_ISI_HAM2_ASD_m_GS13_Stage_Tilted_2012_02_27_2012_02_27.pdf

Issues/difficulties/comments regarding this test:
One could notice that H3 and V3 differ at high frequency from the other instruments. This is due to the fact that we had wrongly plugged those instruments onto the L4C side of a BSC interface. Therefore those instruments did not benefit from the dewhitening filters as the other instruments did.

Acceptance criteria:

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

- *Step 14- GS13 pressure readout*

GS-13 pressure sensors constantly read 77 or 78 KPa.

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

- *Step 15- Actuators Sign and range of motion (Local drive)*

	Negative drive	Positive drive
H1 readout (count)	-23083.026	24046.844
H2 readout (count)	-22944.266	23368.198
H3 readout (count)	-24318.274	24244.29
V1 readout (count)	-19824.716	18694.398
V2 readout (count)	-24564.902	24903.306
V3 readout (count)	-21513.128	21275.082

Table - Range of motion - Local drive

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Static_Tests/
- LLO_HAM-ISI_Unit_2_Range_Of_Motion_20110609.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Range_Motion_HAM_ISI.m

Acceptance criteria:
- Main couplings sensors readout must be at least 16000 counts (~0.02")
- A positive offset drive on one actuator must give positive sensor readout on the collocated sensor. Signs will also be tested when measuring local to local transfer functions.

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

- *Step 16 - Static Testing (Tests in the local basis)*

		H1	H2	H3	V1	V2	V3
Actuators (1000 counts)	H1	1768.52176	1120.3965	1126.4326	2.3293584	-7.4221	33.4536
	H2	1121.76976	1822.10976	1138.1846	10.5282164	-10.28954	9.0632
	H3	1131.02036	1154.148	1849.87592	18.5308684	-32.36534	36.4462
	V1	144.12706	161.86032	-309.1136	1218.91386	-35.6438	-507.9544
	V2	-347.93947	172.49	167.3648	-534.30694	1243.82962	-12.4158
	V3	144.38038	-341.69618	173	-29.688582	-582.03506	1348.44654

Table - Main and cross coupling

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Static_Tests/
- / LLO_HAM_ISI_Unit_2_Sensor_Readout_Local_20110609.mat

Scripts files for taking data in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Static_Test_Local_Basis_HAM_ISI.m

Issues/difficulties/comments regarding this test:
V1 and V2 appear to give responses just lower from the criteria.

Acceptance criteria:

- **Vertical**
  For a +1000 count offset drive on vertical actuators
  - Collocated sensors must be 1400 counts +/- 10%

- **Horizontal**
  For a +1000 count offset drive on horizontal actuators
  - Collocated sensors must be 2000 counts +/- 10%
  - Non-collocated horizontal sensors must be 1250 counts +/-10%

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

- *Step 17 - Linearity test*

	Slope	Average slope	Variation from average(%)
H1	1.84147738	1.8424	-0.09879621
H2	1.83885246		-0.36128864
H3	1.84706619		0.46008485
V1	1.33770934	1.3335	0.41841887
V2	1.32772348		-0.58016727
V3	1.33514264		0.1617484

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

Scripts files for taking data in SVN at: seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- Linearity_Test_Awgstream_HAM_ISI.m

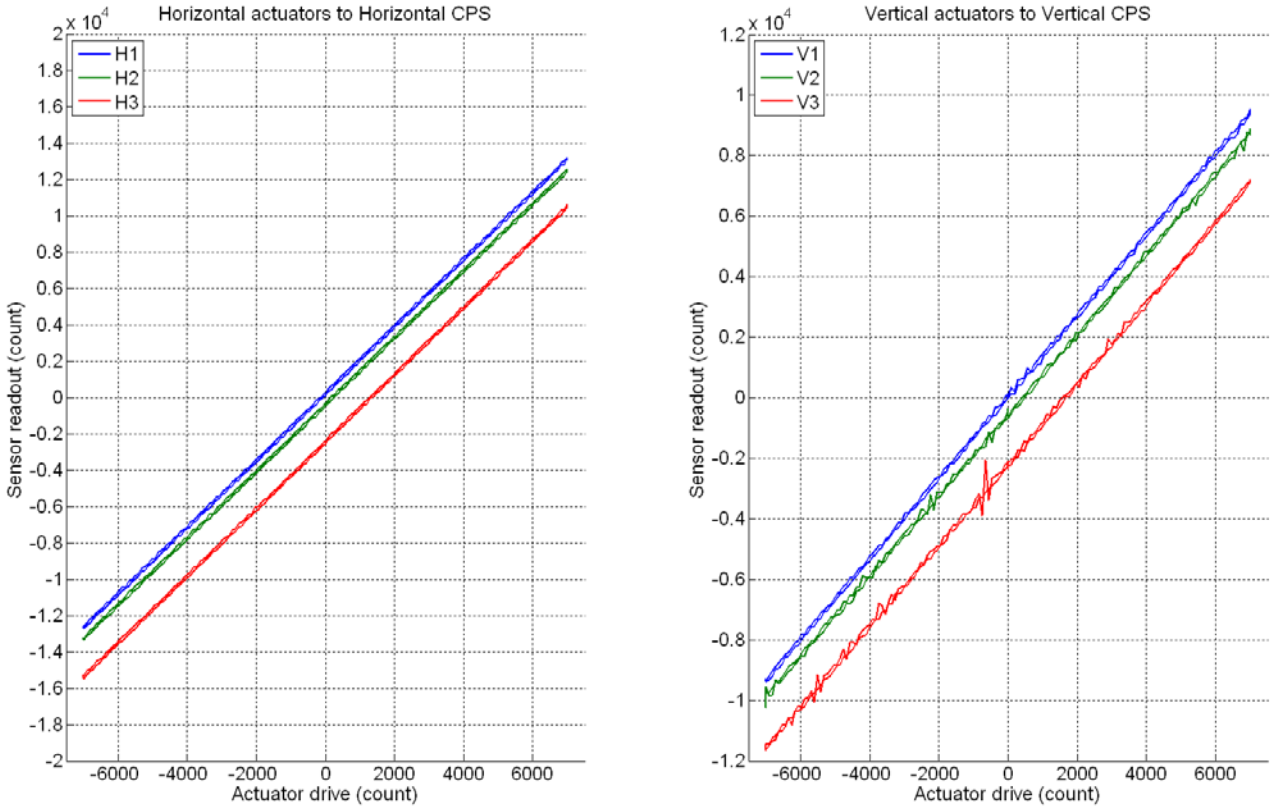


Figure - Horizontal and vertical actuators x HAM-ISI x sensors

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Linearity_Test/

- LLO_HAM_ISI_Unit_2_Linearity_test_20110609.mat

Figures in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Figures/Linearity_Test/

- LLO_HAM_ISI_Unit_2_Linearity_test_20110609.fig
  LLO_HAM_ISI_Unit_2_Linearity_test_20110609.pdf

Acceptance criteria:

- Horizontal and vertical slopes of the triplet actuators x HAM-ISI x sensors: Average slope +/- 1%

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

- *Step 18 - Cartesian Basis Static Testing*

Sensors readout (count)	1000 counts drive	X Drive	Y Drive	Z Drive	Rx Drive	Ry Drive	Rz Drive
	H1	263.528	-390.4432	39.232	-351.599	-234.314	-1870.593
	H2	232.73	510.05	51.46	511.84	-214.09	-1926.44
	H3	-492.32	23.53	10.56	70.06	532.44	-1901.82
	V1	-5.871	6.292	248.899	-510.236	-1619.426	11.019
	V2	-21.28	-33.566	239.421	1633.514	398.43	-57.855
	V3	2.8	-18.2	270.36	-1169.8	1208.911	29.8
	Direction read out	492.38	524.71	256.965	2516.66	2506.73	2404.763

Table - Tests in the general coordinate basis

Issues/difficulties/comments regarding this test:

This is the first ISI oriented in the Y direction. Matrices were redesigned for that purpose.

Acceptance criteria:

For a positive drive in the Cartesian basis:

- Local sensor readout must have the same sign that the reference table (**CONT2ACT check**)
- Cartesian sensors read out must be positive (**DISP2CEN check**) in the drive direction

Test result: **Passed: ___** **Failed: ___**

- *Step 19- Frequency response*
- *Step 19.1 - Local to local measurements*

Local to local transfer functions have been measured with 90 repetitions.

Data files in SVN at:

Local to local transfer functions have been measured with 90 repetitions.

Data files in SVN at:

seismic/HAM-ISI/L1/HAM2/Data/Transfer_Functions/Measurements/Undamped/

- LLO_ISI_HAM3_Data_TF_L2L_50mHz_500mHz_20120201-000859.mat
- LLO_ISI_HAM3_Data_TF_L2L_500mHz_5Hz_20120131-213926.mat
- LLO_ISI_HAM3_Data_TF_L2L_5Hz_200Hz_20120131-205053.mat
- LLO_ISI_HAM3_Data_TF_L2L_200Hz_800Hz_20120131-191720.mat

Data collection script files: seismic/HAM-ISI/L1/HAM2/Scripts/Data_Collection/

- Run_Exc_Batch_L1ISIHAM2.m

Scripts files for processing and plotting in SVN at:

seismic/HAM-ISI/L1/HAM2/Scripts/Control_Scripts/

- Step_1_TF_L2L_L1_ISI_HAM3.m

Figures in SVN at:

seismic/HAM-ISI/L1/HAM2/Data/Figures/Transfer_Functions/Measurements/Undamped/

- LLO_ISI_HAM3_TF_L2L_Raw_from_ACT_to_CPS_2012_01_31.fig
- LLO_ISI_HAM3_TF_L2L_Raw_from_ACT_to_GS13_2012_01_31.fig

Storage of measured transfer functions in the SVN at:
seismic/HAM-ISI/L1/HAM2/Data/Transfer_Functions/Measurements/Undamped/

- LLO_HAM_ISI_Unit_3_Data_TF_L2L_2011_04_06.mat

The local to local transfer functions are presented below.

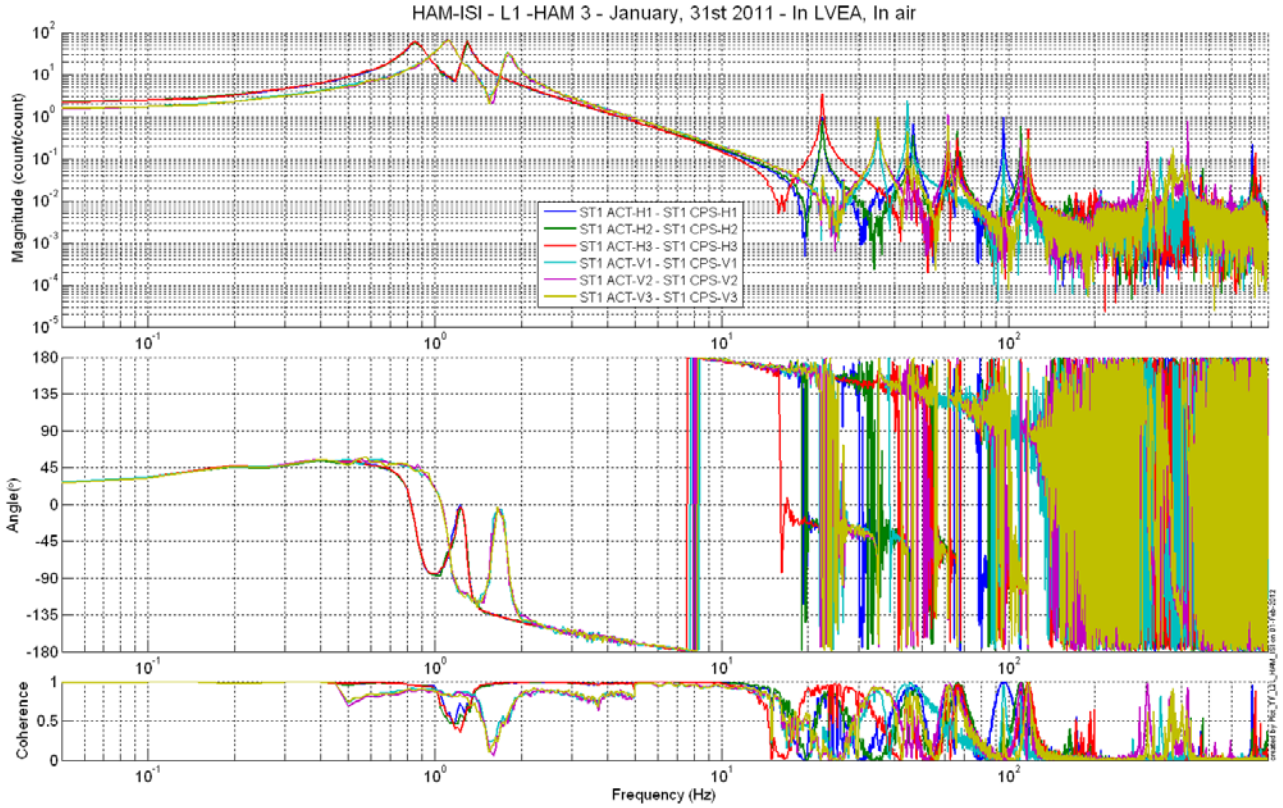


Figure - Local to Local Measurements – Capacitive sensors

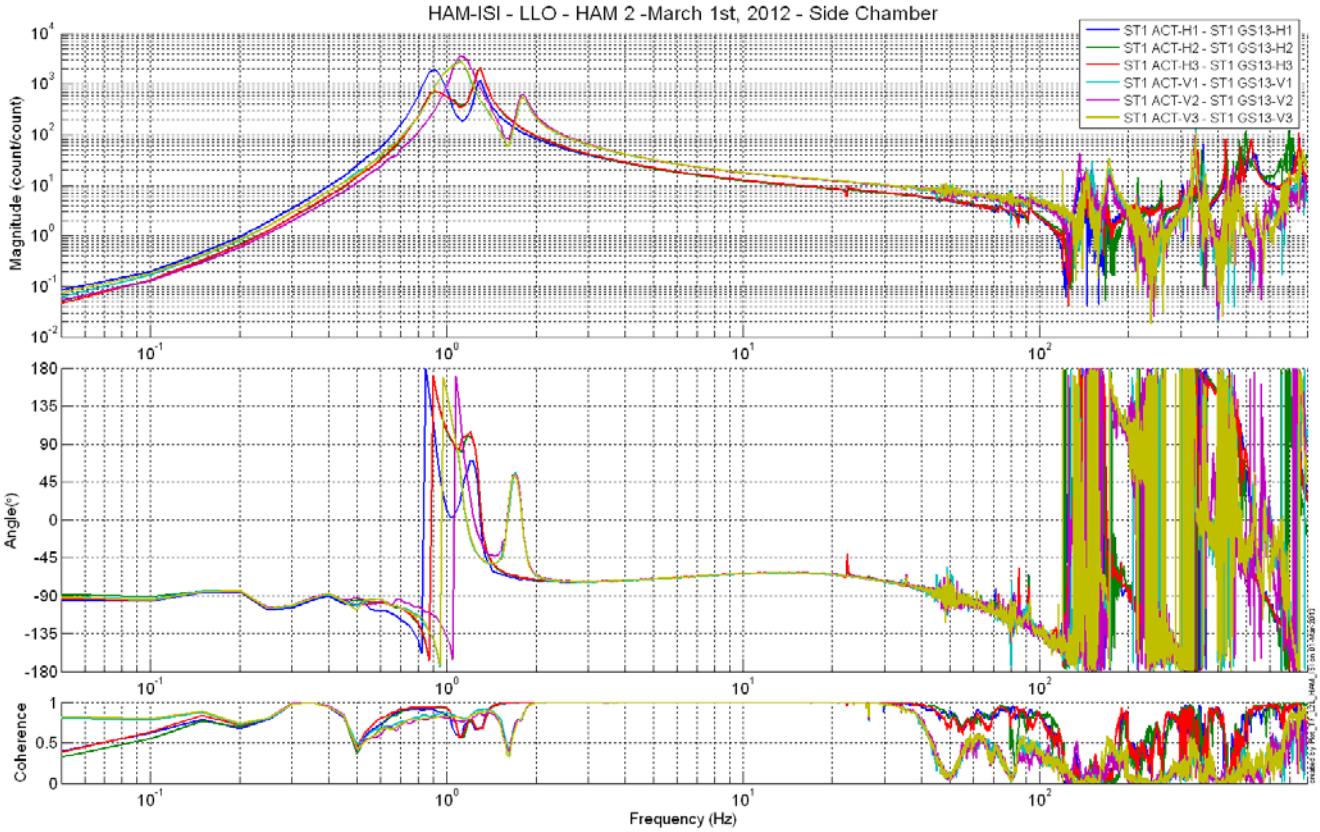
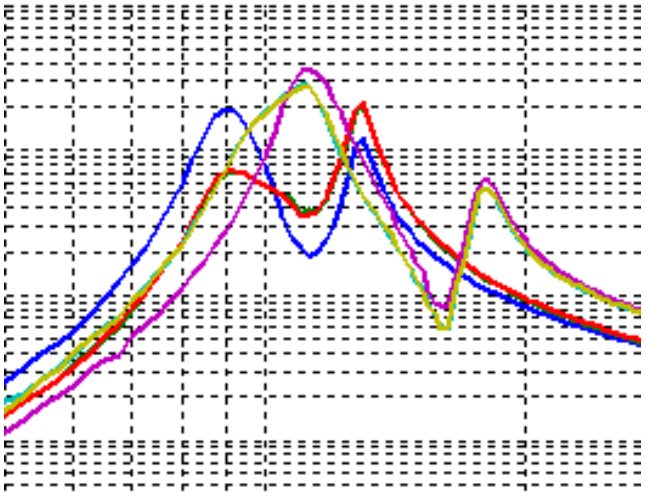


Figure - Local to Local Measurements – Inertial sensors



Zoom around 1 Hz of the Inertial sensors response.

Issues/difficulties/comments regarding this test:

We can see that H1 has a different response from H2, and H3, whereas V2 differs slightly from V1 and V3.

If we compare to testing right after assembly, we can see somewhat similar features except H3 is different from the others. Now, all sensors were changed between the assembly and the side-chamber testing. It so happened that the one which used to be in H3 is now in H1, but all other sensors are different.

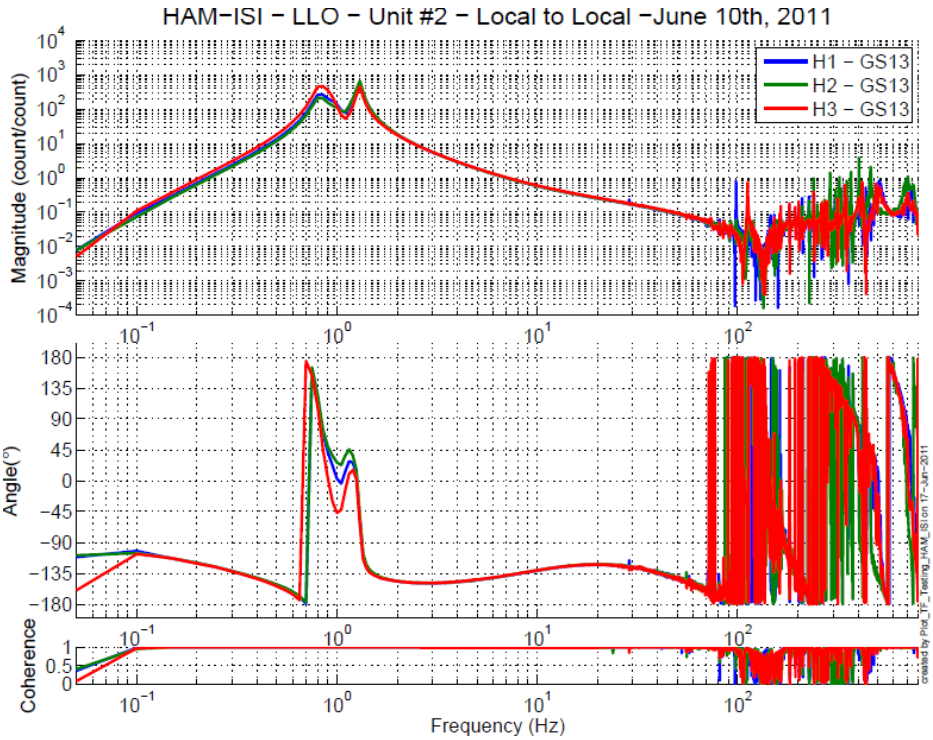


Figure - Local to Local Measurements – Horizontal Inertial sensors

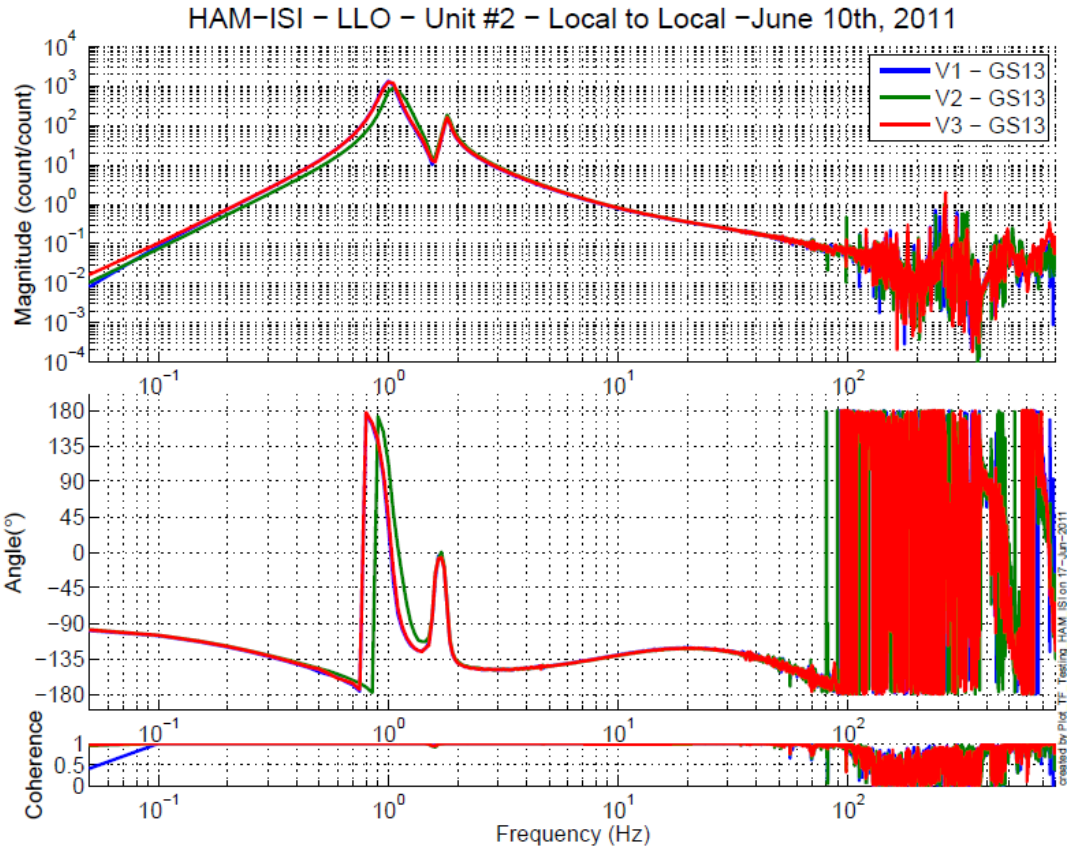


Figure - Local to Local Measurements – Vertical Inertial sensors

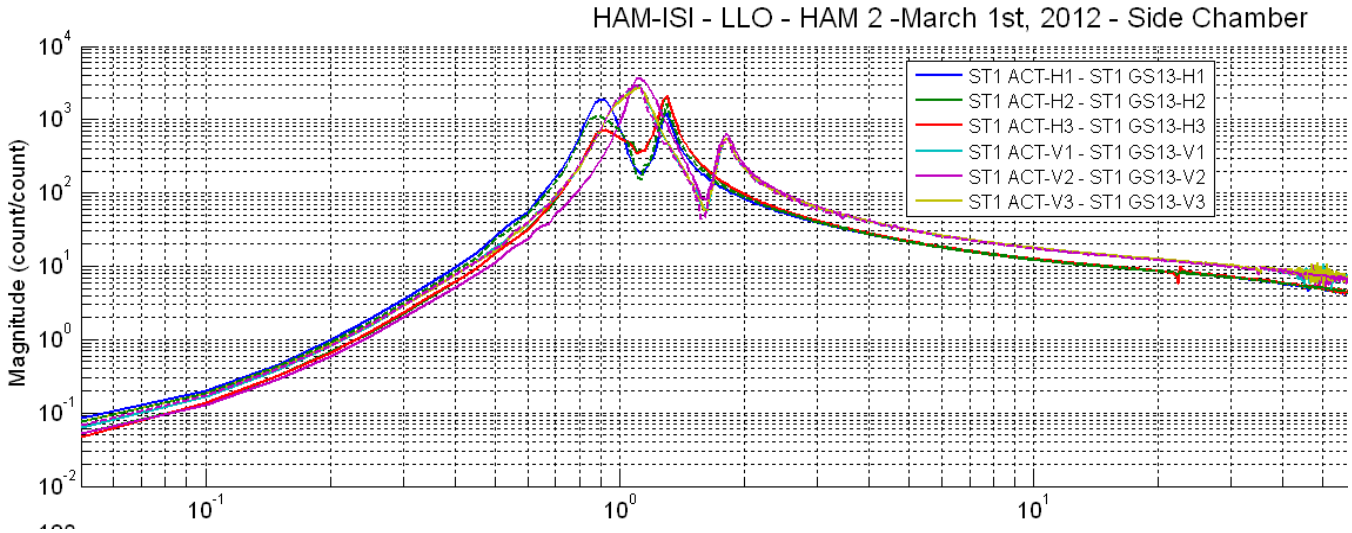
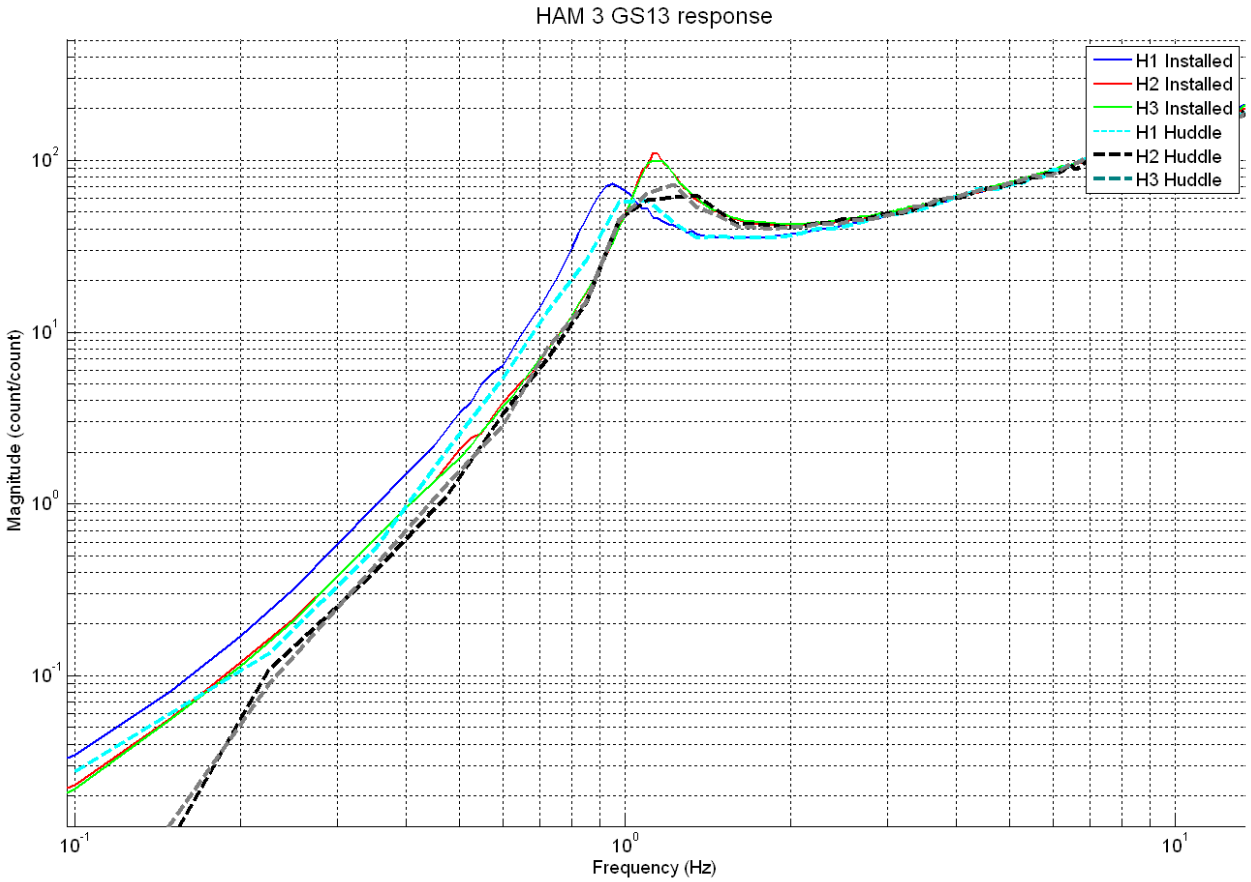


Figure - Local to Local Measurements – Inertial sensors comparison with HAM 3 (dashed)

Finally, when we extract the horizontal seismometers responses and compare it with their huddle tests, we find that we can see the most of the difference between sensors.



Acceptance criteria:

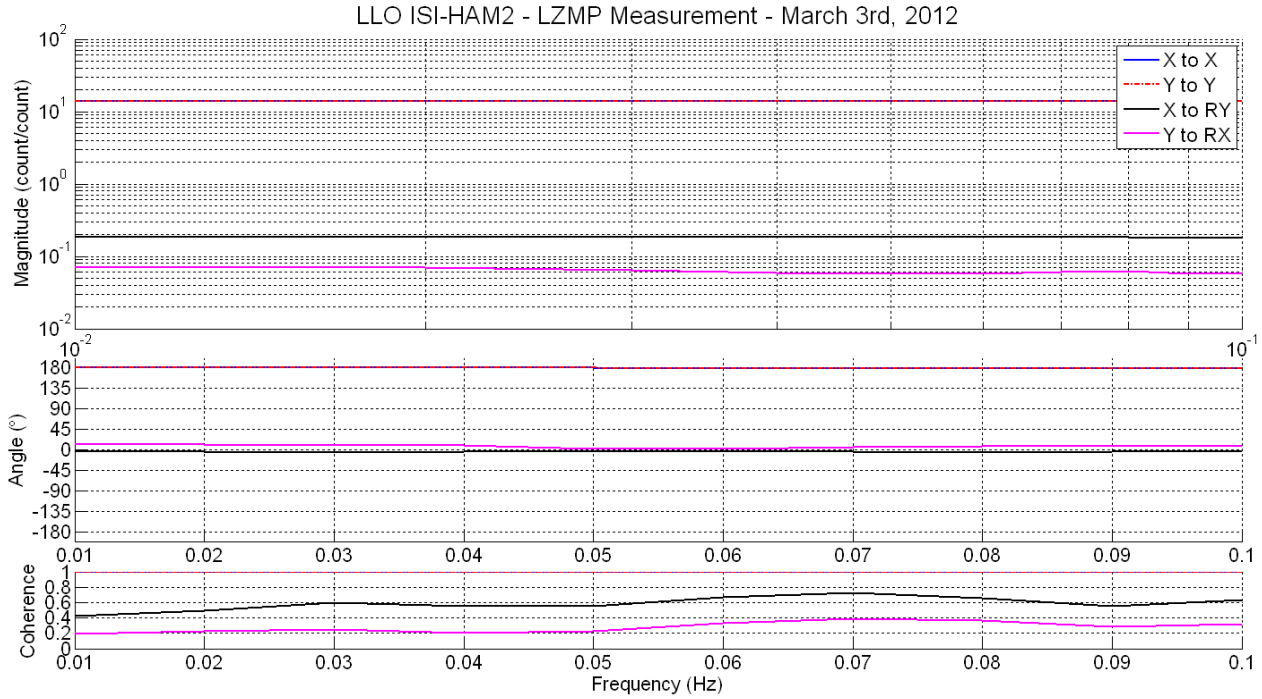
- Local to local measurements
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC
  - Identical shape in each corner

- Cartesian to Cartesian measurements
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC
  - Identical shape X/Y and RX/RY

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

- *Step 20 - Lower Zero Moment Plane*

Since we did not pass one requirement (Y offset, now become X offset) during initial testing, we did re-test it.



X offset 2.465 mm
Y offset 0.947 mm

Issues/difficulties/comments regarding this test:
We can notice that we have a fairly low coherence on both measurements and that additional testing may be useful later.

Acceptance criteria:

- X offset must be less than 2 mm
- Y offset must be less than 2 mm

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

Conclusion Side Chamber testing

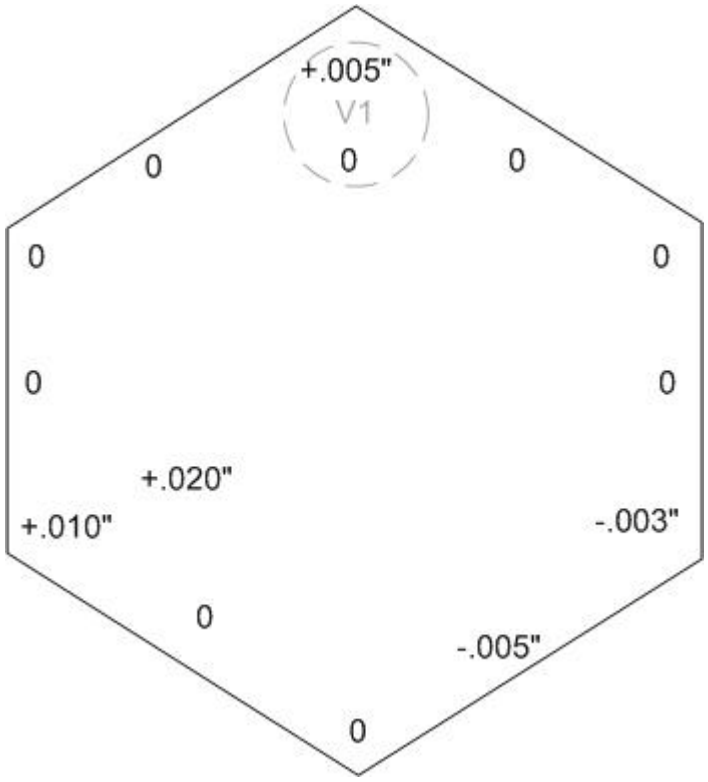
Only a few issues were found during the testing of this unit, which are summed up here:

- Local 2 local transfer functions displays a slightly different behavior around 1 Hz in corner 3 than in the others. After further study this appears to be due to the sensors themselves.
- X LZMP measurements do not meet requirements, we can conduct more tests once in chamber.
- V1 and V2 local to local static testing barely missed requirements.
- H3 CPS displayed a low answer in one test, this is something we can investigate later.

II. INITIAL CHAMBER TESTING

The HAM-ISI was installed in HAM 2 on March 5th 2012, loaded on March 6th and connected to the electronics on March 8th. We initially had to adjust its level using HEPI (indeed dropping the ISI in there lowered the support tubes by about 40 mils). Additionally the locker shims were slightly adjusted again to correct the level. CPS sensors were zeroed again.
Testing mostly happened between March 9th and March 22nd. The testing was extended due to actuator ground loops, which seemingly impacted the slopes of the actuators linearity tests.
When two sets of data are being given for one test, there is one before the resolution of the ground loop issues, and one after.

- *Step 1: Check level of Stage 1 Optical Table*



Acceptance Criteria

- The maximum angle of the table with the horizontal mustn't exceed ~100µrad

  This table appears to have local deformation but no excessive tilt

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

- *Step 2: Blade spring profile*

Re-measured because we had to change shims to meet the platform level requirements.

Blade #	Base (")	Tip(")	Flatness (mils)
1	.4829	.4712	+11.7
2	.4895	.4730	+16.5
3	.4834	.4691	+14.3

Table 2 - Blade profile

Issues/difficulties/comments regarding this test:
Those were re-measured because we adjusted the shims to get the table within level requirements.

Acceptance Criteria:

- Blades must be flat within 0.015" inches.

Test result: **Passed: __** **Failed: X__**

- *Step 3: Gap checks on actuators-after installation on Stage 1*

Not recorded but checked and within requirements.

Acceptance Criteria

- Gaps must be within 0.010” of design value (0.080”)

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

- *Step 4: Mass budget*

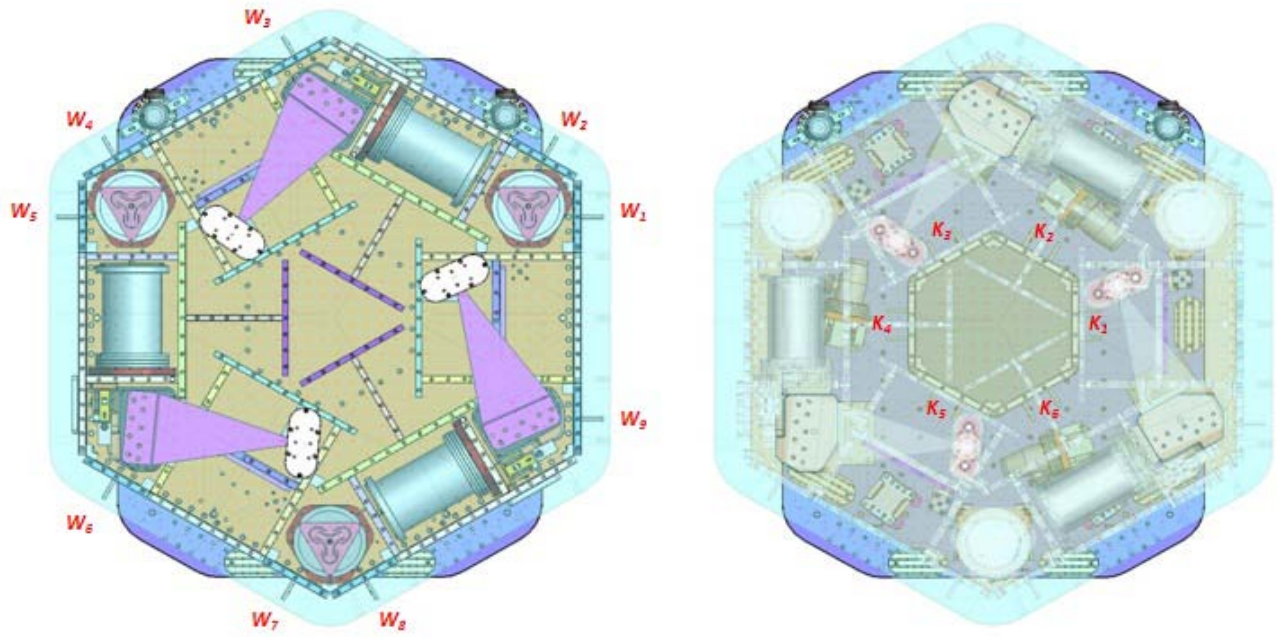


Figure – Keel Masses and Wall masses location

	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
k1					1		1	35.1	15.92
k2	1	1	1				1	31.1	14.11
k3					1		1	35.1	15.92
k4	1	1	1				1	31.1	14.11
k5					1		1	35.1	15.92
k6	1	1	1				1	31.1	14.11
	3	3	3	0	3	0	6	198.6	90.08

Table- Keel masses

	00	01	02	03	04	05	06		
	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
w9	1	1	1	1		1		24	10.89
w1	1	1	2	1		1		26.2	11.88
w2	3		4			1		26.2	11.88
w3	2		1	1		1		23.5	10.66
w4	2	1		1		1		22.4	10.16
w5			1	1		1		22.3	10.12
w6	2	1	1	1		1		24.6	11.16
w7	1			1		1		20.7	9.39
w8	2		2	1		1		25.7	11.66
Side Masses Total	14	4	12	8	0	9	0	215.6	97.79

Table- Side masses

	D972213	D972214	D972215	D0901075				
				2.5 kg	5 kg	10 kg		
	610	375	230	5.5	11	22	lbs	kgs
Top Masses	0	2	0	0	3	3	849	385.10

Table- Optical table masses

	Side	Keel	Top	Total
Weigh (kg)	97.79	90.08	385.10	572.98

Table - Masses distribution (computed using T1100261)

Acceptance Criteria

The Mass budget must be

- 579.1 Kg (cf E1100427)+/-25Kg (5%)

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

- *Step 5: Shim thickness*

Lockers	Shim thickness (mil)
A	130
B	120
C	128
D	120

Table – Shims Thickness

Issues/difficulties/comments regarding this test:
Those shims were changed in order to correct initial tilt found on the optical table.

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

- *Step 6: Lockers adjustment*

Not recorded but within requirements-cf CPS results later.

Acceptance Criteria

- Vertical and horizontal displacement near the lockers must be lower than 2 mils (0.002")

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

- *Step 7 - Electronics Inventory*

Hardware	LIGO reference	S/N
Coil driver	D0902744	S1103308
		S1103332
Anti Image filter	D070081	S1104572
Anti aliasing filter	D1000269	S1104621
		S1104638
Interface chassis	D1000067	S1107434
		S1107435

Table - Inventory electronics

Note that we replaced the BSC-ISI interface that we used for side-chamber testing with the HAM-ISI interface that had gotten replaced.

Acceptance Criteria

- Inventory is complete

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

- *Step 8 - Set up sensors gap*

	No mass	
Table locked	**ADE boxes on**	
Sensors	**Offset (Mean)**	**Std deviation**
H1	248.84	6.5019
H2	-262.73	5.0111
H3	193.05	6.3325
V1	-106.2	6.7945
V2	-223.67	9.3371
V3	-426.2	5.3248

Table – Capacitive position sensor readout after gap set-up

Issues/difficulties/comments regarding this test:
We installed the shielding on the in-air cables after install and had initially forgotten grounding it. Moving the CPS boxes especially against metal surfaces or the shields touching any metal surface, would create offsets on the CPS readouts.

Acceptance criteria:
- All mean values must be lower than 400 cts (a bit less than .0005").
- All standard deviations below 5 counts.
- No cross talk

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

- *Step 9 - Check Sensor gaps after the platform release*

	Table locked		Table unlocked	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Difference**
H1	248.84	6.5019	1165.1	-916.26
H2	-262.73	5.0111	-286.86	24.13
H3	193.05	6.3325	733.42	-540.37
V1	-106.2	6.7945	-1433.3	1327.1
V2	-223.67	9.3371	885.55	-1109.22
`V3	-426.2	5.3248	-3018.1	2591.9

Table – Sensor gaps after platform release

Acceptance criteria:
- Absolute values of the difference between the unlocked and the locked table must be below:
  - 1600 cts for horizontal sensors (~0.002")
  - 1600 cts for vertical sensors (~0.002")
- Considering the acceptance criteria of step 4, all mean values must be lower than
  - 2000 cts for horizontal sensors (~0.0025")
  - 2000 cts for vertical sensors (~0.0025")

Issues/difficulties/comments regarding this test:

We can see that the balancing is not perfect, the table is indeed moving too much vertically (especially around V3) when unlocked. Because the table will be rebalanced later after (and while) the payload is installed, we chose not to spend more time on it.

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

- *Step 10 - Position Sensors unlocked/locked Power Spectrum*

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Spectra/Undamped

- LLO_HAM_ISI_Unit_2_Calibrated_PSD_CPS_GS13_Unlocked_Locked_2012_03_14.m at

Figures in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Figures/Spectra/Undamped
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_2/Figures/Powerspectra/Undamped

- LLO_HAM_Unit_2_Calibrated_PSD_CPS_Unlocked_Locked_2012_03_14.pdf

CPS calibration:
The CPS power spectrums are calibrated by using a sensitivity of 30.2 nm/count.

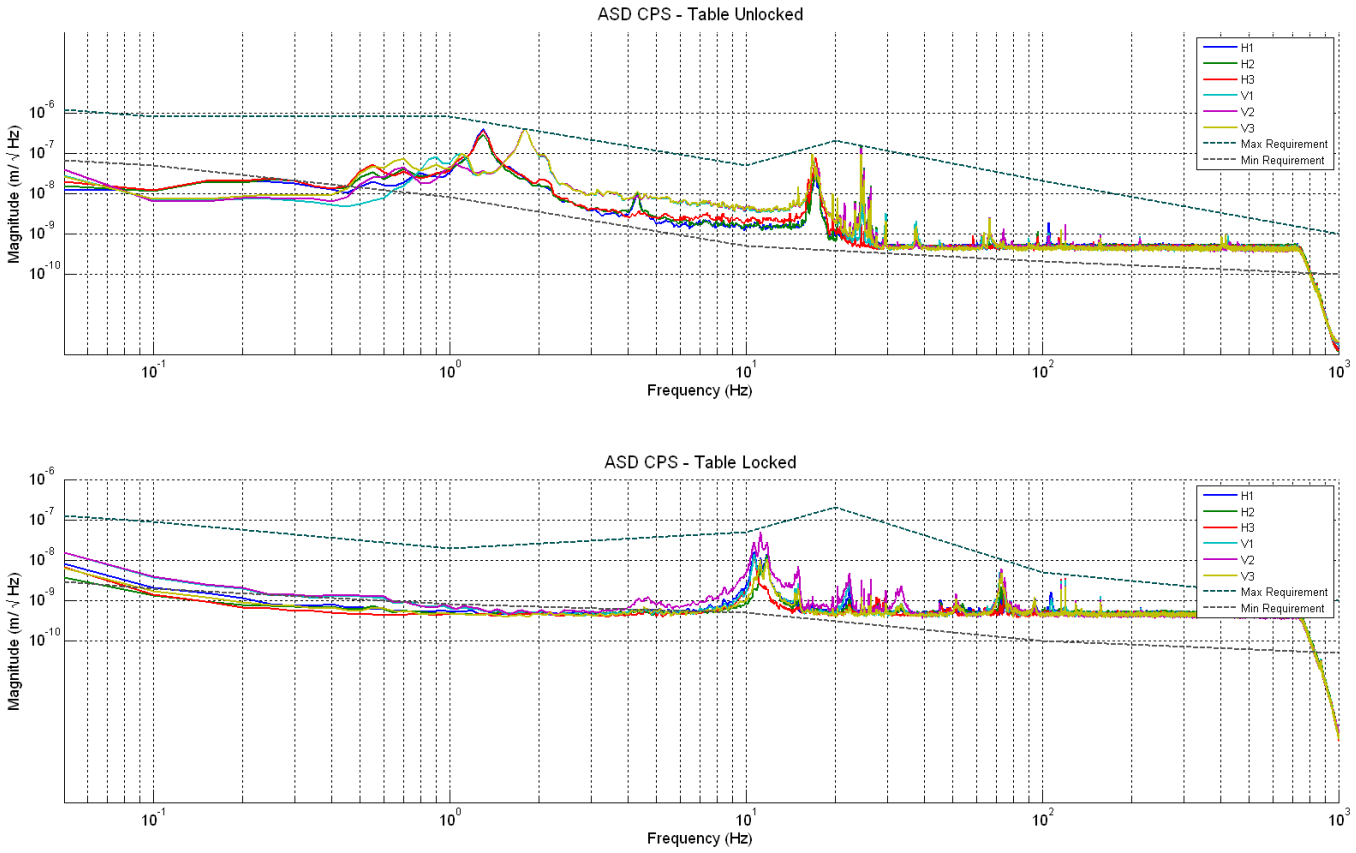


Figure - Calibrated CPS power spectrum

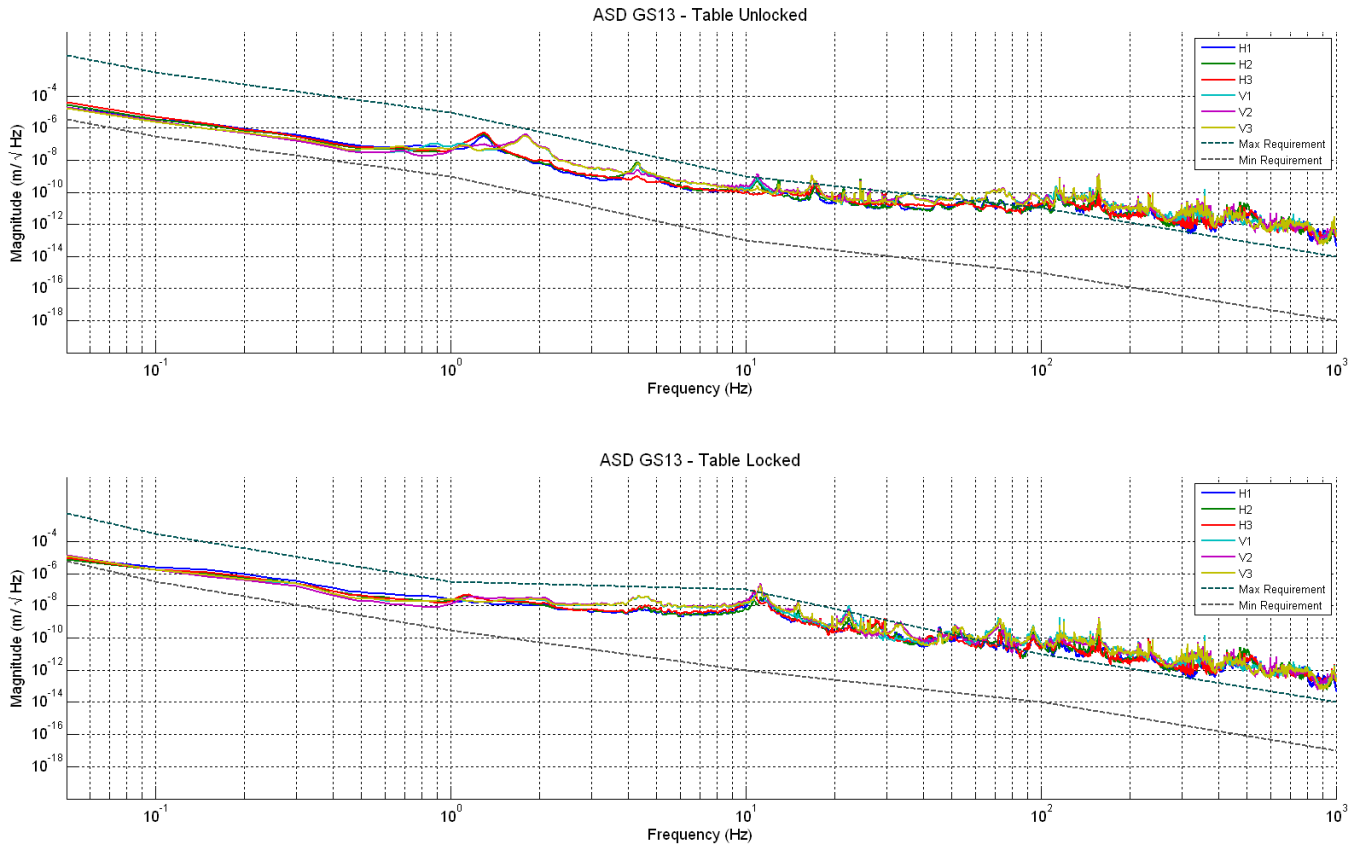


Figure – Power spectrum Calibrated GS13

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Spectra/Undamped/

- LLO_ISI_HAM2_ASD_m_CPS_T240_L4C_GS13_Locked_vs_Unlocked_2012_03_14.mat

Issues/difficulties/comments regarding this test:
H3 CPS seems to have a lower response between 10 and 13 Hz (locked config), this was the only time this was observed, and response appears normal in other configuration.

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- Plot_ASD_Unlocked_Locked_HAM_ISI.m
- Plot_ASD_Unlocked_Locked_Group_HAM_ISI.m

Figures in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Figures/Spectra/Undamped/

- LLO_ISI_HAM2_ASD_m_GS13_Requirements_Locked_vs_Unlocked_2012_03_14.pdf
- LLO_ISI_HAM2_ASD_m_CPS_Requirements_Locked_vs_Unlocked_2012_03_14.pdf

Acceptance criteria:

- No cross talk (peaks at low frequencies + harmonics on measurements)
- Magnitudes of power spectra must be between requirement curves such as in the following figures (dashed lines)

Sensors	ISI state	Frequency (Hz)	$2x10^{-2}$	$1x10^{-1}$	1	10	20	100	1000

GS-13	Table locked	Max	$3x10^{-1}$	$3x10^{-4}$	$3x10^{-7}$	10^{-7}		10^{-11}	10^{-14}
		Min	$3x10^{-4}$	$3x10^{-7}$	$3x10^{-10}$	10^{-12}		10^{-14}	10^{-17}
	Table unlocked	Max	1	$3x10^{-3}$	10^{-5}	10^{-9}		10^{-11}	10^{-14}
		Min	10^{-4}	$3x10^{-7}$	10^{-9}	10^{-13}		10^{-15}	10^{-18}
CPS	Table locked	Max	$2*10^{-7}$	$2x10^{-8}$	10^{-8}	$5x10^{-8}$	$2x10^{-7}$	$5x10^{-9}$	10^{-9}
		Min	$5x10^{-9}$	$2x10^{-9}$	$8x10^{-10}$	$5x10^{-10}$		10^{-10}	$5x10^{-11}$
	Table unlocked	Max	$2x10^{-6}$	$8x10^{-7}$	$8x10^{-7}$	$5x10^{-8}$	$2x10^{-7}$	$2x10^{-8}$	10^{-9}
		Min	10^{-7}	$5x10^{-8}$	$8x10^{-9}$	$5x10^{-10}$		$2x10^{-10}$	10^{-10}

Table - Step 6 -Normal conditions-Sensors powerspectra requirements

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

- *Step 11- GS13 power spectrum -tabled tilted*

The figure below presents the GS13 power spectrum when the table is unlocked and loaded with a 20 Kg mass at one of its corner.

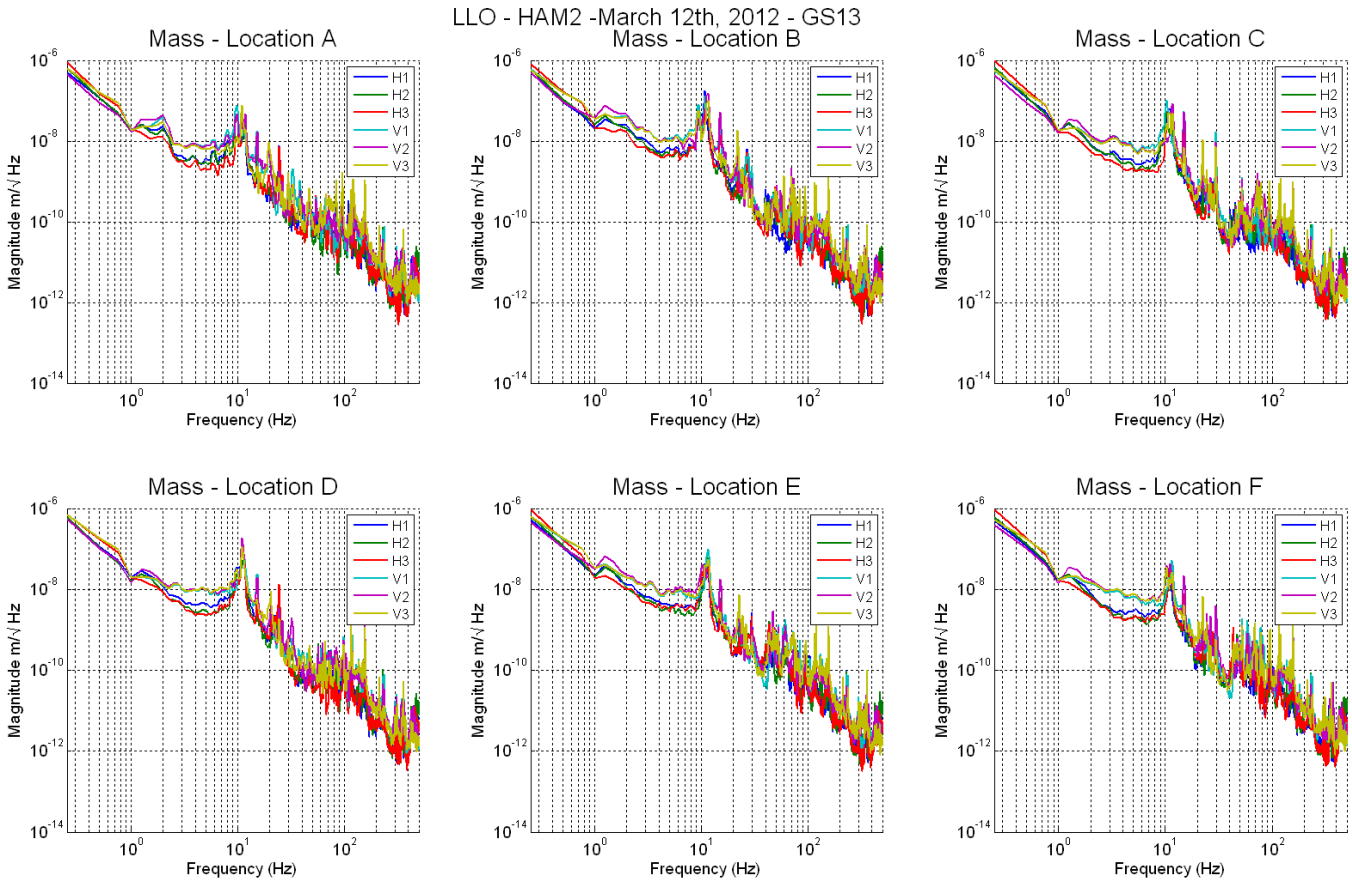


Figure – Power spectrum Calibrated GS13 with mass at corner

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Spectra/Undamped/

- LLO_ISI_HAM2_ASD_m_GS13_Stage_Tilted_2012_03_12.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- Plot_ASD_Tilted_Stage_HAM_ISI.m

Figures in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Figures/Spectra/Undamped/

- LLO_ISI_HAM2LLO_ISI_HAM2_ASD_m_GS13_Stage_Tilted_2012_03_12.pdf

Acceptance criteria:

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

- *Step 12- GS13 pressure readout*

GS-13 pressure sensors constantly read 77 or 78 KPa.

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

- *Step 13- Actuators Sign and range of motion (Local drive)*

- **03/12/12**

	Negative drive	Positive drive
H1 readout (count)	-23073.888	24341.642
H2 readout (count)	-23112.536	23447.74
H3 readout (count)	-24741.966	24378.672
V1 readout (count)	-19926.948	19208.934
V2 readout (count)	-24683.802	25557.282
V3 readout (count)	-22756.788	21081.596

Table - Range of motion - Local drive

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Static_Tests/

- LLO_HAM-ISI_Unit_2_Range_Of_Motion_20120312.mat

- **03/21/12**

	Negative drive	Positive drive
H1 readout (count)	-23489.2	23425.71
H2 readout (count)	-23991	23657.86
H3 readout (count)	-24992.5	24370.29
V1 readout (count)	-19937	19393.21
V2 readout (count)	-24637.1	25639.36
V3 readout (count)	-22379.5	21358.19

Table - Range of motion - Local drive

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Static_Tests/

- LLO_HAM-ISI_Unit_2_Range_Of_Motion_20120321.mat

Scripts files for taking and processing the data, and plotting it in SVN at:

seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- Range_Motion_HAM_ISI.m

Acceptance criteria:

- Main couplings sensors readout must be at least 16000 counts (~0.02")
- A positive offset drive on one actuator must give positive sensor readout on the collocated sensor. Signs will also be tested when measuring local to local transfer functions.

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

- *Step 14: Inventory (E1000052)*

One actuator was changed to solve the ground loop issue.

DCC/Vendor number	Part name	Configuration	S/N	S/N	S/N
D071001	Stage 0 base		002		
D071050	Stage 1 base		001		
D071051	Optical table		002		
D071002	Spring Post		007	005	015
D071100	Spring		34	17	39
D071102	Flexure		42	21	45
ADE	Position sensor	Horizontal	11981	12079	12071
		Vertical	12078	12080	12069
D047812	GS-13 pod	Horizontal	46	39	73
		Vertical	32	19	51
D047823	L4C pod	Horizontal	N/A	N/A	N/A
		Vertical	N/A	N/A	N/A
D0902749	Actuator	Horizontal	L139	L081	L086
		Vertical	L084	L089	**L072**

- *Step 15– Cables inventory – E1100822*

One cable was changed to solve the ground loop issue.

Cable Connects		Cable S/N		
Part Name	Configuration	Corner 1	Corner 2	Corner 3
GS13	Horizontal	S1104670-S114694	S1104663-S1104606	S1104667-S1104592
GS13	Vertical			
Actuator	Horizontal	S1106907	S1104751	S1104499
	Vertical	**S1106674**	S1104606	S1104479

Table – Cables inventory

Acceptance Criteria
- Cable inventory completed
- E110082 spreadsheet updated

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

- *Step 16- Static Testing (Tests in the local basis)*

- **03/12/12**

		H1	H2	H3	V1	V2	V3
Actuators (1000 counts)	H1	1815.7554	1140.44682	1147.0721	-13.442	-12.99658	-1.7162
	H2	1135.0146	1847.06036	1165.68858	-12.4966	9.92384	-2.9238
	H3	1144.9278	1179.62188	1874.04406	-1.9248	-1.1169	1.4338
	V1	156.3542	181.078276	-317.6344	1300.34141	-35.5098	-577.112
	V2	-356.0164	182.38216	171.691251	-585.6892	1327.21362	-29.607
	V3	161.9512	-361.92448	185.35227	-41.395	-615.21274	1402.104

Table - Main and cross coupling

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Static_Tests/
- / LLO_HAM_ISI_Unit_2_Sensor_Readout_Local_20120312.mat

Scripts files for taking data in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Static_Test_Local_Basis_HAM_ISI.m

Issues/difficulties/comments regarding this test:
V1 and V2 appear to again give responses just lower from the criteria.

- **03/21/12**

Following the discovery of ground loops on the actuators (cf next step), we switched a few cables and changed V3 actuators. We then redid the test and got the following results:

		H1	H2	H3	V1	V2	V3
Actuators (1000 counts)	H1	1814.219	1138.267	1151.962	8.048	3.6845	14.6316
	H2	1132.955	1846.599	1161.905	7.2928	16.11664	-1.1842
	H3	1152.421	1162.094	1872.925	10.9982	-6.17976	7.509

	V1	153.1668	172.927	-343.83	1325.871	-29.8296	-563.186
	V2	-363.854	178.665	167.5899	-581.169	1323.611	-24.2644
	V3	154.8223	-342.922	184.4622	-30.7378	-574.745	1355.705

Table - Main and cross coupling

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Static_Tests/

- / LLO_HAM_ISI_Unit_2_Sensor_Readout_Local_20120321.mat

Acceptance criteria:

- **Vertical**
  For a +1000 count offset drive on vertical actuators
  - Collocated sensors must be 1400 counts +/- 10%

- **Horizontal**
  For a +1000 count offset drive on horizontal actuators
  - Collocated sensors must be 2000 counts +/- 10%
  - Non-collocated horizontal sensors must be 1250 counts +/-10%

Issues/difficulties/comments regarding this test:
All vertical actuators now appear to give responses just lower from the criteria; however, they seem to have more similar behavior.

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

- *Step 17 - Linearity test*

Surprisingly enough, this is the test that we had the most issues passing.

- **03/15/12**

Initial results were as such:

	Slope	Average slope	Variation from average(%)
H1	1.8263	1.8454	-1.03500596
H2	1.8424		-0.16256638
H3	1.8675		1.19757234
V1	1.3215	1.3497	-2.09177121
V2	1.3255		-1.79541638
V3	1.4022		3.88718759

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

Scripts files for taking data in SVN at: seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- Linearity_Test_Awgstream_HAM_ISI.m

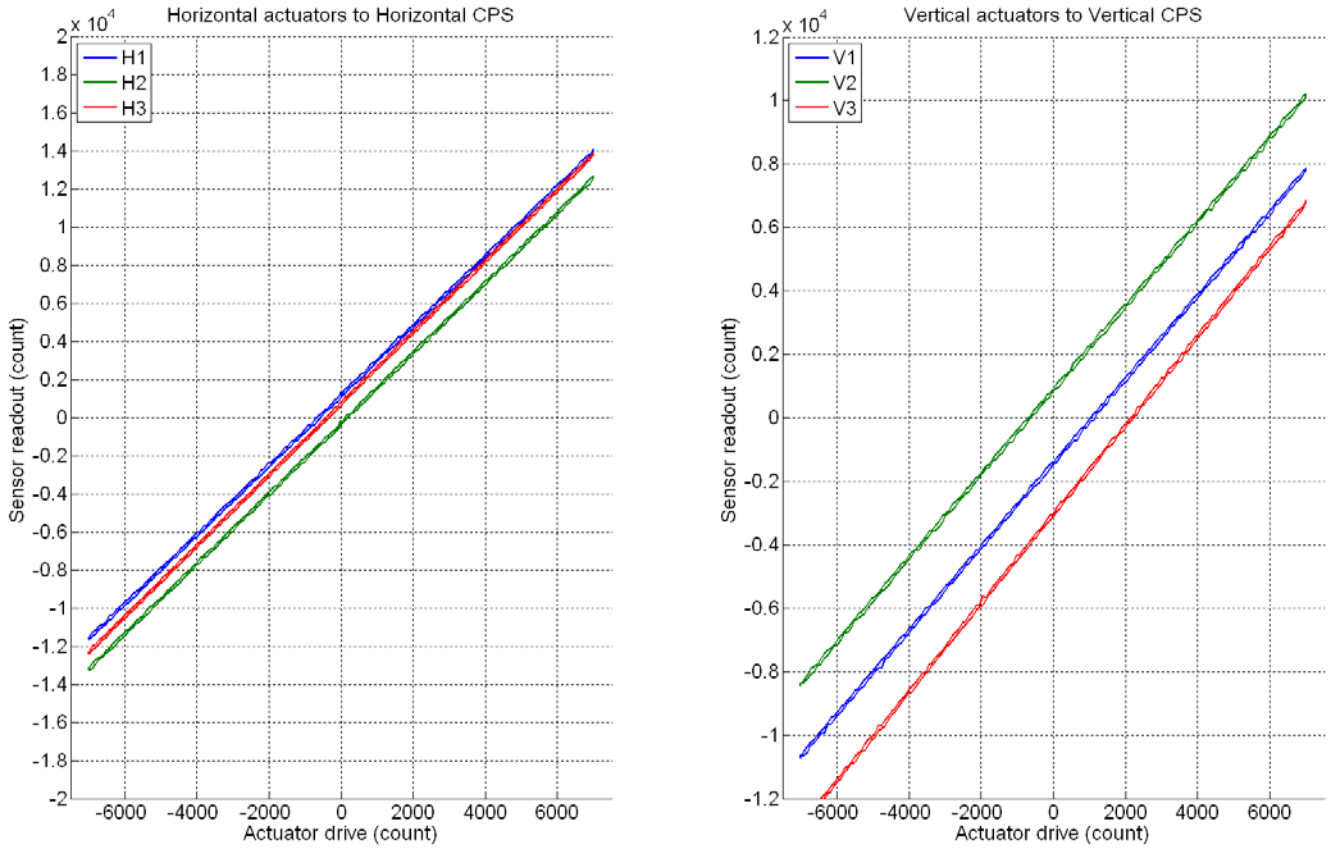


Figure - Horizontal and vertical actuators x HAM-ISI x sensors

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Linearity_Test/

- LLO_HAM_ISI_Unit_2_Linearity_test_20120315.mat

Figures in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Figures/Linearity_Test/

- LLO_HAM_ISI_Unit_2_Linearity_test_20120315.fig
  LLO_HAM_ISI_Unit_2_Linearity_test_20120315.pdf

Acceptance criteria:

- Horizontal and vertical slopes of the triplet actuators x HAM-ISI x sensors: Average slope +/- 1%

After identifying that the difference was not generated by the coil drivers, and that there was no significant difference in resistance measured at the actuators (at the feedthru ~6.2 ohms, at the chassis between 7.2 and 7.4 ohms), we noticed ground loops on H1, V1 and H3. Precisely, air-side of the feedthrus with in-air cables connected, we noticed that pin 3 (cable shield) was at the same potential than the chamber (i.e earth ground).
After solving all those ground loops, we got the following results.

- **03/21/12**

	Slope	Average slope	Variation from average(%)
H1	1.8253	1.8472	-1.18
H2	1.8469		-0.014
H3	1.8693		1.198
V1	1.3183	1.3276	-0.70
V2	1.3282		0.04
V3	1.3364		0.66

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

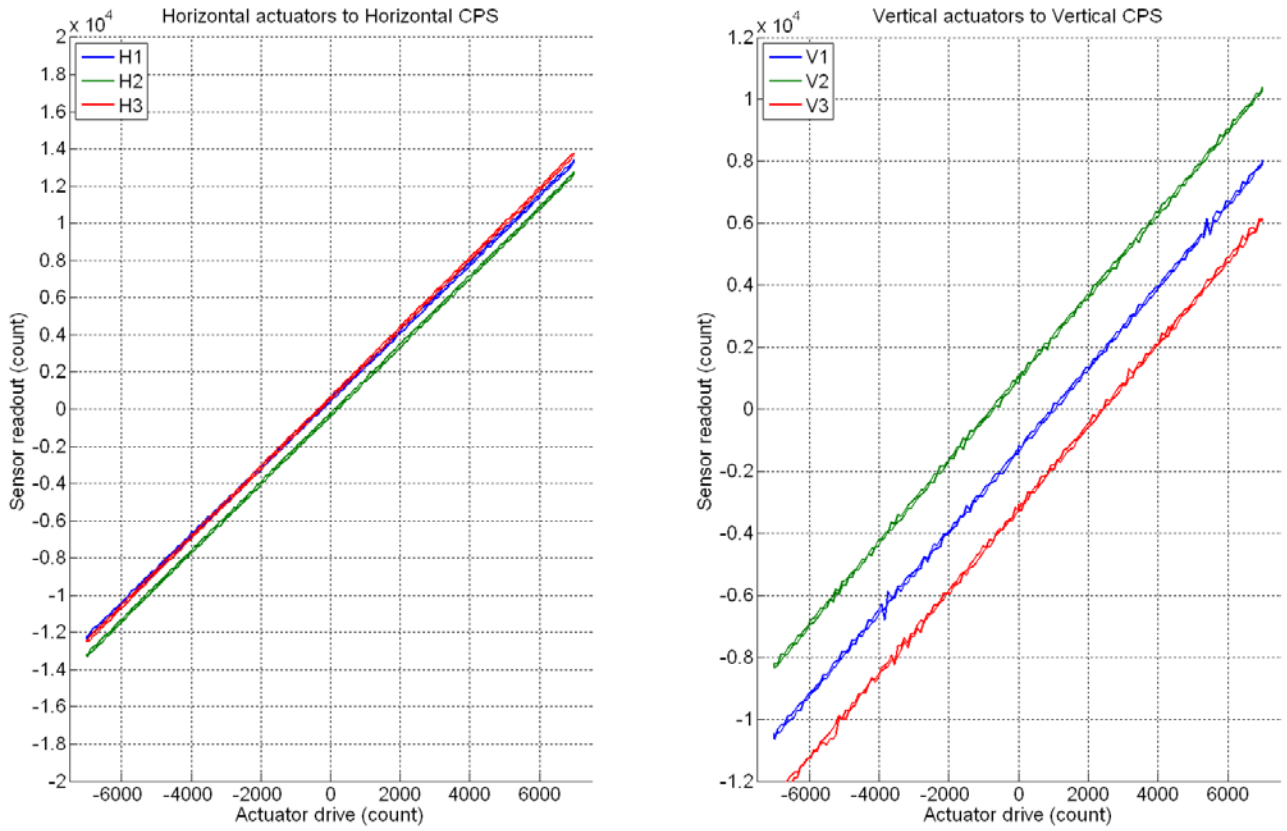


Figure - Horizontal and vertical actuators x HAM-ISI x sensors

Data files in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Linearity_Test/

- LLO_HAM_ISI_Unit_2_Linearity_test_20120321.mat

Figures in SVN at: seismic/HAM-ISI/L1/HAM2/Data/Figures/Linearity_Test/

- LLO_HAM_ISI_Unit_2_Linearity_test_20120321.fig
  LLO_HAM_ISI_Unit_2_Linearity_test_20120321.pdf

Test result: **Passed: __** **Failed: _X__**

- *Step 18- Frequency response*
- *Step 18.1 - Local to local measurements*

Local to local transfer functions have been measured with 90 repetitions.

Data files in SVN at:
seismic/HAM-ISI/L1/HAM2/Data/Transfer_Functions/Measurements/Undamped/
- LLO_ISI_HAM2_Data_TF_L2L_50mHz_500mHz_20120322-033530.mat
- LLO_ISI_HAM2_Data_TF_L2L_500mHz_5Hz_20120321-212557.mat
- LLO_ISI_HAM2_Data_TF_L2L_5Hz_200Hz_20120321-195224.mat
- LLO_ISI_HAM2_Data_TF_L2L_200Hz_800Hz_20120321-181851.mat

Data collection script files: seismic/HAM-ISI/L1/HAM2/Scripts/Data_Collection/
- Run_Exc_Batch_L1ISIHAM2.m

Scripts files for processing and plotting in SVN at:
seismic/HAM-ISI/L1/HAM2/Scripts/Control_Scripts/
- Step_1_TF_L2L_L1_ISI_HAM3.m

Figures in SVN at:
seismic/HAM-ISI/L1/HAM2/Data/Figures/Transfer_Functions/Measurements/Undamped/
- LLO_ISI_HAM3_TF_L2L_Raw_from_ACT_to_CPS_2012_03_21.fig
- LLO_ISI_HAM3_TF_L2L_Raw_from_ACT_to_GS13_2012_03_21.fig

Storage of measured transfer functions in the SVN at:
seismic/HAM-ISI/L1/HAM2/Data/Transfer_Functions/Measurements/Undamped/
- LLO_HAM_ISI_Unit_3_Data_TF_L2L_2012_03_21.mat

The local to local transfer functions are presented below.

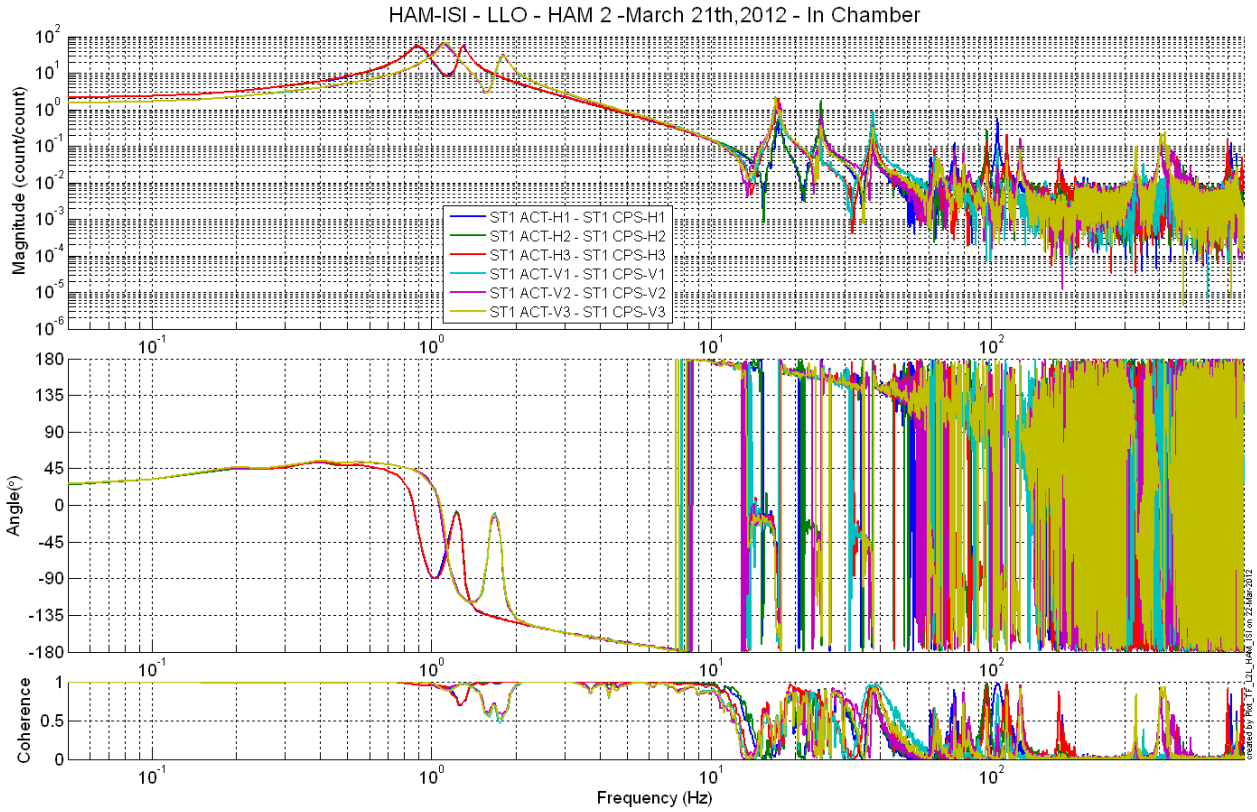


Figure - Local to Local Measurements – Capacitive sensors

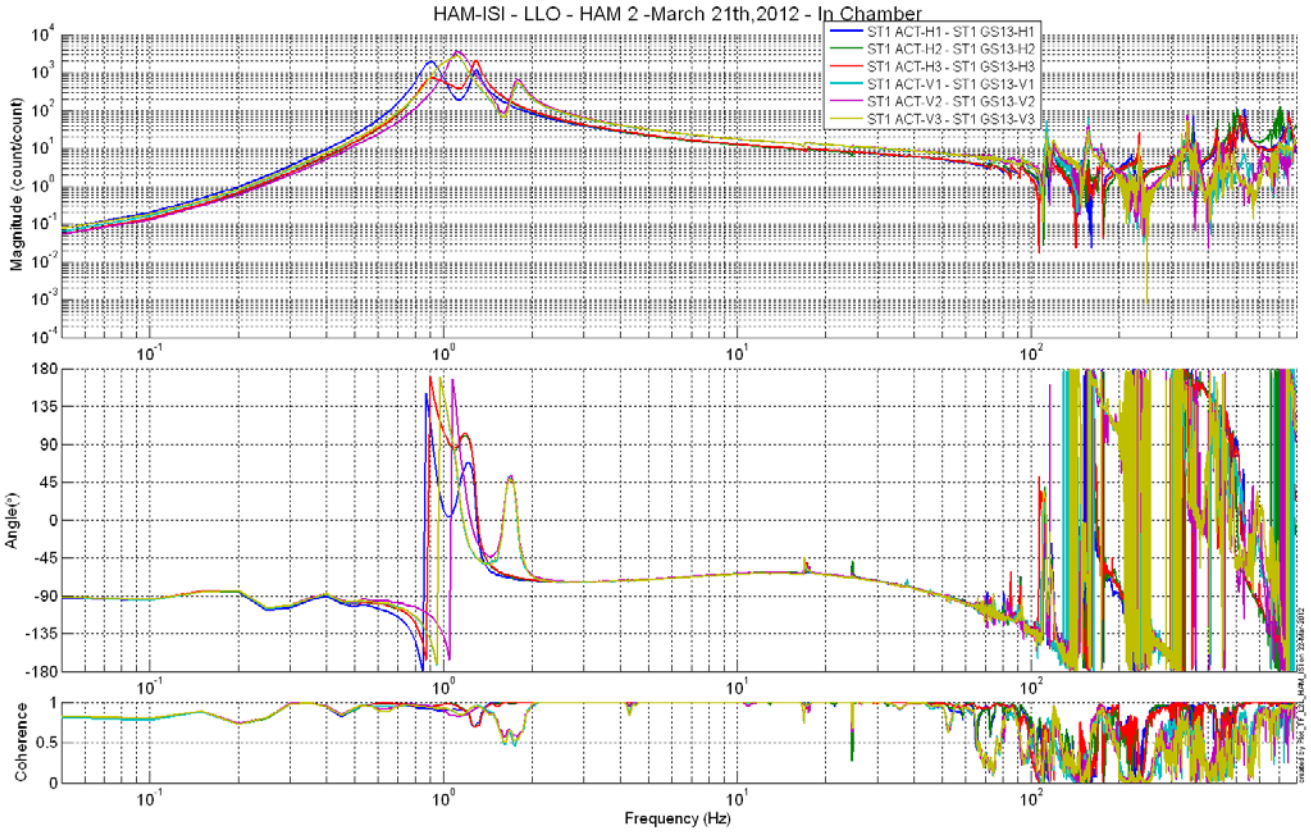


Figure - Local to Local Measurements – Inertial sensors

Acceptance criteria:

- Local to local measurements
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC
  - Identical shape in each corner
- Cartesian to Cartesian measurements
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC
  - Identical shape X/Y and RX/RY

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

Conclusion Initial In-Chamber testing

Once again, we had make a few unexpected adjustments after installing the ISI in the chamber.

- change 2 shims (for level) Those changes were less drastic than those we had to make on HAM-ISI 3 (see E1200104)
- change V3 actuator (for ground loops)
- change V1 cable (for ground loops)

Most minor issues found on this ISI during side-chamber testing were confirmed during in chamber tests.

- Local 2 local transfer functions displays a slightly different behavior around 1 Hz in corner 3 than in the others. We still believe this to be due to the sensors themselves.
- All vertical local to local static testing barely missed requirements (i.e. displacement is slightly lower than anticipated.
- Even after solving ground loops issue, the slopes from the linearity tests differ from each other slightly more than expected. However, results are much more consistent than right after installation.

We did not retest the LZMP, but will once the chamber is closed.