

aLIGO HAM-ISI, LLO Unit 3, Testing Validation

LIGO-G1100507-v2

April 19th, 2011

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References

- E1000309 - aLIGO HAM-ISI, Pre-Integration Testing Procedure, Phase I (post assembly, before storage)- Please note that v5 was used but we're now using v6
- E1000300 - HAM-ISI LLO test stand: software and electronic check
- E1000327 aLIGO SEI Testing Report, HAM-ISI, LLO - Unit 3

Goals:

- Present tests performed on HAM-ISI LLO Unit 3
- Validate HAM-ISI LLO Unit 3

- Step 1 - Check torques on all bolts
- Step 2 - Check gaps under Support Posts
- Step 3 - Pitchfork/Boxwork flatness before Optical Table install
- Step 4 - Blade spring profile

Passed

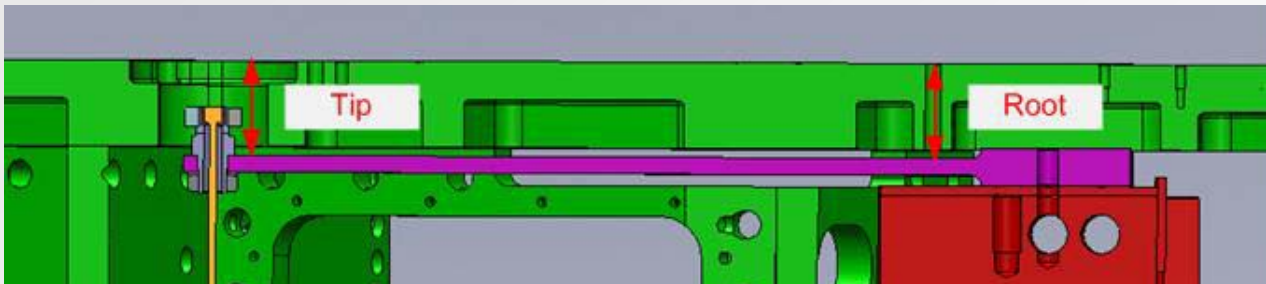
Passed

Passed

Blade #	Base (")	Tip(")	Flatness (mils)
1	.495	.491	+4
2	.501	.489	+12
3	.498	.490	+8

Acceptance Criteria : Blades must be flat within 0.020" inches

Passed



Note that all locker shims are identical at 125 mils.



•Step 5 - Gap checks on actuators

Failed

Actuator	Front Gap (1/1000")	Back Gap (1/1000")
V1	80	90
V2	90	75
V3	95/85	65/80
H1	85	
H2	80	
H3	80	

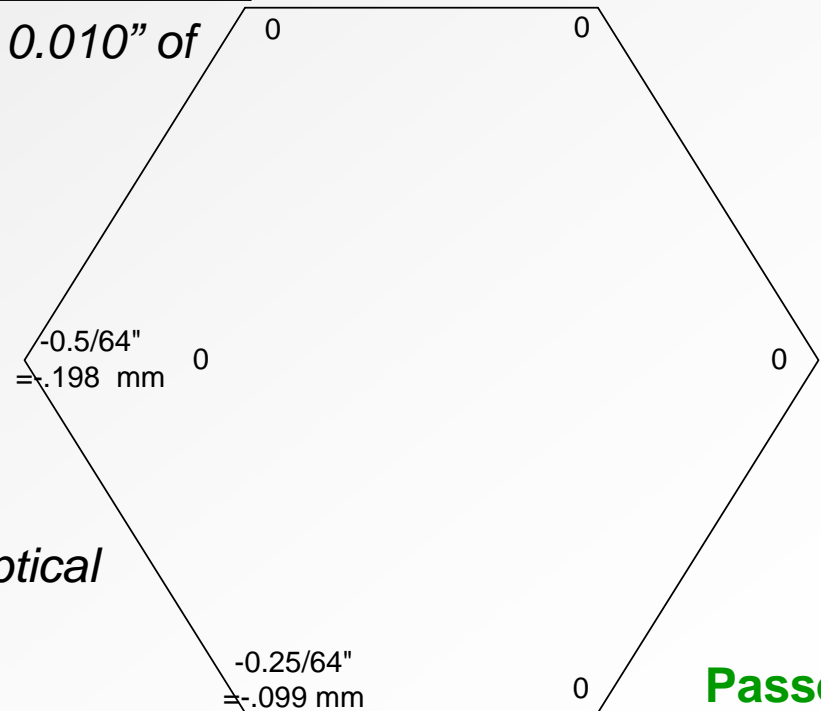
Acceptance Criteria : Gaps must be within 0.010" of design. Can be adjusted before install

•Step 6 - Check level of Stage 1

Acceptance Criteria: Maximum tilt of the optical table: 100 μ rad

Max angle= $(.5/64)/85.59= 91$ urad

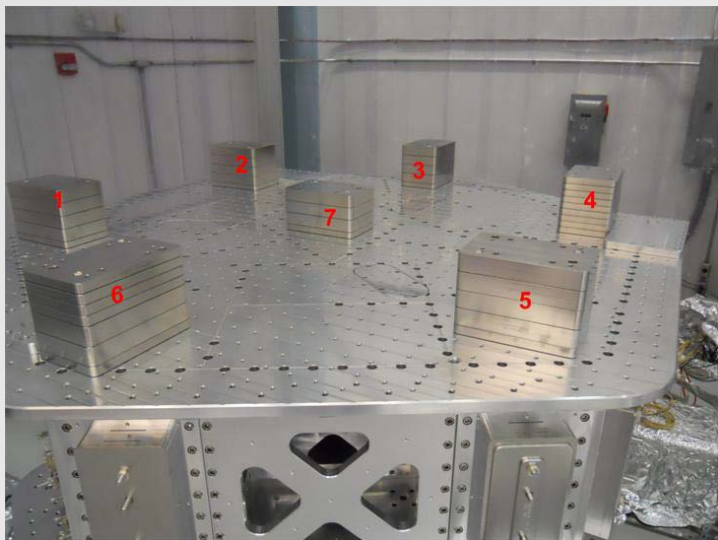
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Passed

- Step 7 - Mass budget and lockers shim thickness

Optical Mass (Kg)	Wall Mass (Kg)	Keel Mass (Kg)	Total Mass (Kg)
305.00	178.58	90.08	573.66



Lockers shim thickness

Lockers	Shim thickness (mil)
A	125
B	125
C	125
D	125

Acceptance Criteria : 596.7Kg +/-25Kg (4%)

Passed

- Step 8 - Lockers adjustment

D.I at Lockers	Dial indicators V	Dial indicators H
A	0.5	-1
B	2	0
C	0.25	0
D	-1.5	-1.5

Acceptance Criteria : Vertical and horizontal displacement near the lockers must be lower than 2 mils

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Passed

- Step 1 to 3 – Actuators, Sensors and Electronics Inventory
- Step 4 - Set up sensors gap

Passed

Table locked	10 Kg masses at each corners		No mass	
	ADE boxes on		ADE boxes on	
Sensors	Offset (Mean)	Std deviation	Offset (Mean)	Std deviation
H1	-36.967	1.2	-109.44	1.5
H2	254.8	1.1	243.71	0.8
H3	-23.343	0.7	-91.761	1.1
V1	-264.62	0.6	-52.461	1.6
V2	-148.73	1.8	24.719	1.5
V3	196.35	1.4	296.66	1.2

Acceptance criteria:

- All mean values must be lower than 400 cts (a bit less than .0005”).
- All standard deviations below 5 counts.

Comments: The two satellite boxes are now synchronized

- **Step 5 - Measure the Sensor gap**

Sensors	Gap measured on the Jig	Gap measured on the table
H1	NR	0.080"
H2	NR	0.085"
H3	NR	0.085"
V1	NR	0.085"
V2	NR	0.085"
V3	NR	0.085"

Comments:

- *Difficult to measure without scratching the target*
- *No information of gaps measured on the Jig*

Acceptance criteria:

- *Measured gap must be 0.080"±0.002"*

Failed

- Step 6 - Check Sensor gaps after the platform release

Sensors	Table locked		Table unlocked	
	Offset (Mean)	Std deviation	Offset (Mean)	Diff
H1	-274.44	0.83234	664.2	938.64
H2	-43.197	0.75333	-327.25	-284.053
H3	159.76	0.74358	-561.14	-720.9
V1	-296.64	1.0669	583.93	880.57
V2	245.48	1.4453	495.1	249.62
V3	-362.15	1.627	-1144.2	-782.05

Acceptance criteria:

- Absolute values of the difference between the unlocked and the locked table must be below 1600 cts ($\sim 0.002''$)
- Considering the acceptance criteria of step 4, all mean values must be lower than 2000 cts ($\sim 0.0025''$)

Passed

- **Step 7 - Check range of motion (hand pushing)**
 - **Step 7.1 – Test N^o1**

Sensors	CPS read out		Calculated after calibration	
	UP (Counts)	Down (Counts)	UP (mil)	Down (mil)
V1	20269	-20331	24.0	-24.1
V2	20234	-20363	23.9	-24.1
V3	19885	-19746	23.5	-23.4

Sensors	CPS read out		Calculated after calibration	
	CW(-RZ)	CCW (+RZ)	CW (mil)	CCW (mil)
H1	18281	-22331	21.6	-26.4
H2	24413	-19937	28.9	-23.6
H3	18099	-22126	21.4	-26.2

Acceptance criteria:

- *The vertical sensor readout be positive when the optic table is pushed in the +Z direction*
- *The horizontal sensor readout be negative when the optic table is pushed in the +RZ direction*
- *Absolute value of all estimated motions must be higher than 16000counts (~0.020")*

Passed

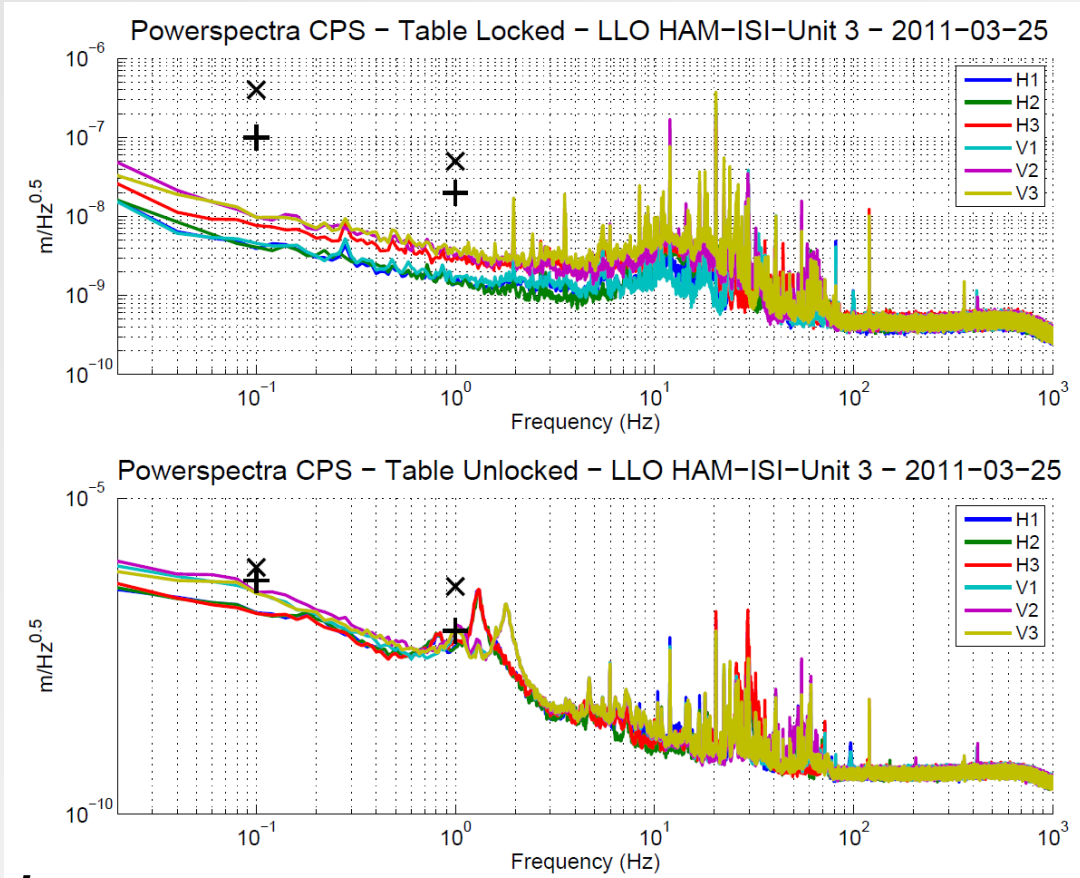
- **Step 7 - Check range of motion (hand pushing)**
 - **Step 7.2 – Test N^o2**

	Push in positive direction	Push in negative direction	Railing	Actuator Gap Check
H1	20691	-26431		X
H2	24701	-24100		X
H3	25028	-22929		X
V1	19785	-20422		X
V2	31629	-32519		X
V3	19762	-21787		X

Acceptance criteria:

- *No contact point on sensors*
- *Absolute value of sensor read out must be higher than 16000counts (~0.020")*
- *No contact point on actuators*
- *Note that we're not railing on V2-different from all other platforms tested so **Passed far***

• Step 8 - Capacitive position sensor Power Spectrum



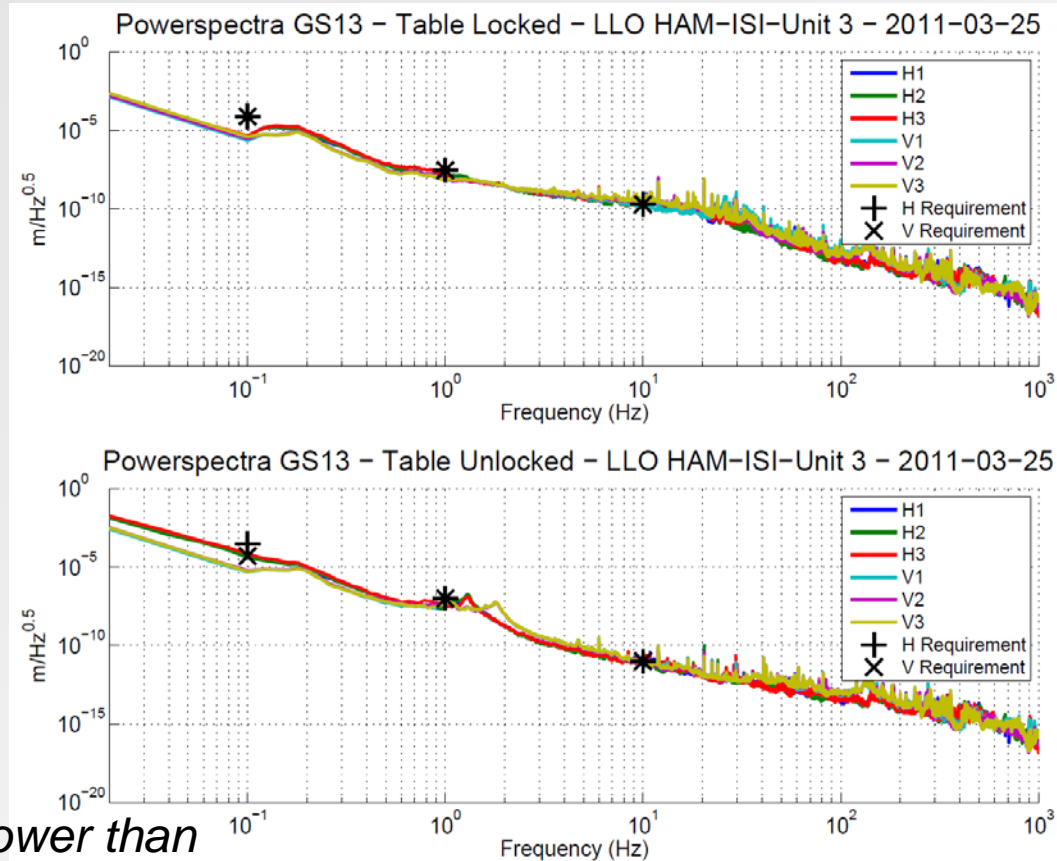
Acceptance criteria:

- Magnitudes must lower than

	Locked		Unlocked	
	at 0.1Hz	at 1Hz	at 0.1Hz	at 1Hz
Horizontal CPS	1.E-07	2.E-08	5.E-07	8.E-08
Vertical CPS	4.E-07	5.E-08	8.E-07	4.E-07

Passed

• Step 9 - GS13 Power Spectrum (Locked and Unlocked configuration)



Acceptance criteria:

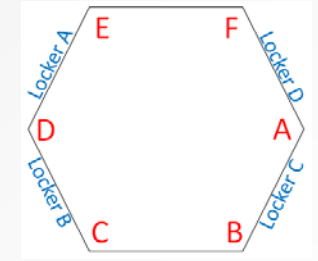
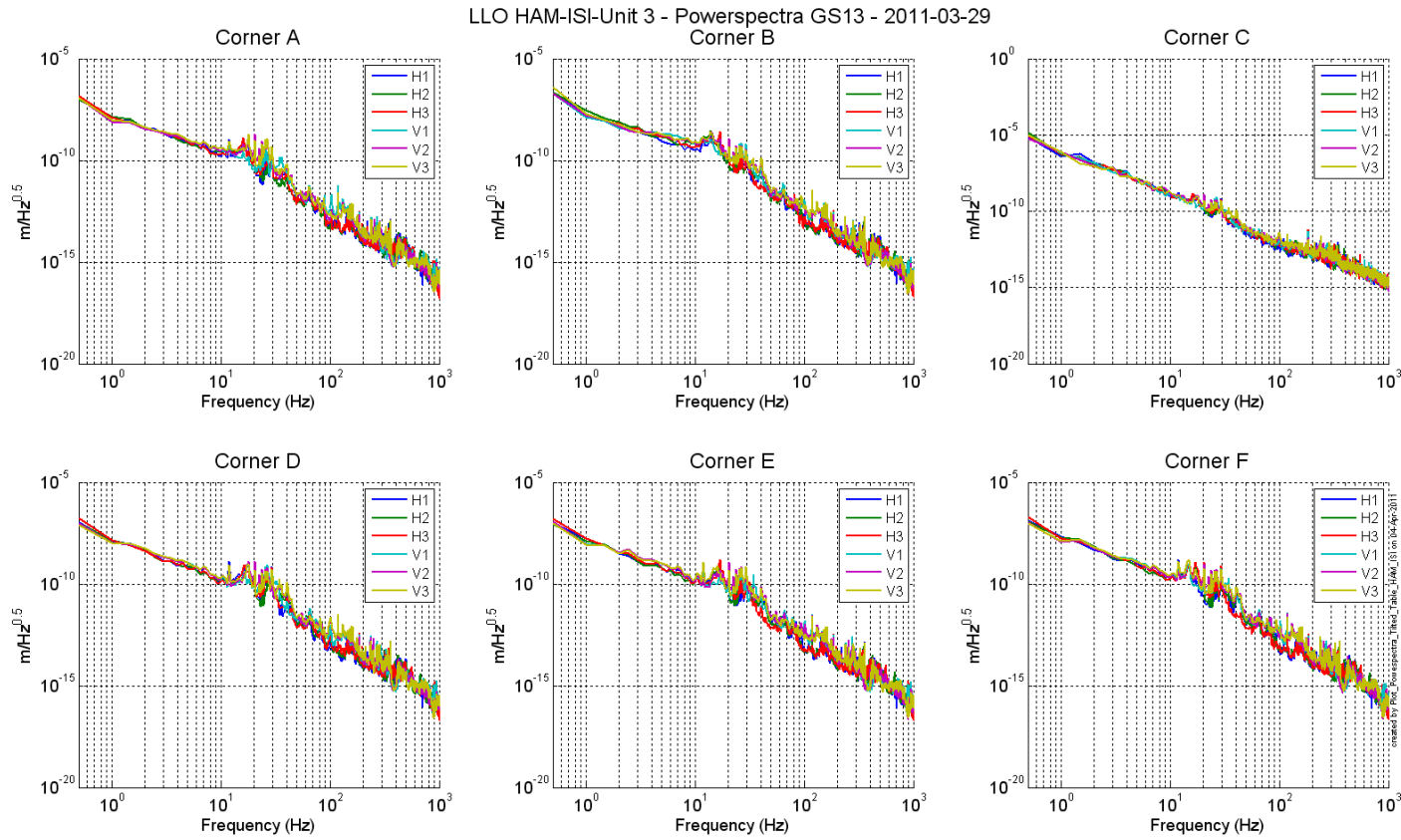
- Magnitudes must be lower than

Table locked			
	at 0.1Hz	at 1Hz	at 10Hz
H & V Geophones	8.E-05	3.E-08	2.E-10

Table unlocked			
	at 0.1Hz	at 1Hz	at 10Hz
Horizontal Geophones	3.E-04	1.E-07	1.E-11
Vertical Geophones	5.E-05	1.E-07	1.E-11

Passed

- **Step 9 - GS13 Power Spectrum** (*Table unlocked with a mass of 20 Kg at each corner of the optic table (1 mass at the time)*)



Acceptance Criteria:
- To be redefined

	Unlocked (tilted with masses)		
	at 0.1Hz	at 1Hz	at 10Hz
H & V Geophones	8.E-05	3.E-08	2.E-10

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- **Step 10 - Coil Driver, cabling and resistance check**
- **Step 11 - Actuators Sign and range of motion (Local drive)**
 - **Step 11.1 - Actuators sign**

Passed

Acceptance criteria: *A positive offset drive on one actuator must give positive sensor readout on the collocated sensor*

Passed

- **Step 11.2 - Range of motion - Local drive**

	Negative drive	Positive drive
H1 readout (count)	-24840	23704
H2 readout (count)	-23504	24473
H3 readout (count)	-25079	24232
V1 readout (count)	-19988	19535
V2 readout (count)	-25296	27191
V3 readout (count)	-22424	21599

Acceptance criteria: *Main couplings readout must be at least +/-16000counts (~0.002")*

Passed

- **Step 12 - Vertical Capacitive Position Sensors Calibration (using dial indicators)**

Vertical sensitivity: 845.3 count/mil 0.63% from nominal value)

Acceptance criteria: Deviation from nominal value < 2%. (Nominal is 840 count/mil)

- **Step 13 – Vertical Spring Constant**

Vertical spring constant : 2.50e5N/m (+3.1% from nominal value)

Passed

Acceptance criteria:

Spring constant is within +/- 10/-1% of 2.428e5 N/m (HPD FEA Results).

- **Step 14 - Static Testing (Tests in the local basis)**

Passed

		Sensors (counts)					
		H1	H2	H3	V1	V2	V3
Actuators (1000 counts)	H1	1967.669	1210.834	1224.792	-3.392	12.744	-33.92
	H2	1207.929	2017.293	1256.419	11.939	21.785	-21.05
	H3	1224.299	1259.544	2015.90	37.030	16.072	-30.849
	V1	201.7530	172.320	-313.735	1415.569	-43.636	-546.33
	V2	-276.287	261.940	230.952	-554.369	1437.609	-44.960
	V3	159.632	-385.887	142.389	44.354	-612.036	1403.71

Acceptance criteria: For a +1000 count offset drive

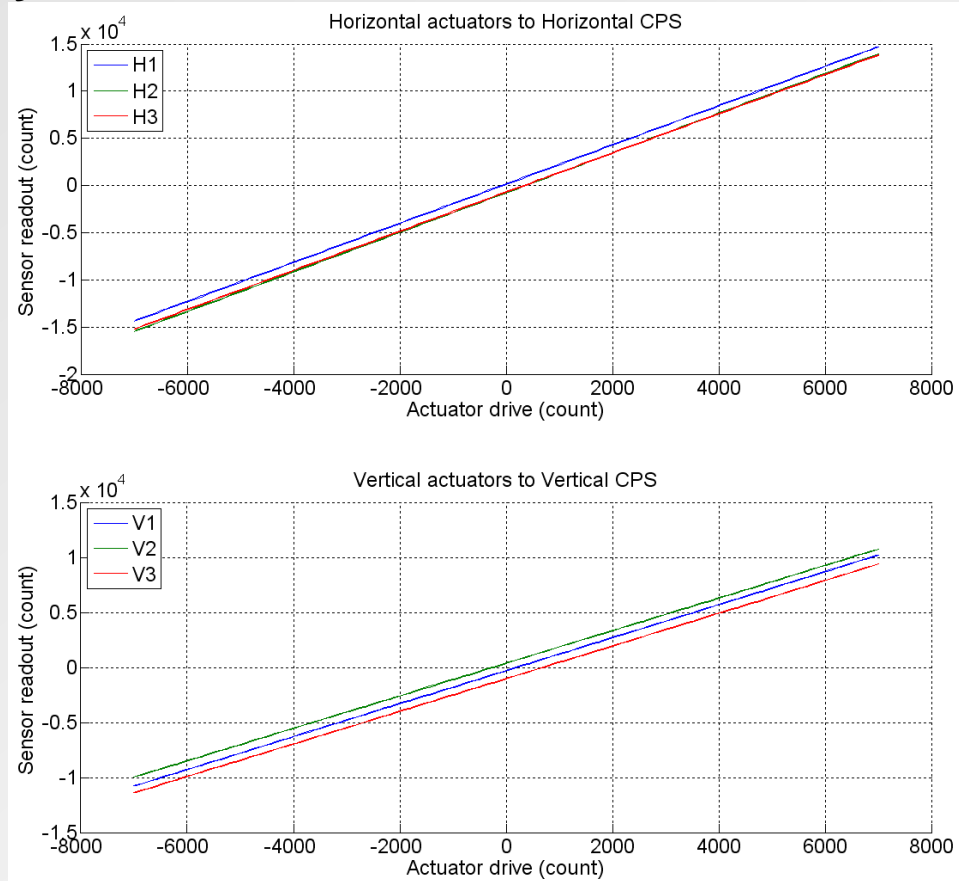
- On Vertical actuators :

- Collocated sensors must be 1400 counts +/- 10%

- On Horizontal actuators :

- Collocated sensors must be 2000 counts +/- 10%
- Non-collocated horizontal sensors must be 1250 counts +/- 10%

• Step 15 – Linearity test

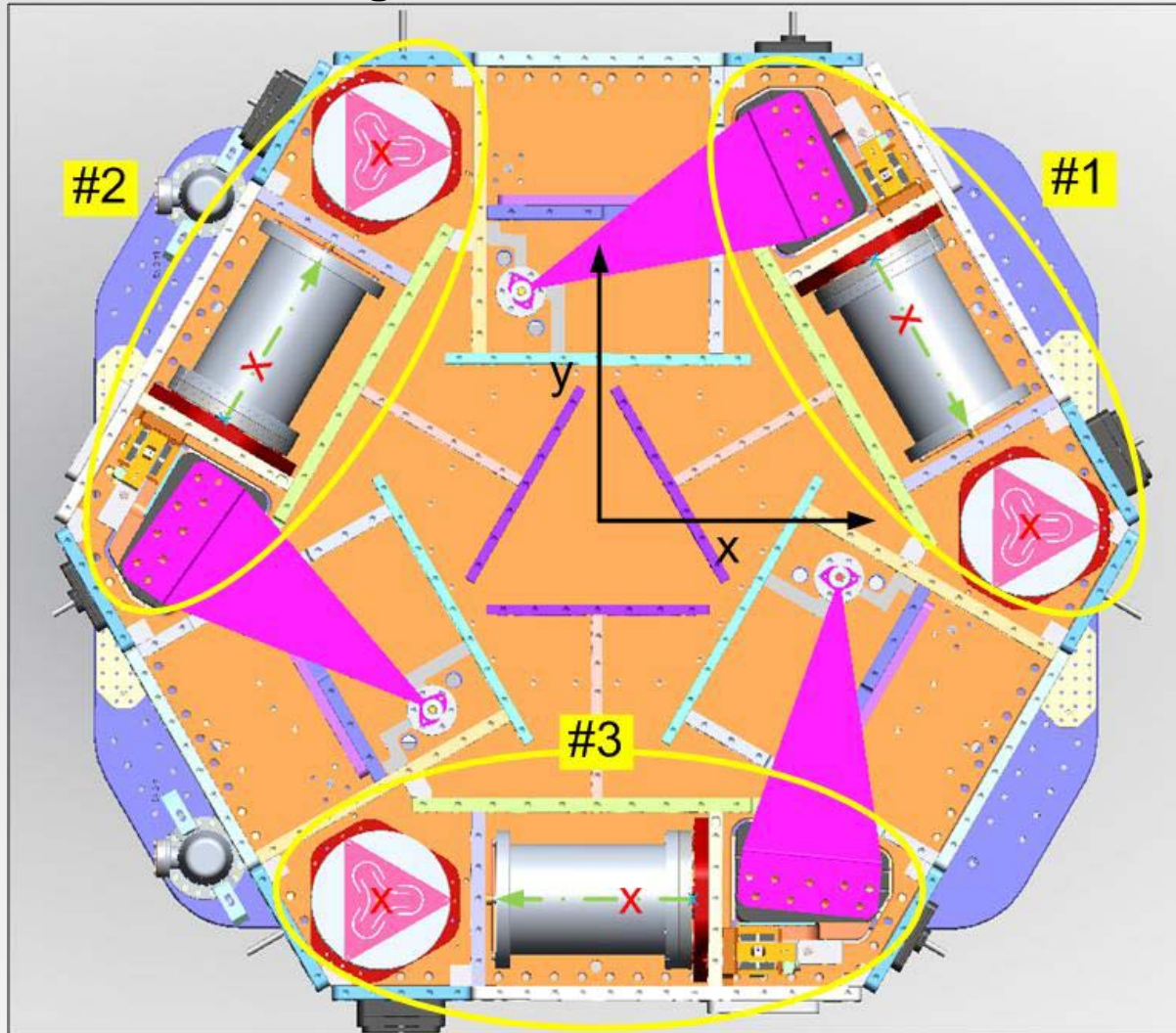


	Slope	Offset	Average slope	Variation from average (%)
H1	2.077	127.6	2.0845	-0.37
H2	2.102	-763		0.83
H3	2.075	-711		-0.46
V1	1.498	-282	1.4872	0.74
V2	1.479	368.3		-0.53
V3	1.484	-1024		-0.20

Acceptance criteria: Average slope $\pm 1.0\%$

Passed

- Step 16 - Static tests in the general coordinate basis



Stage 1 Sensors GS-13 H and V, Stage 0-1 H Position Sensors and Actuators

- **Step 16 - Static tests in the general coordinate basis**

Tests (for a +1000 counts actuation in each Cartesian direction)

- Cartesian to local (**CONT2ACT** matrix)
- Cartesian to Cartesian (**DISP2CEN** matrix)

		X Drive	Y Drive	Z Drive	Rx Drive	Ry Drive	Rz Drive
Sensors readout (count)	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

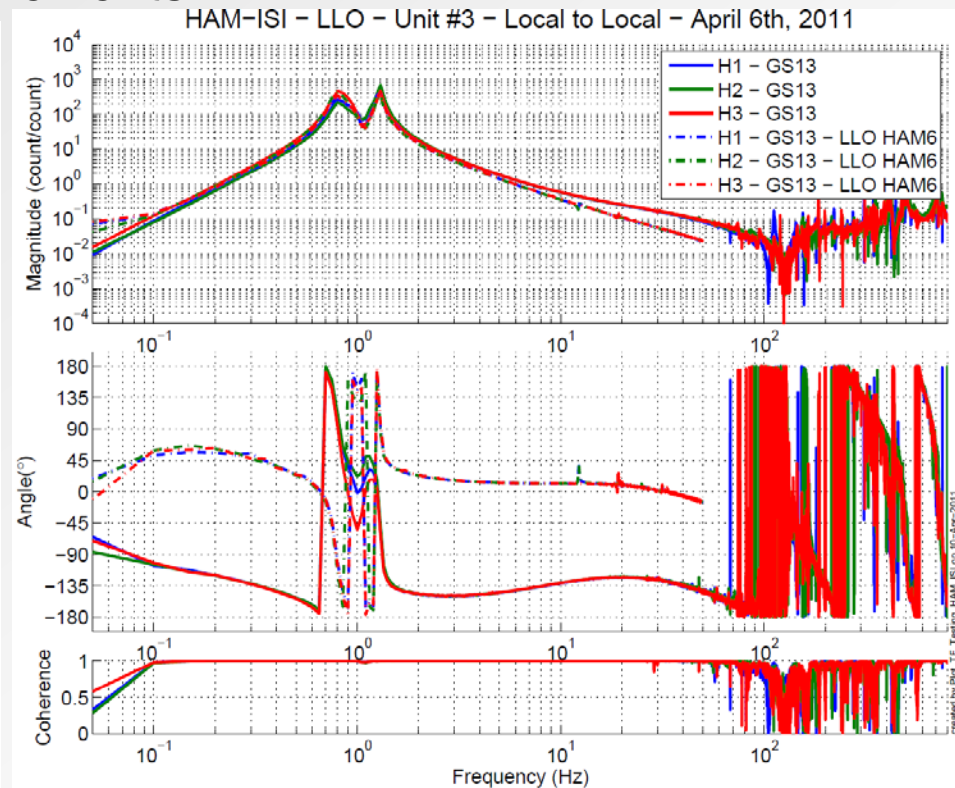
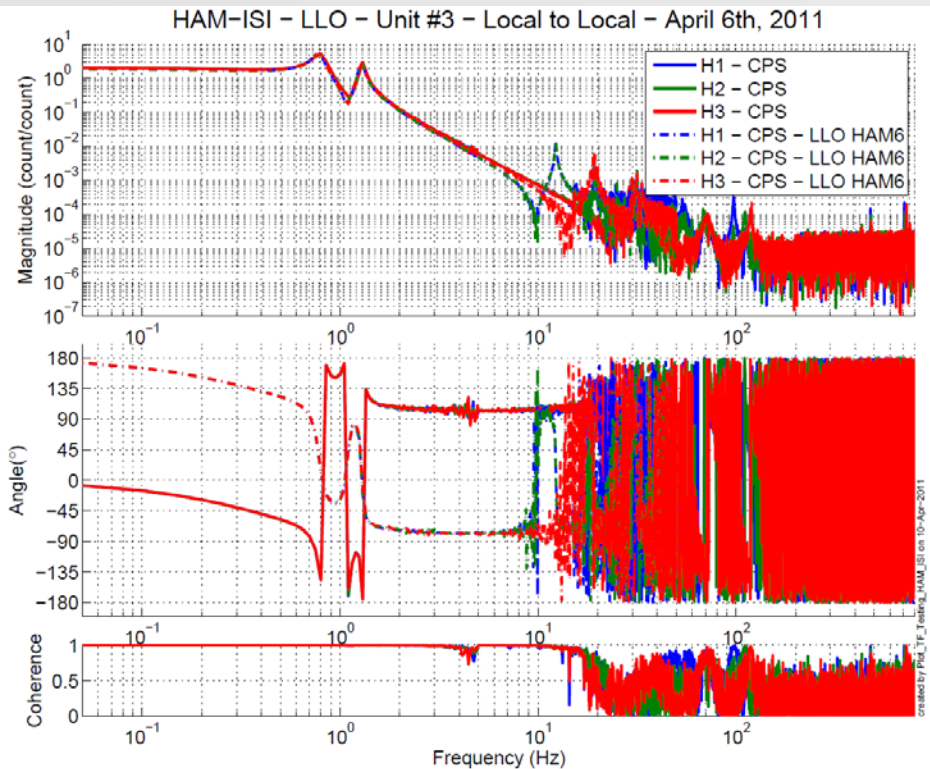
Acceptance criteria : For a positive drive in the Cartesian basis:

- 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

		X Drive	Y Drive	Z Drive	Rx Drive	Ry Drive	Rz Drive
Sensors readout (count)	H1	+	-				-
	H2	+	+				-
	H3	-	0				-
	V1			+	-	-	
	V2			+	+	+	
	V3			+	-	+	
	Direction read out	+	+	+	+	+	+

Passed

- **Step 18 – Frequency response – Comparison with HAM6**
 - **Step 18.1 – Local to local measurements**



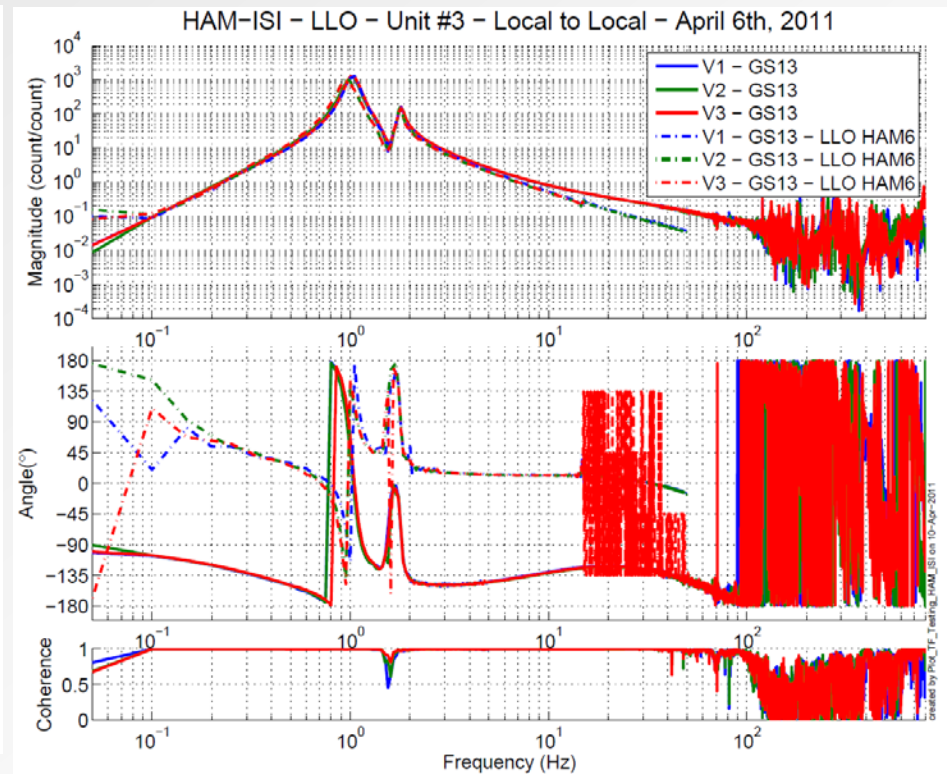
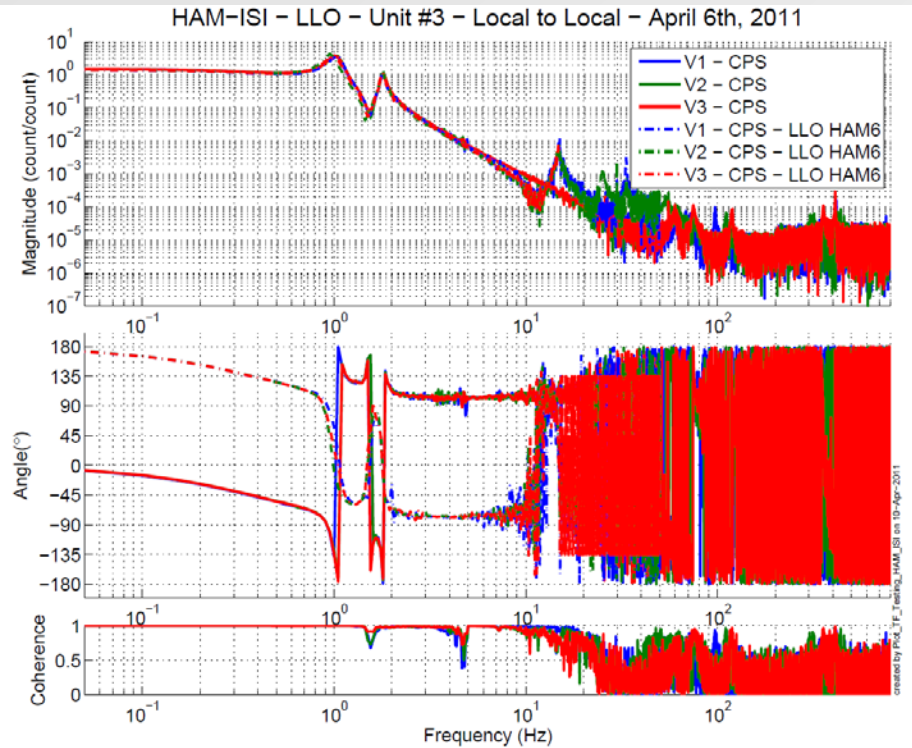
Acceptance criteria:

- No major difference with the reference transfer functions (LLO-HAM6)
- Phase – less than 10° - In Phase – Out of Phase
- Damping (fit by eye with HAM6 transfer functions)
- DC gain
- Eigen frequencies shift less than 5%

Passed

- Step 18 – Frequency response – Comparison with HAM6
 - Step 18.1 – Local to local measurements

Vertical sensors



Acceptance criteria:

- No difference with the reference transfer functions (HAM6 - SVN)
- Phase – less than 10^0 - In Phase – Out of Phase
- Damping (fit by eye with HAM6 transfer functions)
- DC gain
- Eigen frequencies shift less than 5%

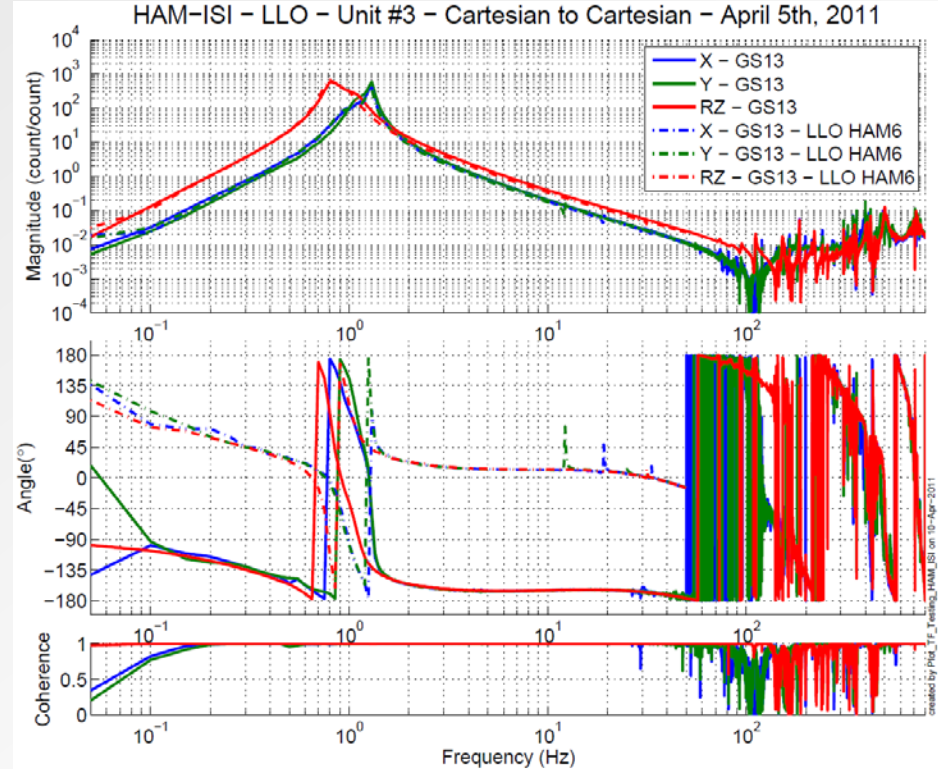
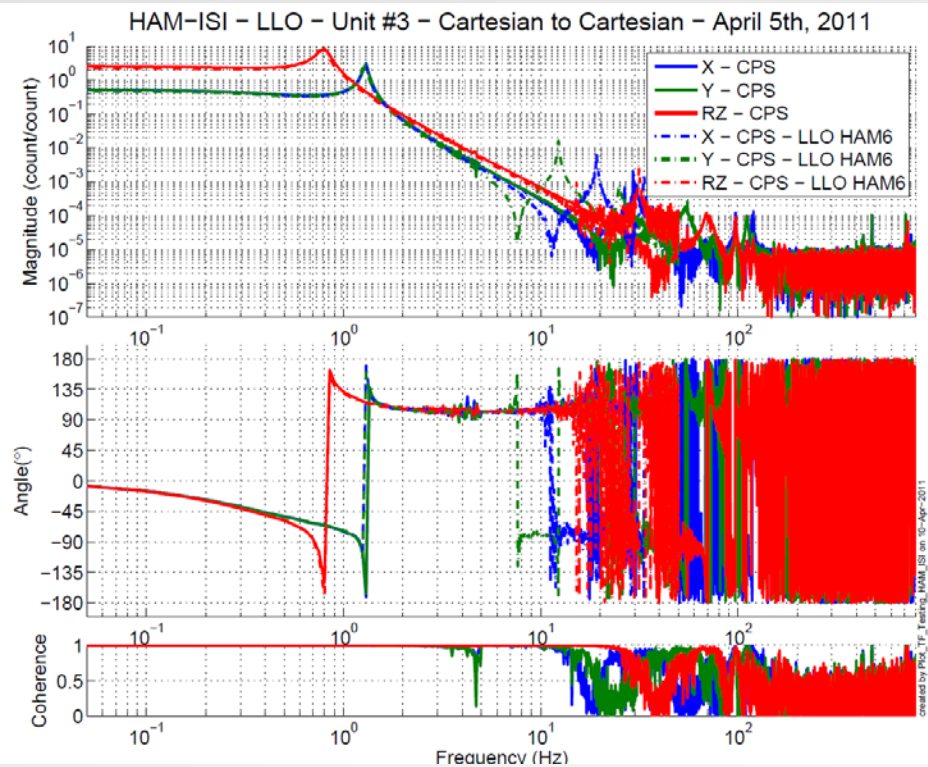
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Passed

20

- Step 18 – Frequency response – Comparison with HAM6
 - Step 18.2 – Cartesian to Cartesian measurements

X, Y, RZ direction



Acceptance criteria:

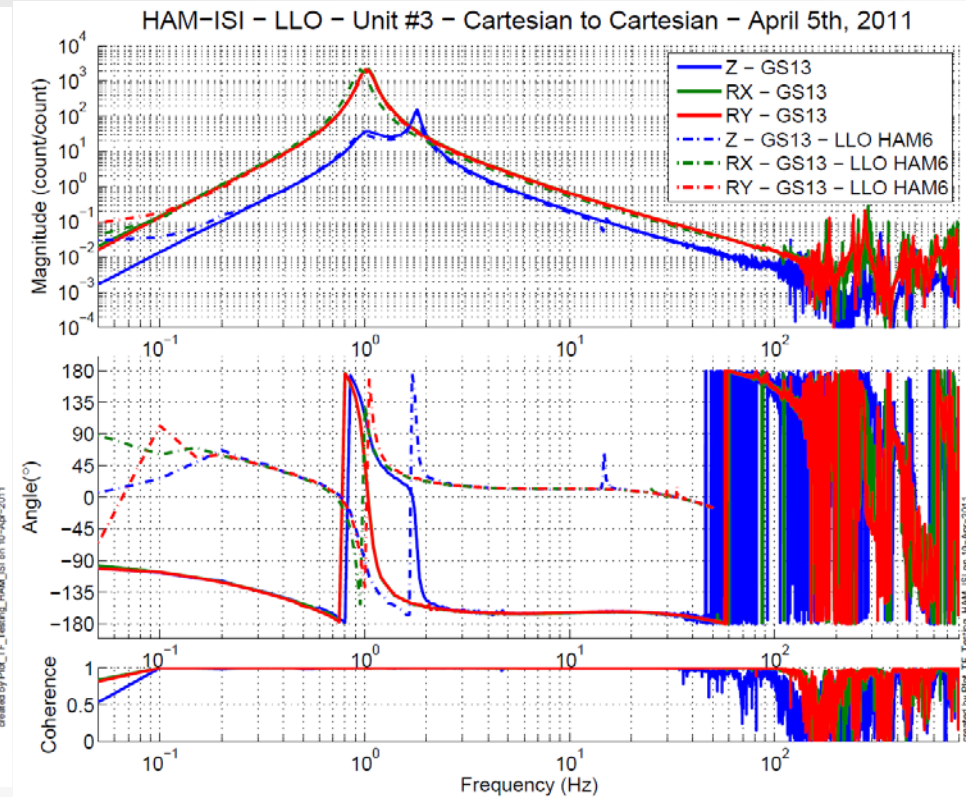
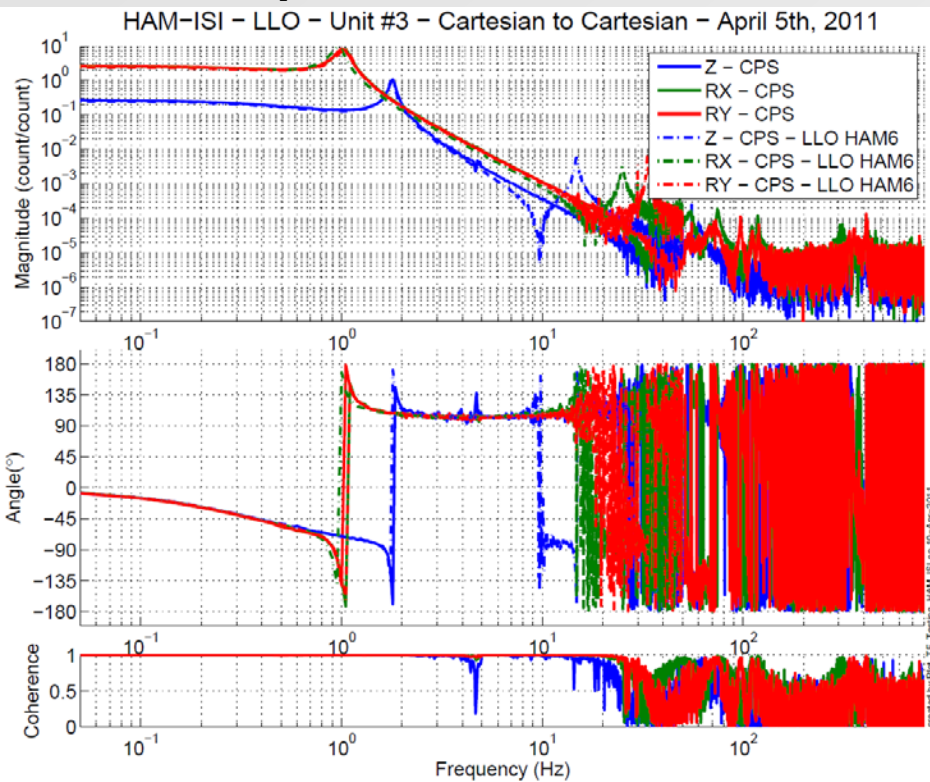
- No difference with the reference transfer functions (HAM6 - SVN)
- Phase – less than 10^0 - In Phase – Out of Phase
- Damping (fit by eye with HAM6 transfer functions)
- DC gain
- Eigen frequencies shift less than 5%

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Passed

21

- Step 18 – Frequency response – Comparison with HAM6
 - Step 18.2 – Cartesian to Cartesian measurements



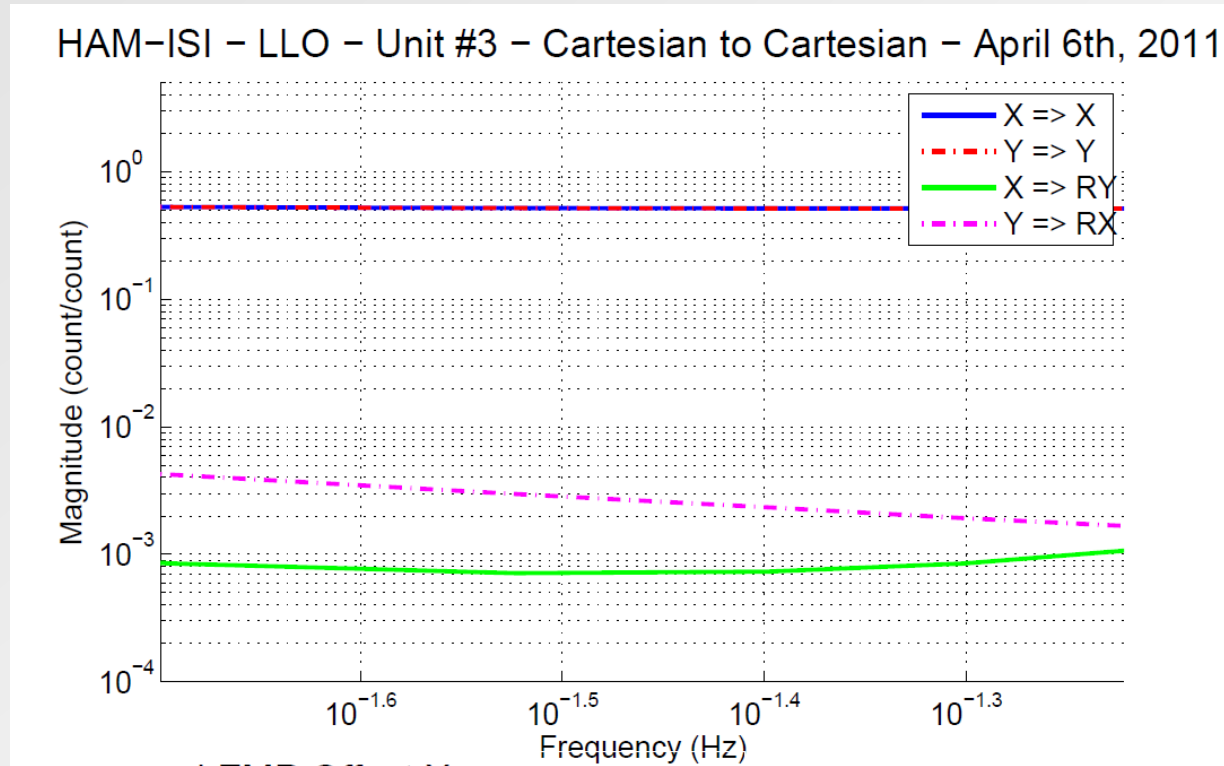
Acceptance criteria:

- No difference with the reference transfer functions (HAM6 - SVN)
- Phase – less than 10^0 - In Phase – Out of Phase
- Damping (fit by eye with HAM6 transfer functions)
- DC gain
- Eigen frequencies shift less than 5%

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Passed

- Step 19 - Lower Zero Moment Plan (TF between 10 mHz and 100 mHz)



X Offset: 0.399 mm

Y Offset: 0.738 mm

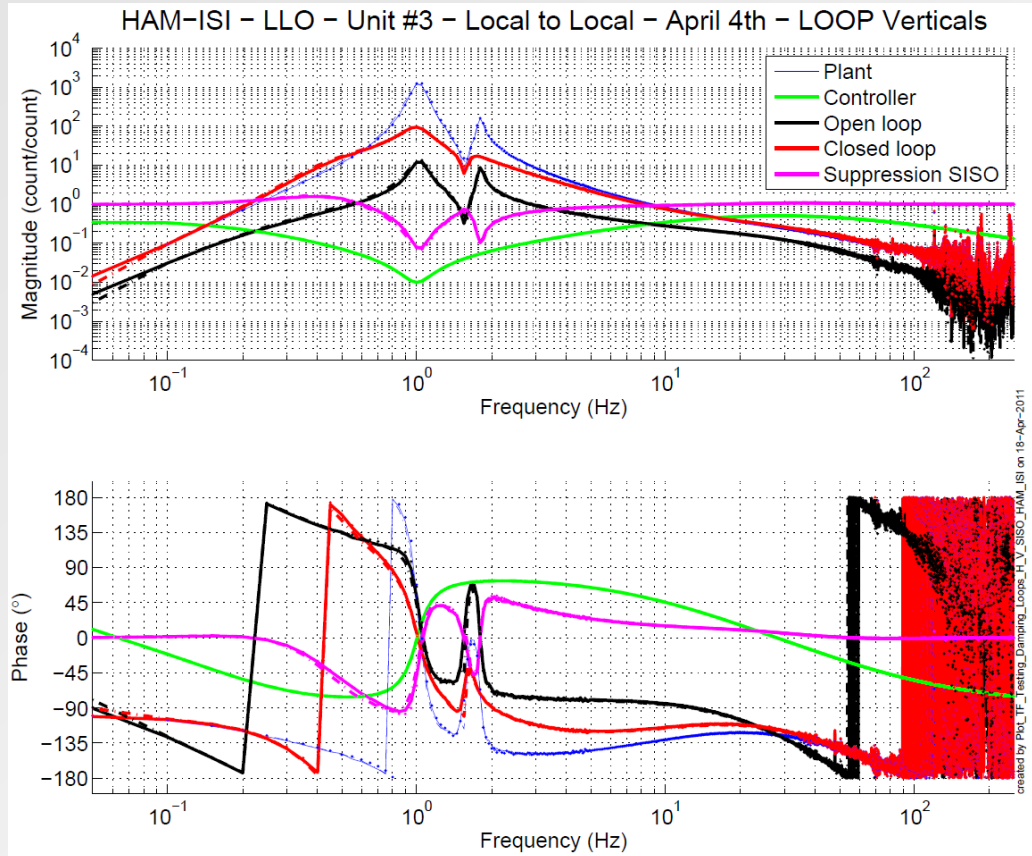
Acceptance criteria

- Both offsets should be inferior to 1 mm

Passed

- Step 20 – Damping loops
 - Step 20.1 – Transfer functions – Simulations

Vertical damping loops – (HAM6 filters + new electronics compensation)



V1 : solid line
V2 : dash line
V3 : dash-dot line

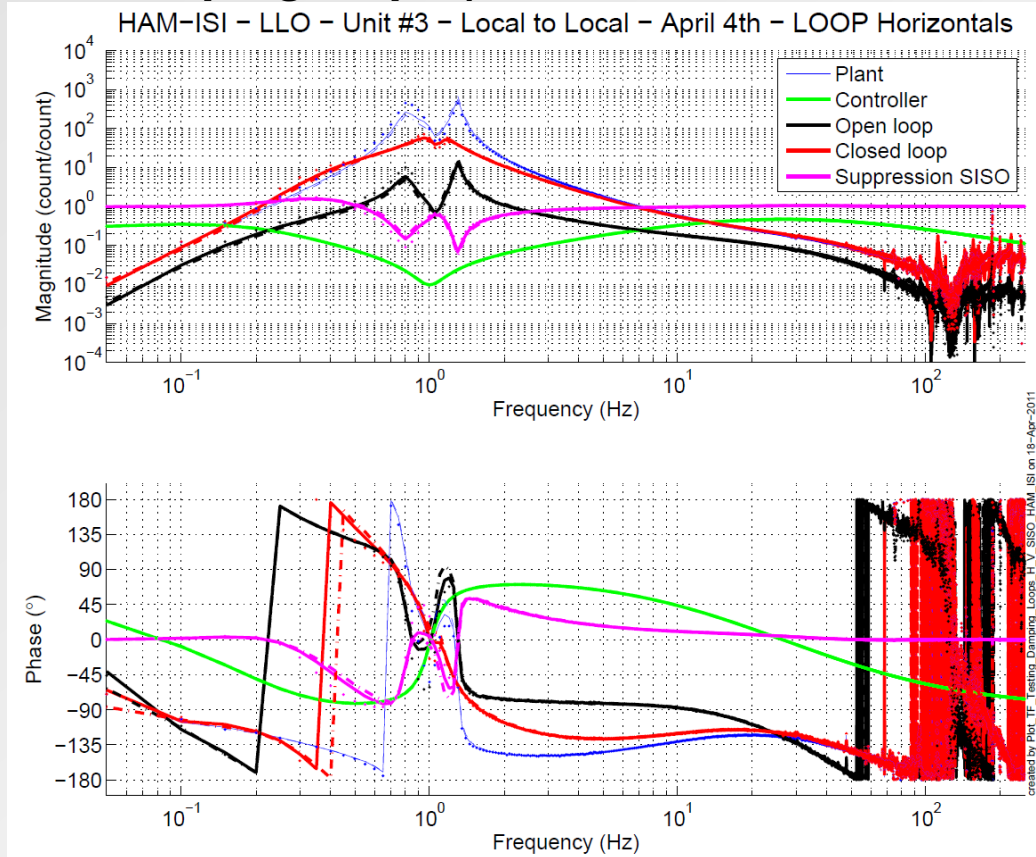
Acceptance criteria:

- Ham 6 damping loop must implemented and stable with
 - Phase margin must be at least 45° G1100507-V2
 - Gain margin must be at least 20dB

Passed

- Step 20 – Damping loops
 - Step 20.1 – Transfer functions – Simulations

Horizontal damping loops (HAM6 filters + new electronics compensation)



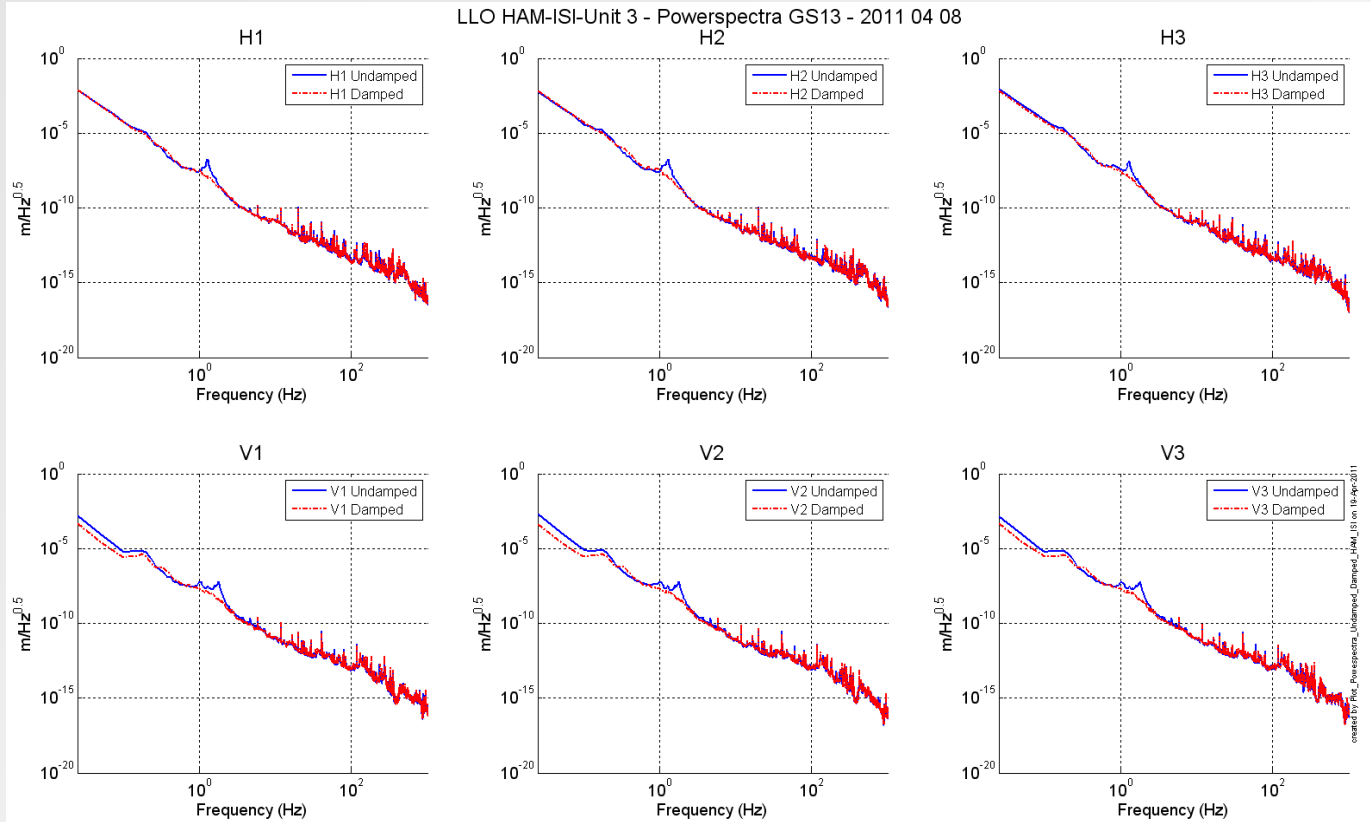
H1 : solid line
H2 : dash line
H3 : dash-dot line

Acceptance criteria:

- Ham 6 damping loop must implemented and stable with
- Phase margin must be at least 45° G1100507-V2
- Gain margin must be at least 20dB

Passed

- Step 20 – Damping loops
 - Step 20.2 – Powerspectrum – Experimental
- All damping filters engaged*



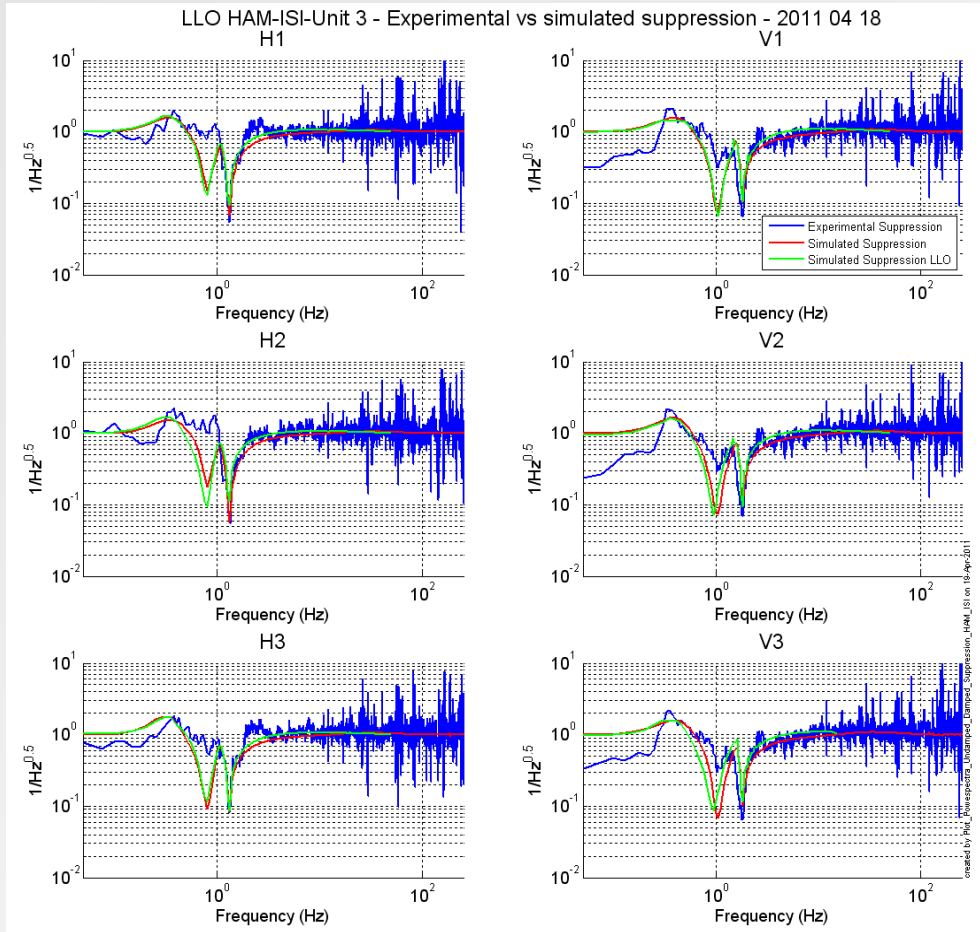
Acceptance criteria:
Ham 6 damping loop must implemented and stable

Passed

- Step 20 – Damping loops

- Step 20.2 – Suppression – Experimental vs simulation vs HAM6 simulation

All damping filters engaged



*Blue : Measurement
Red : Simulation
Green : HAM6*

Acceptance criteria:

Ham 6 damping loop must implemented and stable

- **Missing information**

- *Some assembly measurements were done but not recorded at the time*
 - *Actuator gaps*

- **Tests results**

- *Passed without major difficulties*

- **Failed tests**

- *Actuator gaps (1 measurement slightly over)*
- *Sensor gaps*

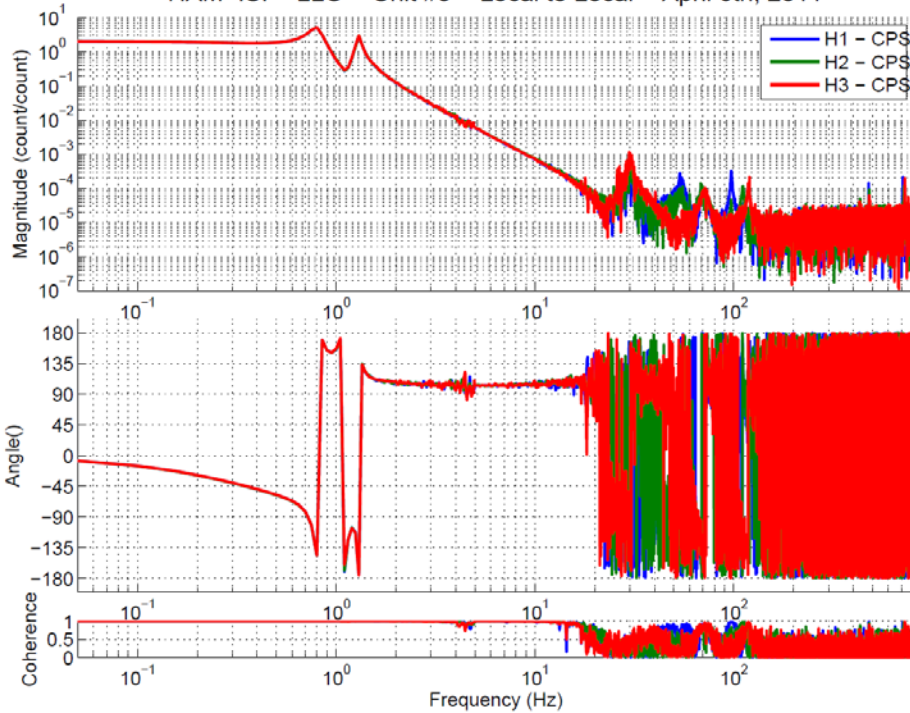
Questions?

Back Up Slides

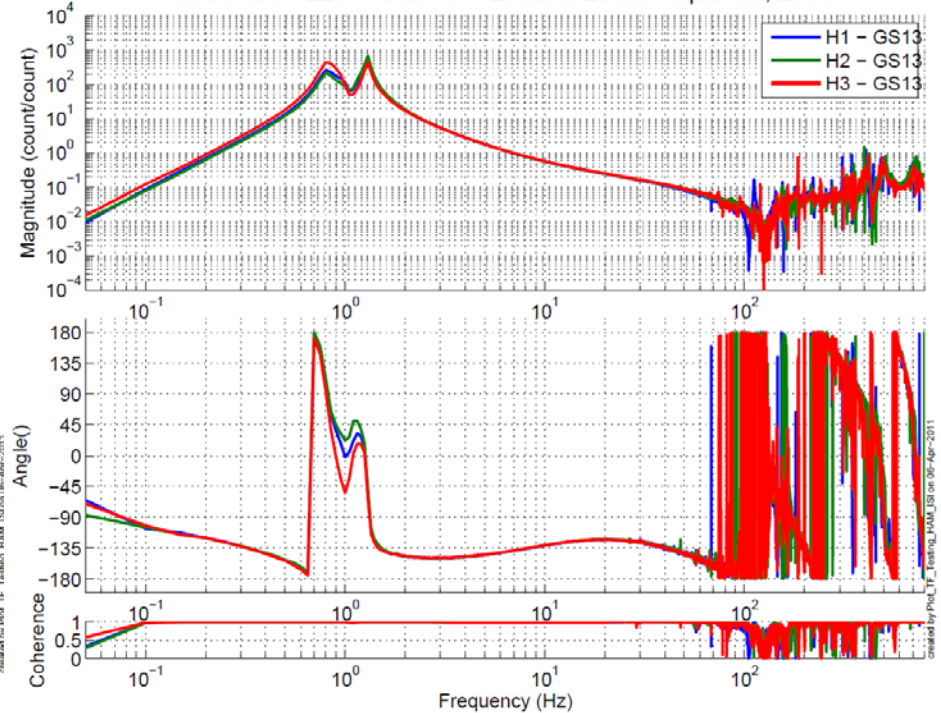
- Step 17 – Frequency response
 - Step 17.1 – Local to local measurements

Horizontal sensors

HAM-ISI - LLO - Unit #3 - Local to Local - April 6th, 2011



HAM-ISI - LLO - Unit #3 - Local to Local - April 6th, 2011



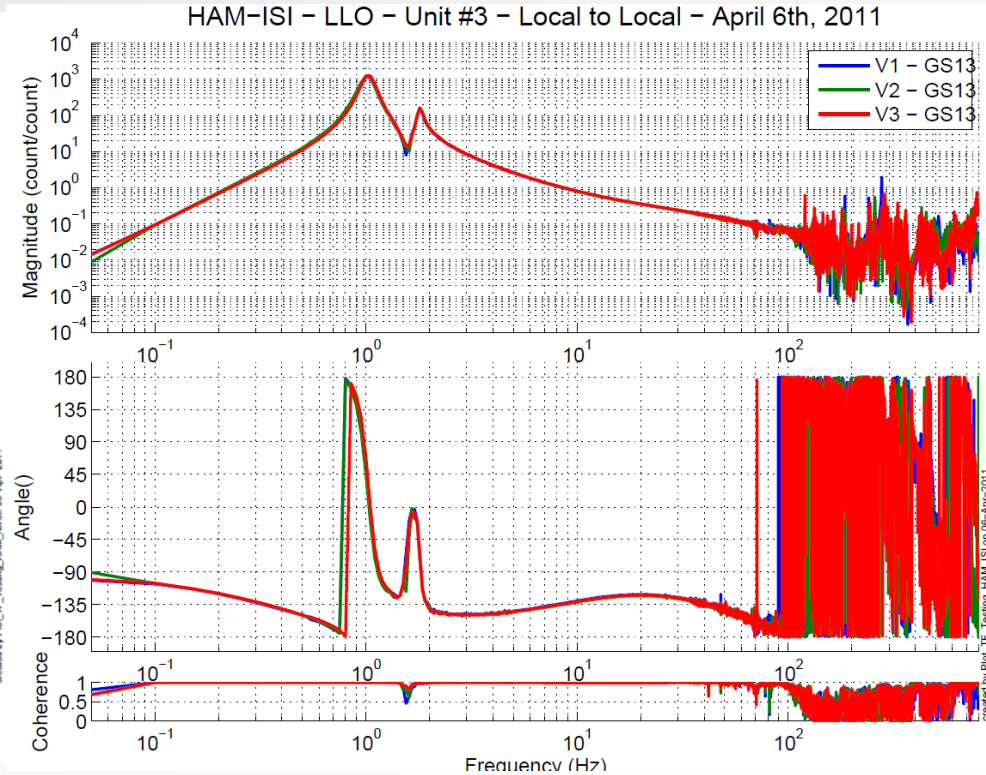
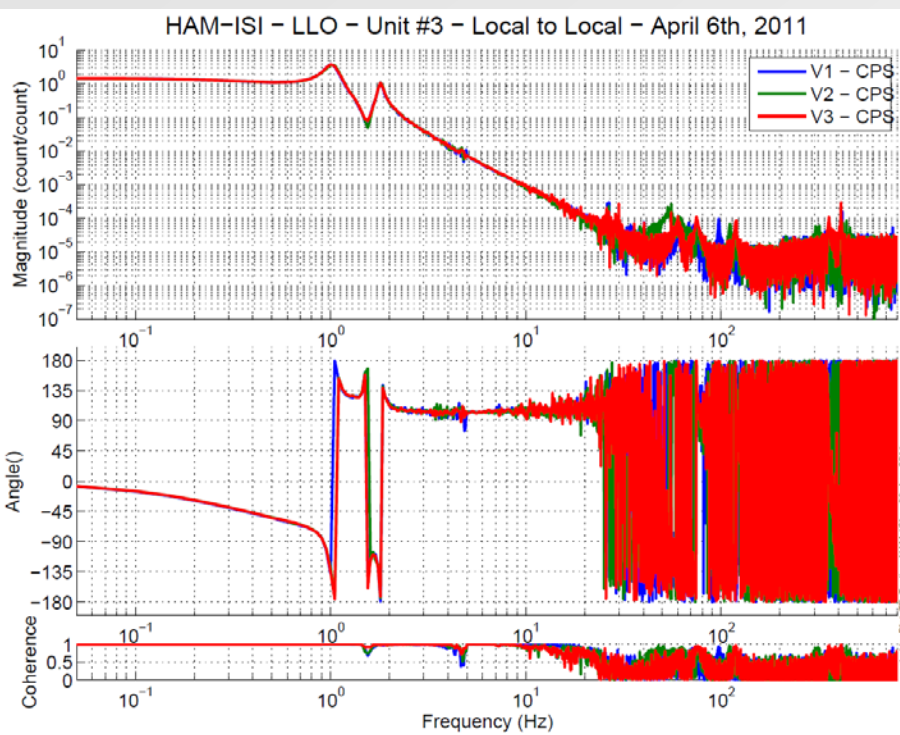
Acceptance criteria:

- On CPS, the phase must be 0° at DC
- On Geophones, the phase must be -90° at DC

Passed

- Step 17 – Frequency response
 - Step 17.1 – Local to local measurements

Vertical sensors



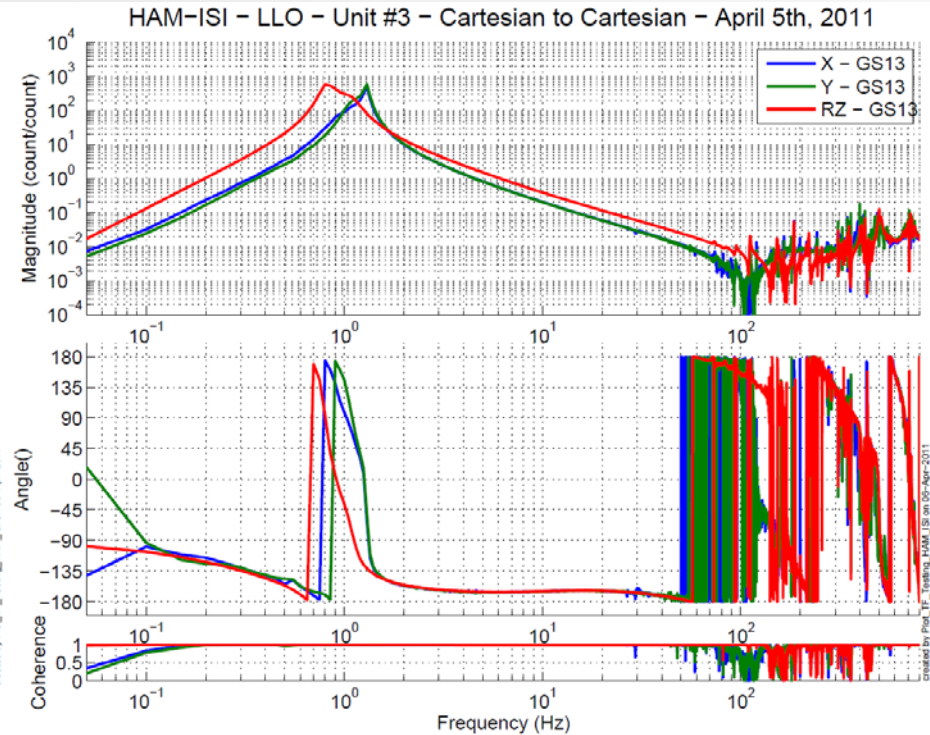
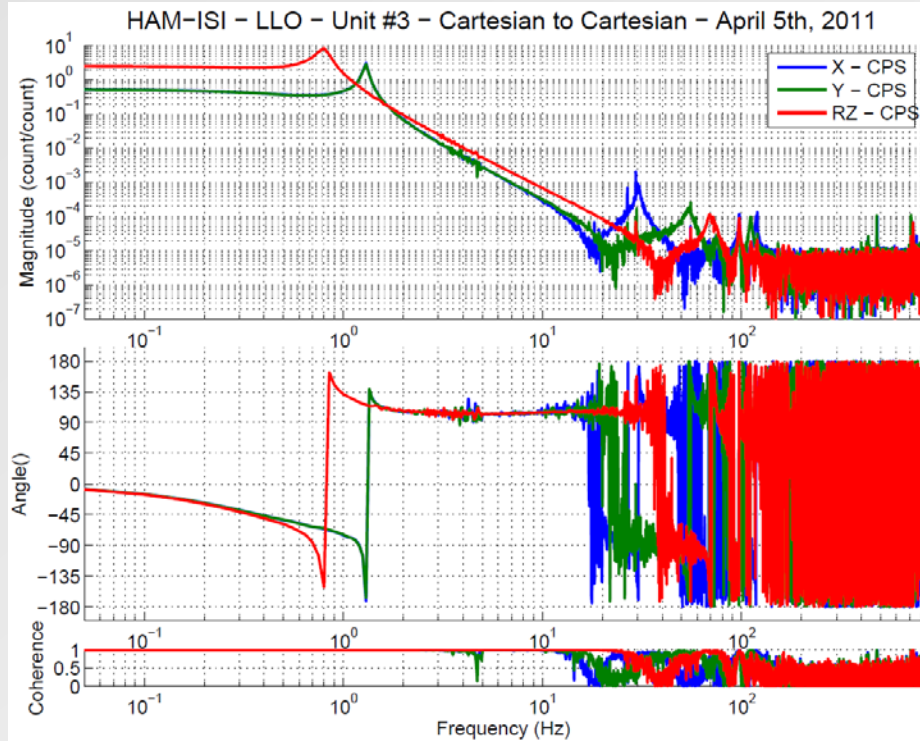
Acceptance criteria:

- On CPS, the phase must be 0° at DC
- On Geophones, the phase must be -90° at DC

Passed

- Step 17 – Frequency response
 - Step 17.2 – Cartesian to Cartesian measurements

X, Y, RZ direction

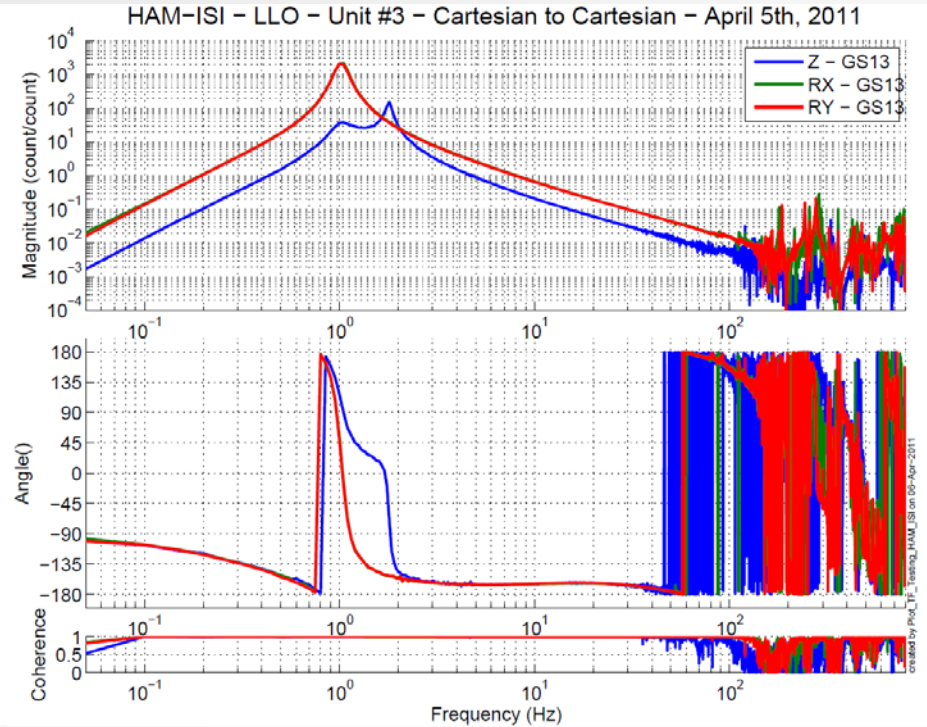
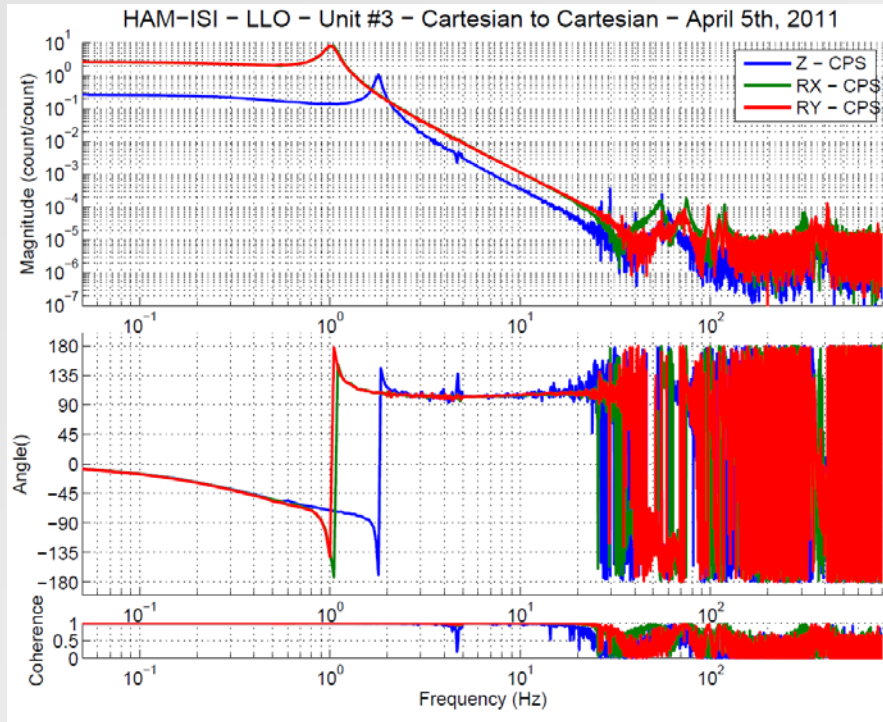


Passed

Acceptance criteria:

- On CPS, the phase must be 0° at DC
- On Geophones, the phase must be -90° at DC

- Step 17 – Frequency response
 - Step 17.2 – Cartesian to Cartesian measurements
Z, RX, RY direction



Acceptance criteria:

- On CPS, the phase must be 0° at DC
- On Geophones, the phase must be -90° at DC

Passed