LIGO Laboratory / LIGO Scientific Collaboration

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aLIGO HEPI Assembly Validation Procedure

E1300824

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Distribution of this document:
Advanced LIGO Project

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Contents

The Gap Checks are all specific to the HAM, if doing all this is reasonable, why not specify doing it for the BSC?

Introduction

This document summarizes the steps to be done to validate HEPI assemblies. Corresponding reports must be posted in :

LIGO-E1300454: aLIGO HEPI Testing Reports

Sub-Components Testing

- Kaman Inductive Position Sensors: calibration, linearity, factory data, noise measurements (E0900426 – HEPI Kaman Sensor Receiving Analysis - Results posted in the SVN)
- HEPI actuator linearity test (E1100338 – aLIGO HEPI Actuators Test Results)
- L4C test (Q0900007)

Assembly Validation

After installation along procedure Exxxxxx, and aligment along procedure Exxxxxx, and once HEPI is in final configuration (alignment completed).

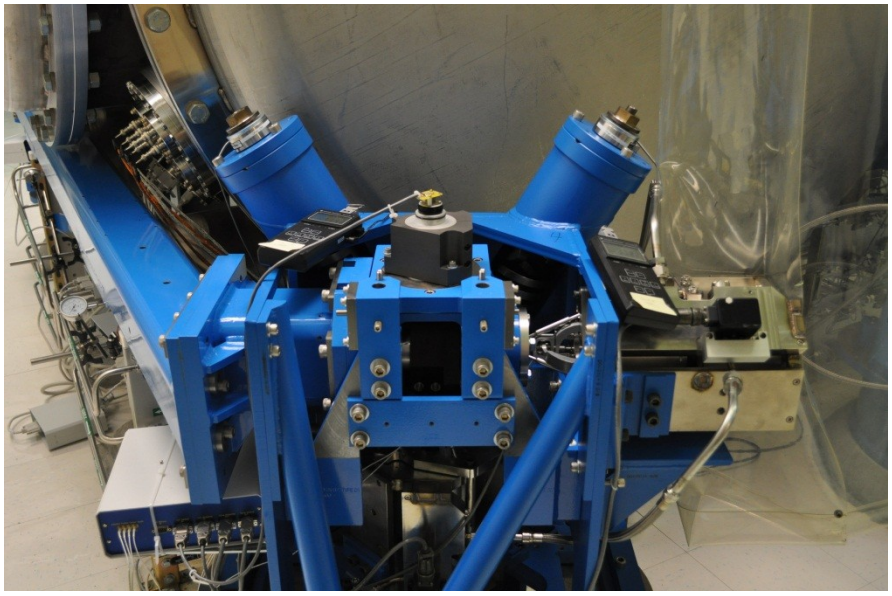
1 Load Cells assembly

- Spring attachment

For the BSC HEPI springs, check the assembly per D030324. See LLO aLOG 7162 for more details.

- Load cell values

BSC HEPI load cell capacity → 3000 lbs
HAM HEPI load cell capacity → 2000 lbs



HAM-HEPI example at LASTI

	Left Spring (lbs)	Right Spring (lbs)
Pier 1	1347	949
Pier 2	1458	1631
Pier 3	1267	1157
Pier 4	1142	1722

Acceptance criteria:

- The values must not exceed 80% of the load cell capacity (2400lbs for BSC and 1600lbs for HAM).

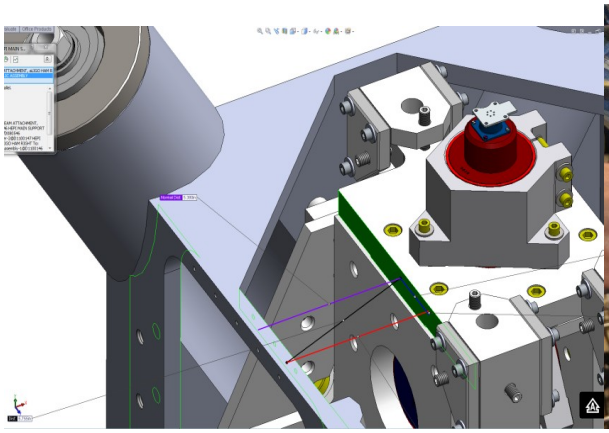
Test result: **Passed: ___** **Failed: _X_**

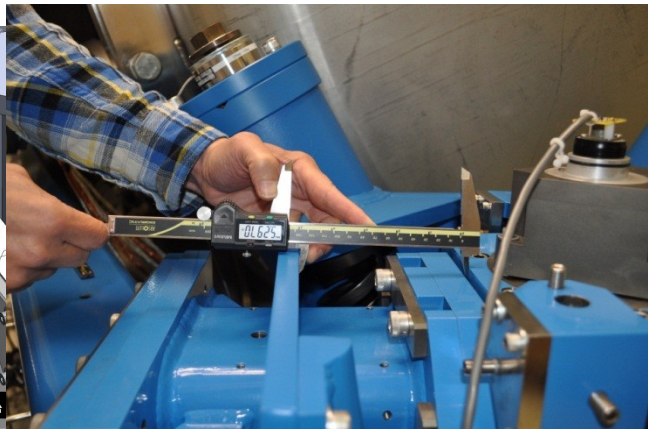
2 Bellows

The bellows are hard to access and tests are hard to proceed. After several discussions and brainstorming sessions, it has been decided not to measure the gaps on HEPI-HAM and HEPI-BSC.

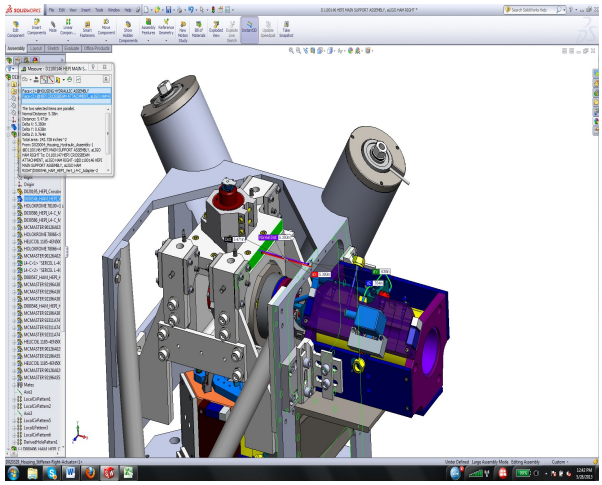
3 Boot Location

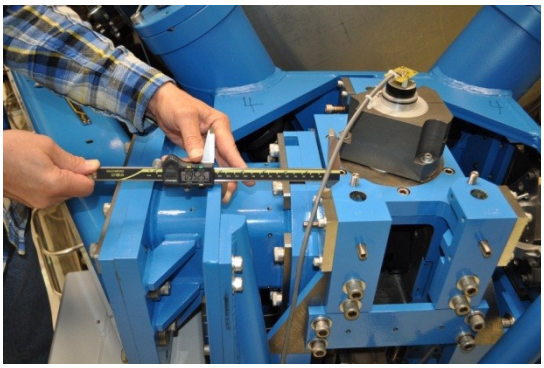
Tangential Left: 5.380”



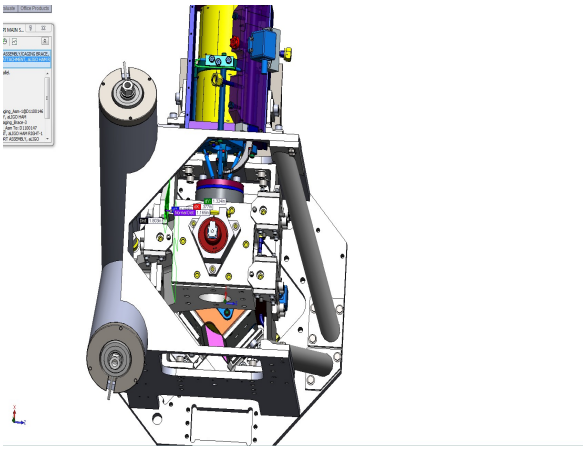


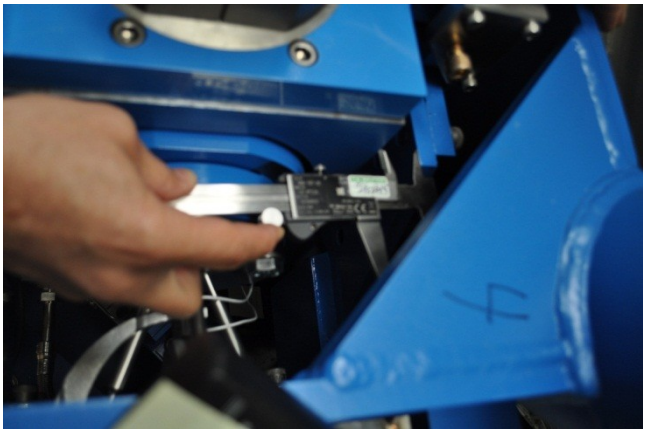
Tangential Right: 5.380”



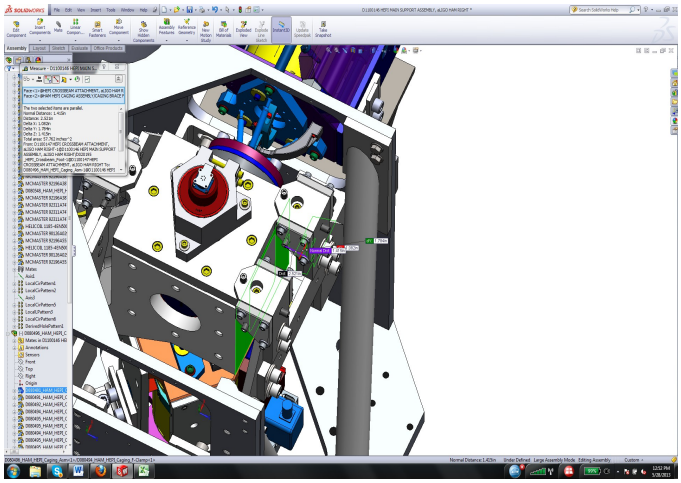


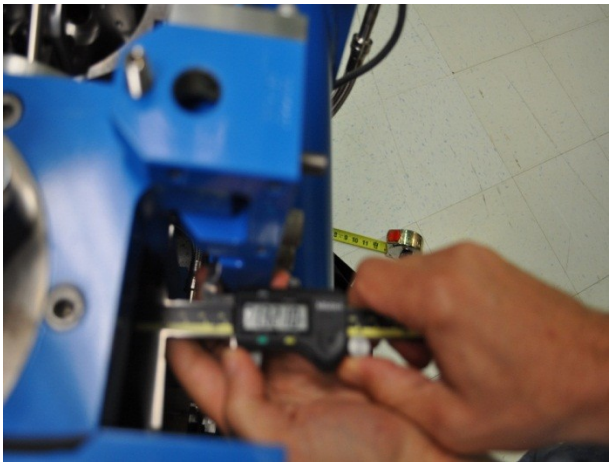
Radial Back: 1.17”



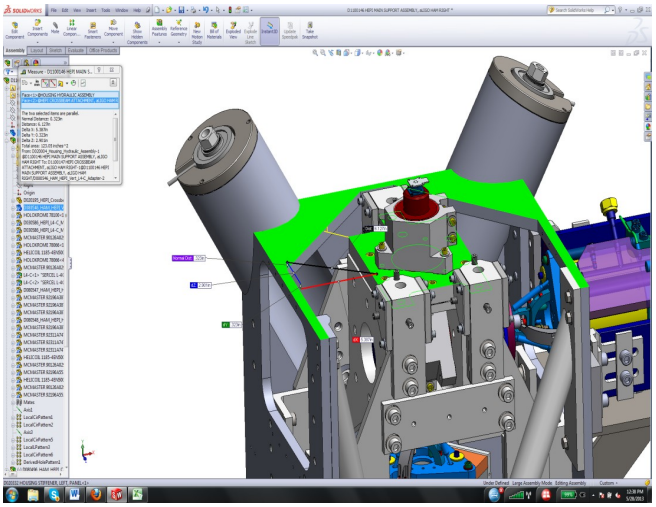


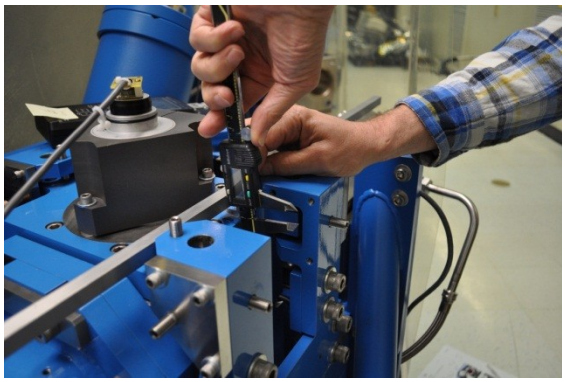
Radial Front: 1.42”





Vertical: 0.32”





	Pier 1	Pier 2	Pier 3	Pier 4	Nominal
Point 1 a (Tangential)	5.19	5.22	5.26	5.31	5.38
Point 1 b (Tangential)	5.20	5.23	5.28	5.26	5.38
Point 2 a (Tangential)	5.56	5.53	5.53	5.43	5.38
Point 2 b (Tangential)	5.54	5.53	5.49	5.49	5.38
Point 3 (Radial Back)	1.14	1.14	1.14	1.14	1.17
Point 4 (Radial Front)	1.35	1.41	1.31	1.34	1.42
Point 5 (Vertical)	0.44	0.44	0.44	0.47	0.32

	Pier 1	Pier 2	Pier 3	Pier 4	Requirements
Point 1 a (Tangential)	-0.19	-0.16	-0.12	-0.07	+/- 0.20
Point 1 b (Tangential)	-0.18	-0.15	-0.10	-0.12	+/- 0.20
Point 2 a (Tangential)	0.18	0.15	0.15	0.05	+/- 0.20
Point 2 b (Tangential)	0.16	0.15	0.11	0.11	+/- 0.20
Point 3 (Radial Back)	-0.03	-0.03	-0.03	-0.03	+/- 0.10
Point 4 (Radial Front)	-0.06	-0.01	-0.11	-0.08	+/- 0.15
Point 5 (Vertical)	0.12	0.12	0.12	0.15	+/- 0.20

Acceptance criteria:

-

Test result: **Passed: __X__** **Failed: ____**

Argument for by bypassing this test.

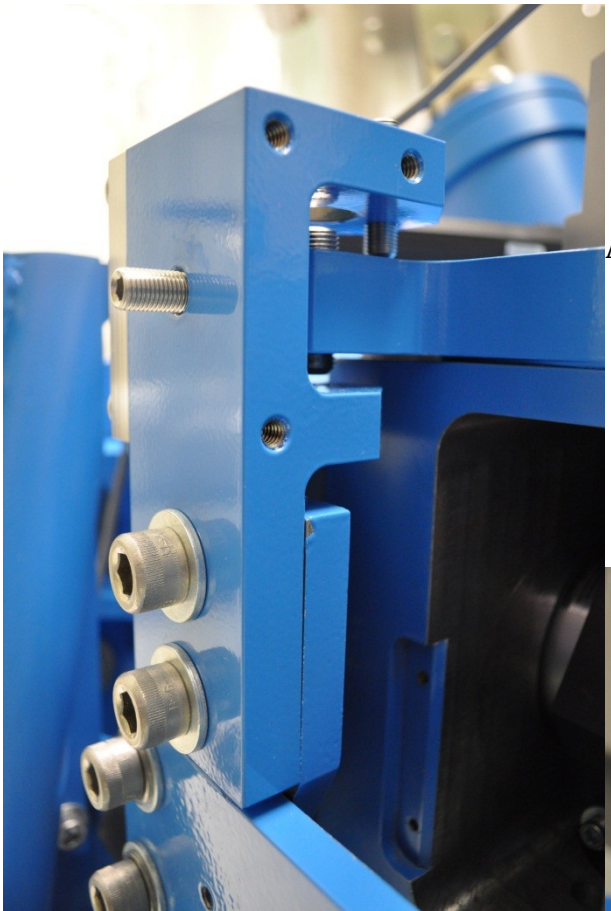
In a world of perfect fabrication & assembly and never moving the Crossbeam location, this data might be useful. It might have made sense to make these measurements during initial assembly of each housing assembly but we used jigs to position the Foot in the Housing and so these would have been perfect. And, we aren't going back to that state—back to individual housings.

However, after installation, the platforms are moved, often more than a couple mm, in response to the initial alignment. Additionally, when payloaded the HAM HEPI Crossbeam twists tilting the Foot in the Housing. The measurements made do not really check any clearances. If the fabrication of the Housing and the Foot were perfect and the IAS shift and payloading shifts did not occur, it would give an indication of potential clearance problems elsewhere.

4 Check Stops Gaps

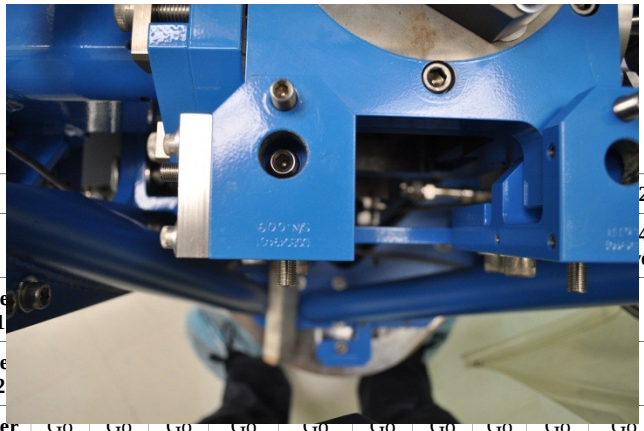
The stops must not touch the boot. There is 15 stops per boot, 5 per F bracket. There is actually only 13 stops and one of those is not accessible.

Argument for bypassing this test: If these stops were used as an Earthquake stop and set to an exact depth, and, if they were never locked again after setting, maybe then it would be worth doing this. But the locks have been opened and closed many times during the commissioning of the platform so only the last time would it really have any validity. When unlocking the platforms, these gaps (where visible, are check visually and are opened way more than 1/16”.



Acceptance criteria:

- A 0.062” shim must fit into the gaps



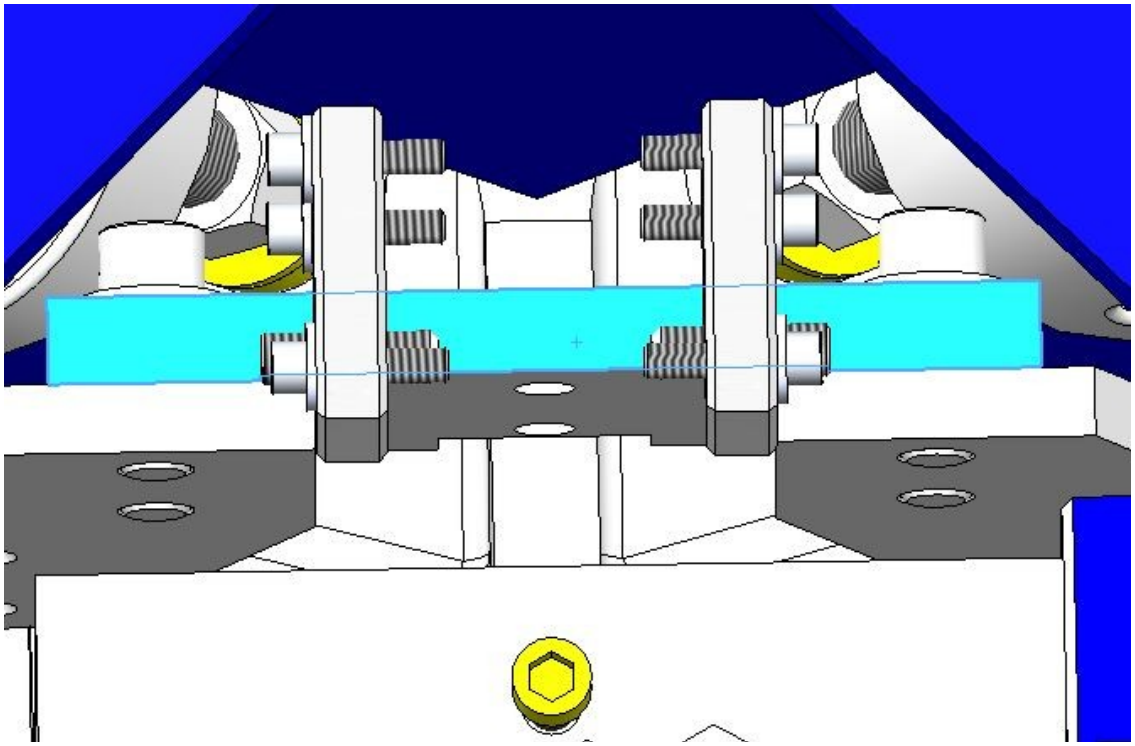
											2			Bracket 3					
											4 e	Gap4 under	Gap 5	Gap 1	Gap 2	Gap 3	Gap4 above	Gap4 under	Gap 5
Pie 1												Go	Go	Go	Go	Go	Go	Go	Go
Pie 2												Go	Go	Go	Go	Go	Go	Go	Go
Pier 3	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go		Go	Go	Go	Go	Go	Go	Go	Go
Pier 4	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go		Go	Go	Go	Go	Go	Go	Go	Go

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

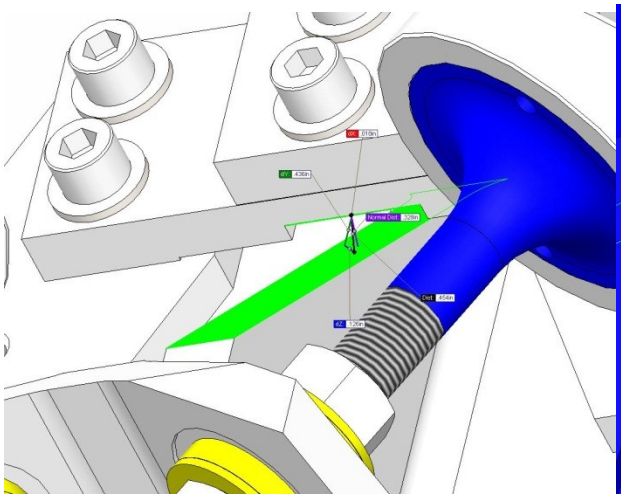
5 Gaps check

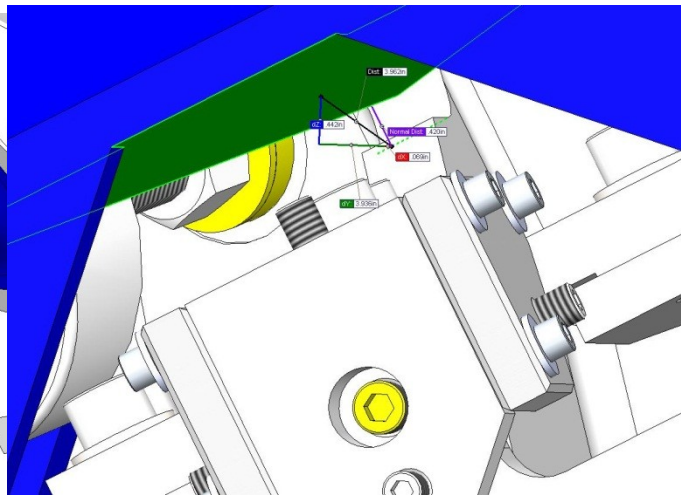
Four particular gaps need to be check.

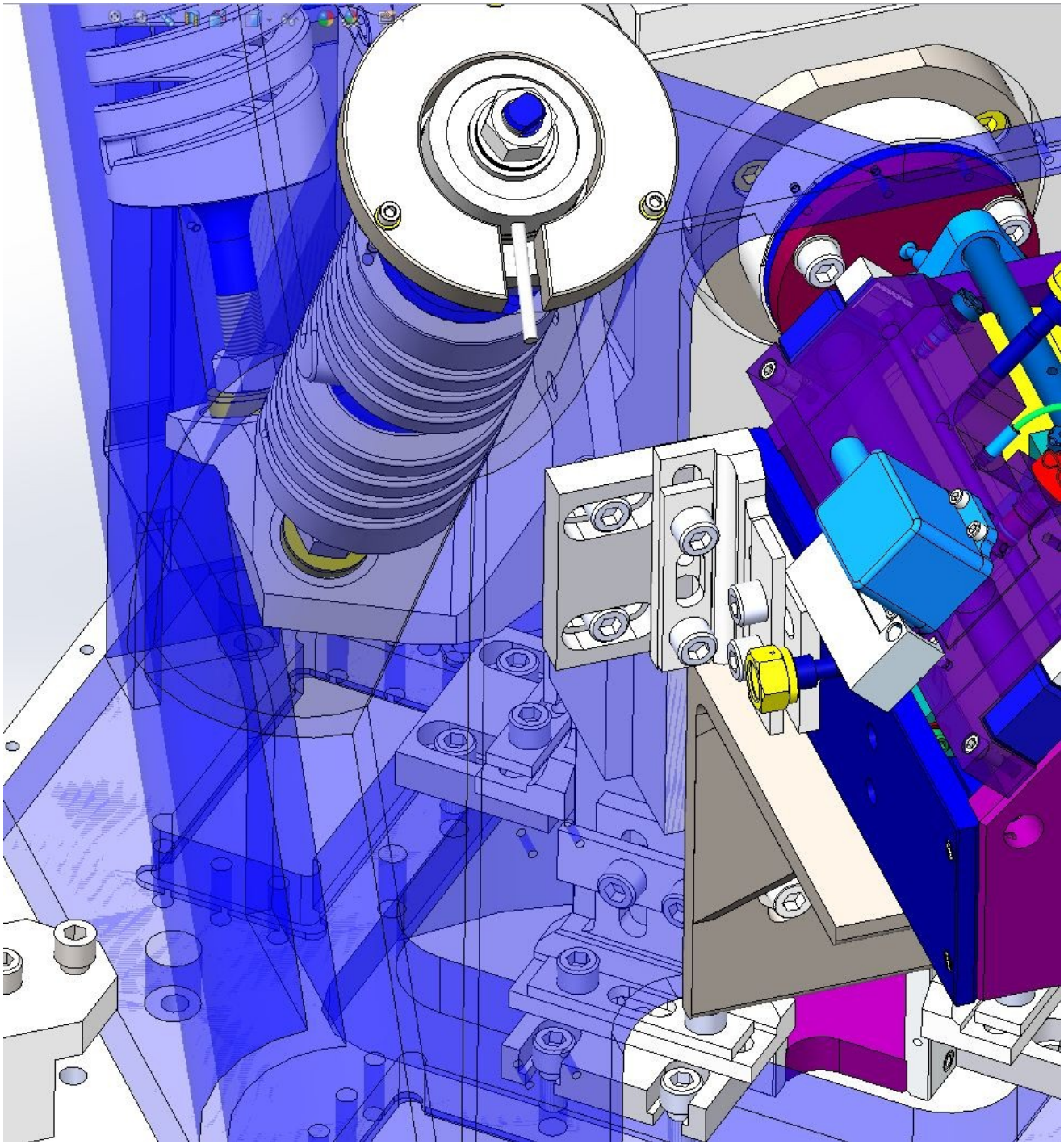
Argument against checking these Gaps: All subsequent actuation test confirm that these close points are not touching. These are checked visually and by hand however. Maybe now however, that we have a final IFO operation point, these gaps should be checked again.



The F bracket has been removed for a better visibility







Acceptance criteria:

- a 0.08” shim must fit in these two gaps

Issues/difficulties/comments regarding this test: Gap#1 is tricky to reach. At LASTI, the solution found was to tape the shim to an extension (rod, rigid ruler, etc.).
Gap#2 should be reachable by hand.
Gap#3 and 4 are tricky, but should also be doable (no picture)

Gap#1

Gap#2

	Gap#1	Gap#2	Gap#3	Gap#4
Pier 1	Go	Go	Go	Go
Pier 2	Go	Go	Go	Go
Pier 3	Go	Go	Go	Go
Pier 4	Go	Go	Go	Go

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

6 IPS Centering

Scripts files for processing and plotting in SVN at:
/SeiSVN/seismic/HEPI/Common/Testing_Functions_HEPI/Offset_STD_IPS_HEPI.m

All the loops must be turned off during this test.

	H1	H2	H3	H4	V1	V2	V3	V4
Mean (counts)								
Accep-tance	+/- 15000	+/- 15000	+/- 15000	+/- 15000	+/- 15000	+/- 15000	+/- 15000	+/- 15000

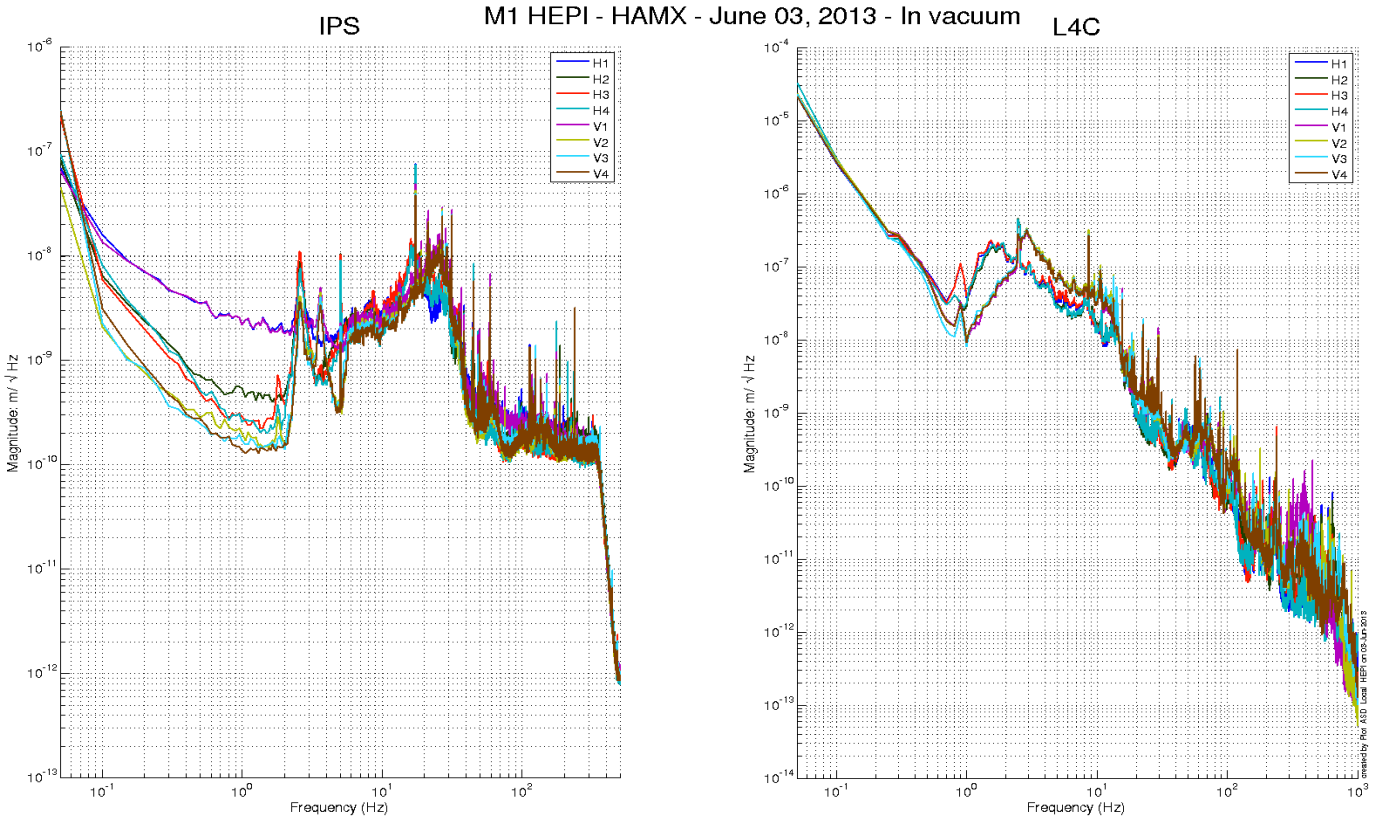
Test result: **Passed: _X_** **Failed: ___**
Comments—For this measurement to have meaning different from Section 15, it must be specified when the data is to be taken. The IPS values collected in section 15, would be those just after initial alignment and the Actuators are first attached. Before that point, the IPS readings should be more like zero, not at half their range. For much of the installation, electronics were not available and platform motion was monitored with Dial Indicators.

7 Sensor ASD

Scripts files for processing and plotting in SVN at:
/SeiSVN/seismic/HEPI/Common/Testing_Functions_HEPI/ASD_Measurements_Local_HEPI.m

Data in SVN at:
SeiSVN/seismic/HEPI/M1/HAMX/Data/Spectra/Undamped/
M1_HPI_HAMX_ASD_m_IPS_L4C_2013_06_03_120859.mat

Figures in SVN at:
/SeiSVN/seismic/HEPI/M1/HAMX/Data/Figures/Spectra/Undamped



Issues/difficulties/comments regarding this test:
Measurements were performed with all PreFilters ON.

Acceptance criteria: **A reference good spectra might be a good thing to have here.**

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

8 SUS-watchdogs interaction test

This test will be obsolete very soon, as the payload-HEPI WD connection is planned for removal.

9 Static Test local drive

Scripts files for processing in SVN at:
/SeiSVN/seismic/HEPI/Common/Testing_Functions_HEPI/Static_Test_Local_Basis_HEPI.m

. Drive of 100 counts (in progress)

	H1	H2	H3	H4	V1	V2	V3	V4
H1	8350.9418	-5056.1049	-327.0384	-1879.51872	-178.9088	209.3388	192.18836	-370.0864

H2	-4104.049	8306.5349	-1822.531974	-448.11792	134.8916	-100.465	-301.80668	139.7868
H3	-233.5984	-2065.5751	8170.4572	-4615.56692	178.7694	-183.7838	-239.1095	118.1154
H4	-1807.7793	-701.3897	-4558.2268	9000.50088	-488.2914	367.591	-1.00976	-441.0128
V1	-87.0864	1.56718	302.0506	-174.51156	7490.8344	918.82254	-1656.35338	784.3534
V2	182.2748	-404.56522	-128.0876	486.57564	833.8752	7402.042	675.00182	-1629.1482
V3	309.8688	-477.33554	-80.087	272.82164	-1436.731	1099.12212	7236.42762	695.124
V4	-177.839	74.78868	291.7698	-126.46464	955.694	-1414.8926	824.44686	7487.4108

Table - Main couplings and cross couplings

. Drive of 1000 counts (in progress)

	H1	H2	H3	H4	V1	V2	V3	V4
H1	8350.9418	-5056.1049	-327.0384	-1879.51872	-178.9088	209.3388	192.18836	-370.0864
H2	-4104.049	8306.5349	-1822.531974	-448.11792	134.8916	-100.465	-301.80668	139.7868
H3	-233.5984	-2065.5751	8170.4572	-4615.56692	178.7694	-183.7838	-239.1095	118.1154
H4	-1807.7793	-701.3897	-4558.2268	9000.50088	-488.2914	367.591	-1.00976	-441.0128
V1	-87.0864	1.56718	302.0506	-174.51156	7490.8344	918.82254	-1656.35338	784.3534
V2	182.2748	-404.56522	-128.0876	486.57564	833.8752	7402.042	675.00182	-1629.1482
V3	309.8688	-477.33554	-80.087	272.82164	-1436.731	1099.12212	7236.42762	695.124
V4	-177.839	74.78868	291.7698	-126.46464	955.694	-1414.8926	824.44686	7487.4108

Table - Main couplings and cross couplings

. Drive of 5000 counts (Nominal value handled by testing script)

	H1	H2	H3	H4	V1	V2	V3	V4
H1	8350.9418	-5056.1049	-327.0384	-1879.51872	-178.9088	209.3388	192.18836	-370.0864
H2	-4104.049	8306.5349	-1822.531974	-448.11792	134.8916	-100.465	-301.80668	139.7868
H3	-233.5984	-2065.5751	8170.4572	-4615.56692	178.7694	-183.7838	-239.1095	118.1154
H4	-1807.7703	-701.3897	-4558.2268	9000.50088	-488.2914	367.591	-1.00976	-441.0128
V1	-87.0864	1.56718	302.0506	-174.51156	7490.8344	918.82254	1656.35338	784.3534
V2	182.2748	-404.56522	-128.0876	486.57564	833.8752	7402.042	675.00182	-1629.1482
V3	309.8688	-477.33554	-80.087	272.82164	-1436.731	1099.12212	7236.42762	695.124
V4	-177.839	74.78868	291.7698	-126.46464	955.694	-1414.8926	824.44686	7487.4108

Table - Main couplings and cross couplings

Issues/difficulties encountered during this test:

Acceptance criteria: The results in these three tables must be the same (within xxx%)

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

Looking at the diagonal drives and offset coupling is certainly valid. However, this script was never in a form (at LHO) to run the three offset rounds and then normalize the results. This seems excessive and I (HughR) had not looked at this document, I only looked at previous assembly validation reports, HAM2 for example notes:

Drive of 1000 and 2500 counts were skipped. Static_Test_Local_Basis_HEPI.m drives at 5000 counts only.

It makes more sense to speak specifically about the range of acceptable amplitudes on the off diagonal groups:

The elements inside the above red boxes should be significantly less than those off diagonal elements in the green boxes to their left or right. That being said, note too the size of the element in H1 row and the H3 Column and how much smaller it is than the adjacent H2 & H4 Columns. The H1 Actuation (H1 Row) moves H2 the most as it is the same crossbeam, it pivots about the opposite corner (H3—smallest value.)

10 Linearity Test/Range of motion in the local basis

Scripts files for processing and plotting in SVN at:
/SeiSVN/seismic/HEPI/Common/Testing_Functions_HEPI/Linearity_Test_Awgstream_HEPI.m

Data in SVN at:
SeiSVN/seismic/HEPI/M1/HAMX/Data/Spectra/Undamped/
M1_ISI_HAMX_ASD_m_CPS_T240_L4C_GS13_Locked_vs_Unlocked_2012_02_07.mat

Figures in SVN at:
/SeiSVN/seismic/HEPI/M1/HAMX/Data/Figures/Spectra/Undamped

	Slopes	Offsets
H1	1.63	1800.40
H2	1.88	-522.55
H3	1.63	1959.94
H4	1.76	-177.98
V1	1.54	-4082.29
V2	1.54	-1558.79
V3	1.42	-516.54
V4	1.56	-5144.56

Issues/difficulties encountered during this test:

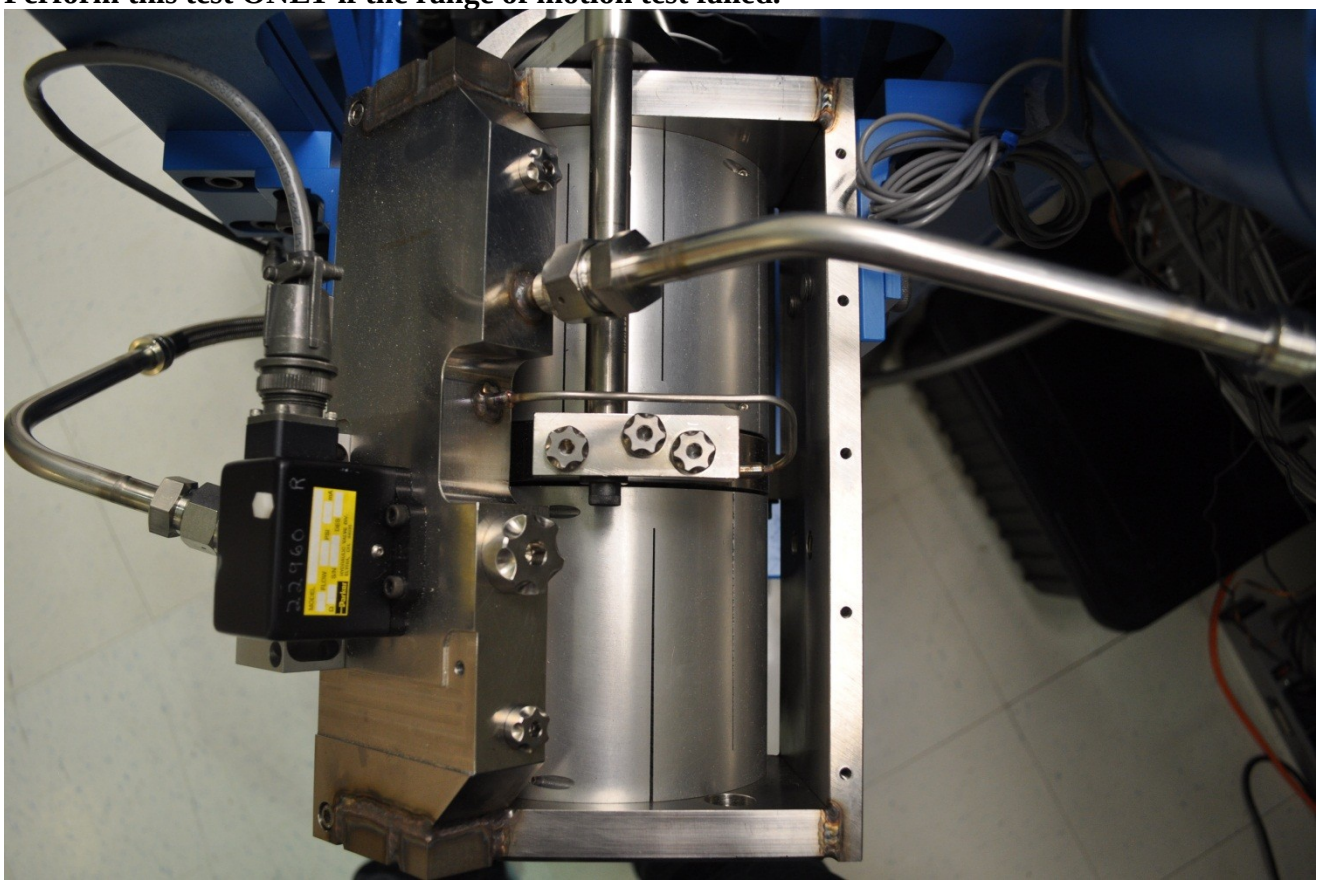
Acceptance criteria: **Very important test, some range of acceptable values would be nice to have, Fabrice?**

-

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

11 Actuator Plate to Shields gap

Perform this test ONLY if the range of motion test failed.



Three gaps per actuator need to be checked.

Acceptance criteria:

- A 0.1” shim must fit into the gap #1
- A 0.05 shim must fit into gap #2 and #3

	Horizontal			Vertical		
	Gap #1	**Gap #2**	**Gap #3**	**Gap #1**	**Gap #2**	**Gap #3**
Pier 1	Go	Go	Go	Go	Go	Go
Pier 2	Go	Go	Go	Go	Go	Go
Pier 3	Go	Go	Go	Go	Go	Go
Pier 4	Go	Go	Go	Go	Go	Go

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

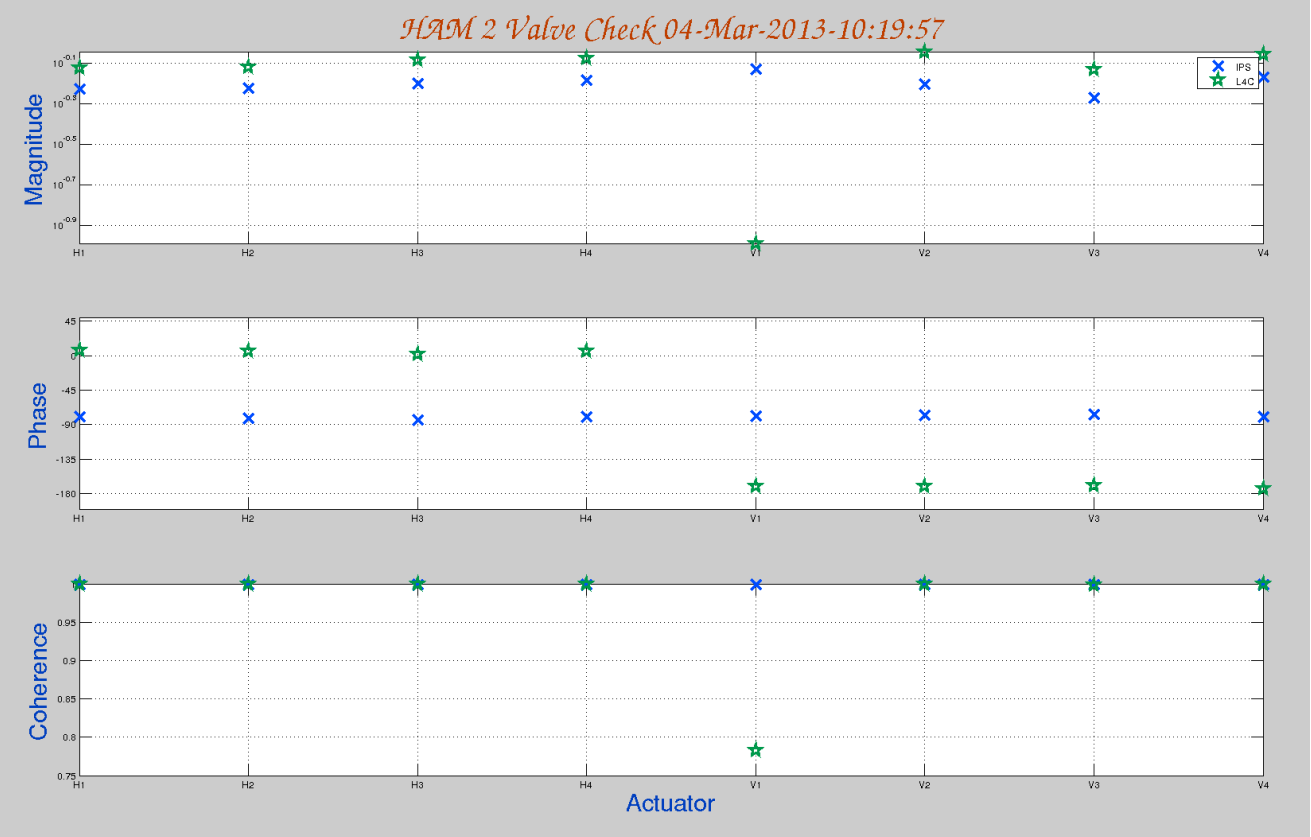
Arguments against checking these gaps—Welding fabrication of the bellows to the Actuator plate will likely result in the two surfaces not being parallel(gaps 2 & 3.) Likewise, the assembly of the Tripod to Actuator Plate will make the parallelism of the Tripod base and the Actuator top plate iffy. Given the surfaces involved, seeing, much less checking everywhere for the gap makes a single gap check insufficient. The ROM and Linearity Tests will confirm that these gaps are obstruction free.

12 Valve Check

Scripts files for processing and plotting in SVN at:
/SeiSVN/seismic/HEPI/M1/HAMX/Scripts/Valve_Check/plot_valve_check.m

Data in SVN at:
SeiSVN/seismic/HEPI/M1/HAMX/Data/Spectra/Undamped/
/SeiSVN/seismic/HEPI/M1/HAMX/Scripts/Valve_Check

Figures in SVN at:
/SeiSVN/seismic/HEPI/M1/HAMX/Scripts/Valve_Check



Acceptance criteria:

-

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

This function script never worked at LHO and I (HughR) only tried it a couple times. Depends on who you talk to, the check is okay or not worth doing. The Static Test Local Drive is sufficient.

13 Local-to-local measurements

Band (Hz)	Resolution	Amplitude	Nreps	Time (s)	Time (min)	Time (h)
100 - 500	0.5	4000 - 4000	250	4176	69.6	1.2
10 - 100	0.25	4000 - 4000	200	6592	109.9	1.8
0.7 - 10	0.05	4000 - 4000	75	12320	205.3	3.4
0.1 - 0.7	0.025	4000 - 4000	30	10080	168.0	2.8
0.01 - 0.1	0.01	4000 - 4000	10	8960	149.3	2.5
0.002 - 0.01	0.002	4000 - 4000	2	12160	202.7	3.4
						15.1

Data files in SVN at:
/SeiSVN/seismic/HEPI/M1/HAMX/Data/Transfer_Functions/Measurements/Undamped/

- M1_HPI_HAMX_Data_TF_L2L_200Hz_1000Hz_20120201-174407.mat
- M1_HPI_HAMX_Data_TF_L2L_5Hz_200Hz_20120201-183140.mat
- M1_HPI_HAMX_Data_TF_L2L_500mHz_5Hz_20120201-191513.mat
- M1_HPI_HAMX_Data_TF_L2L_100mHz_500mHz_20120201-202848.mat
- M1_HPI_HAMX_Data_TF_L2L_10mHz_100mHz_20120201-212025.mat

Data collection script files:
/SeiSVN/seismic/HEPI/Common//Transfer_Function_Scripts/

- Run_TF_L2L_10mHz_100mHz.m
- Run_TF_L2L_100mHz_500mHz.m
- Run_TF_L2L_500mHz_5Hz.m
- Run_TF_L2L_5Hz_100Hz.m
- Run_TF_L2L_100Hz_1000Hz.m

Scripts files for processing and plotting in SVN at:
/SeiSVN/seismic/HEPI/M1/HAMX/Scripts/Control_Scripts/release/

- Step_1_TF_Loc_to_Loc_M1_HEPI_HAMX.m

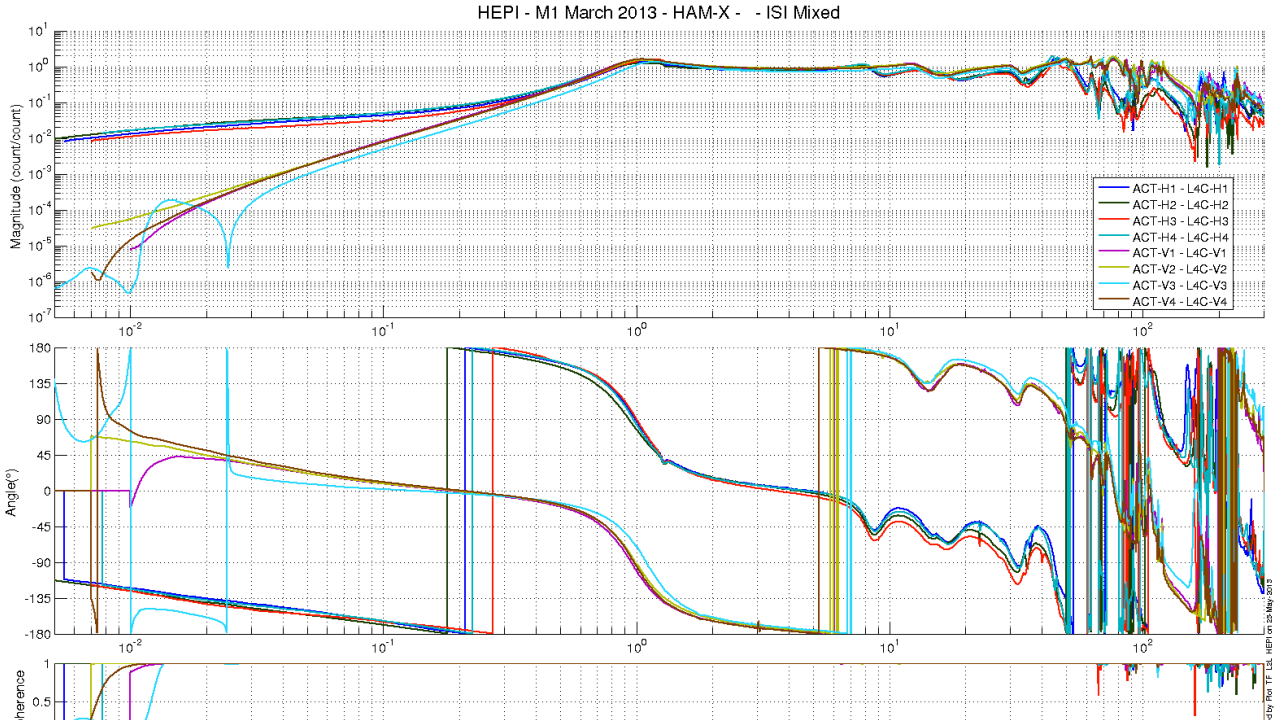
Figures in SVN at:
/SeiSVN/seismic/HEPI/M1/HAMX/Data/ Figures/Transfer_Functions/Measurements/Undamped/

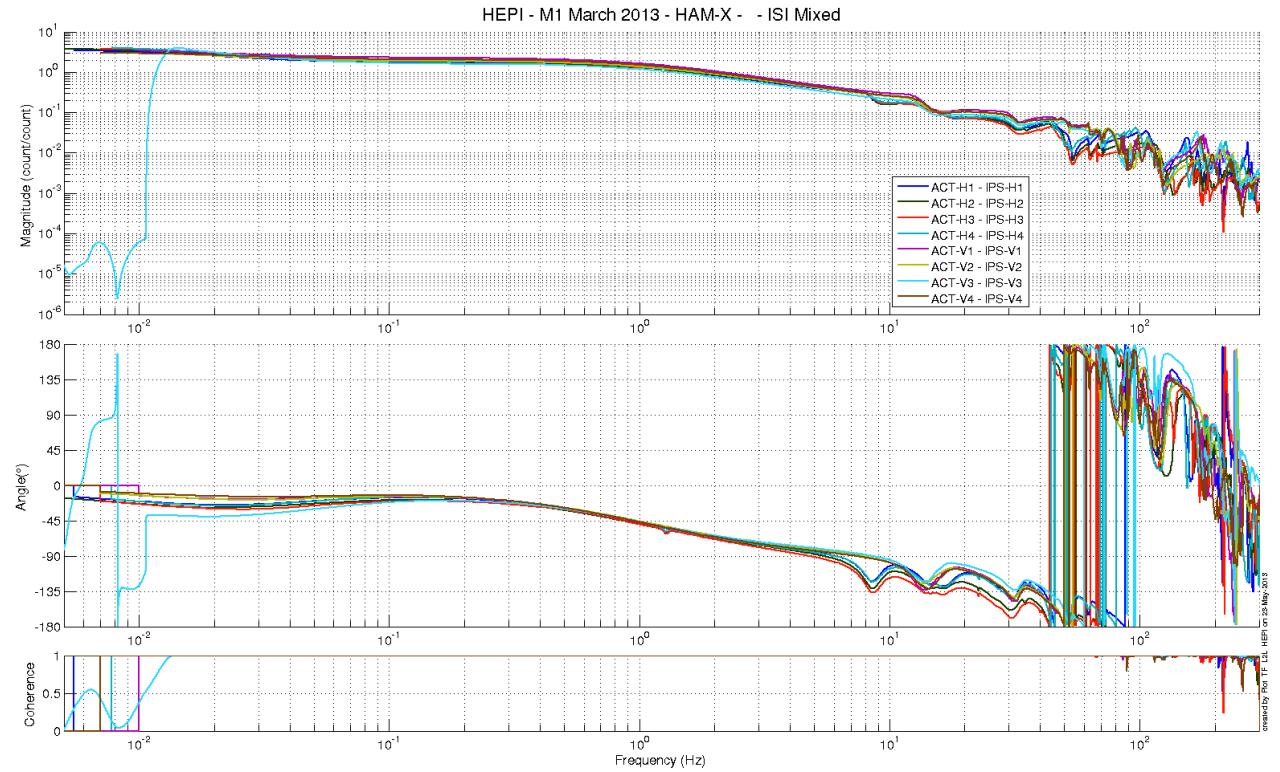
- M1_HPI_Unit_1_TF_L2L_Raw_from_ACT_to_CPS_2012_02_02_With_3_Washers_Under_Top_Mass.fig
- M1_HPI_Unit_1_TF_L2L_Raw_from_ACT_to_GS13_2012_02_02_With_3_Washers_Under_Top_Mass.fig

Storage of measured transfer functions in the SVN at:
/SeiSVN/seismic/HEPI/M1/HAMX/Data/Transfer_functions/ Simulations/Undamped/

- M1_HPI_Unit_1_TF_L2L_Raw_2012_02_02_With_3_Washers_Under_Top_Mass.mat

The local-to-local transfer functions are presented below.





Issues/difficulties/comments regarding this test:

Acceptance criteria:

- On IPS, the phase must be 0º at DC
- On geophones, the phase must be 90º at DC
- Identical shape in each corner

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

14 Alignment offsets:

Those are the IPS readouts that were recorded with HEPI locked, after alignment work was performed. The opposite of those values is to be installed as offset of the IPS filter banks when the Isolation loops are turned on. This way, HEPI will be operating in its *preferred alignment* state.

	IPS Read-outs HEPI Locked	Offset Value
H1	1331.1	-1331.1
H2	957.72	-957.72
H3	2157.4	-2157.4
H4	-1303.6	1303.6
V1	-2742.7	2742.7
V2	-511.83	511.83
V3	1034	-1034
V4	-2882.9	2882.9

Acceptance criteria:
Offsets were recorded.

Test result: **Passed: ___** **Failed: ___**
Comments: The values right after alignment and Actuator attachment will shift as subsequent testing (everything else in this report) will settle and shift the platform at into a more stable and unstressed state.
The process should be, Align and attach the Actuator, run all the tests, disconnect the Actuator and recenter them. Confirm the alignment and then reattach the Actuators.