LIGO Laboratory / LIGO Scientific Collaboration

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aLIGO HEPI L1 HAM5 Assembly Validation Report

E1300926-V2

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Distribution of this document:
Advanced LIGO Project

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Contents

Introduction

This document summarizes the different tests which have been done to validate HEPI L1 HAM5. All tests were run after the payload installation was completed inside the chamber, in June 2013.

Sub-Components Testing

- Kaman Inductive Position Sensors: calibration, linearity, factory data, noise measurements (E0900426 – HEPI Kaman Sensor Receiving Analysis - Results posted in the SVN)

  **Note:** these serial numbers have not been recorded at the time of install and are not hidden.

- HEPI actuator linearity test (E1100338 – aLIGO HEPI Actuators Test Results).

  **Note:** these serial numbers have not been recorded at the time of install but are still accessible and will be recorded.

- L4C test (Q0900007)

	Horizontal	Vertical
Pier 1		L41621
Pier 2		L41631
Pier 3		L41638
Pier 4		L41625

Note: the Horizontal L4Cs have not been recorded at the time of install and are now really hard to access, that's why the serial numbers do not appear a=on this table.

Figures in SVN at:
/HEPI/L1/HAM5/Data/Figures/Spectra/Ground/
- *hepi_ham5_l4c_horiz_huddle.png*
- *hpi_ham5_l4C_vert_huddle.png*
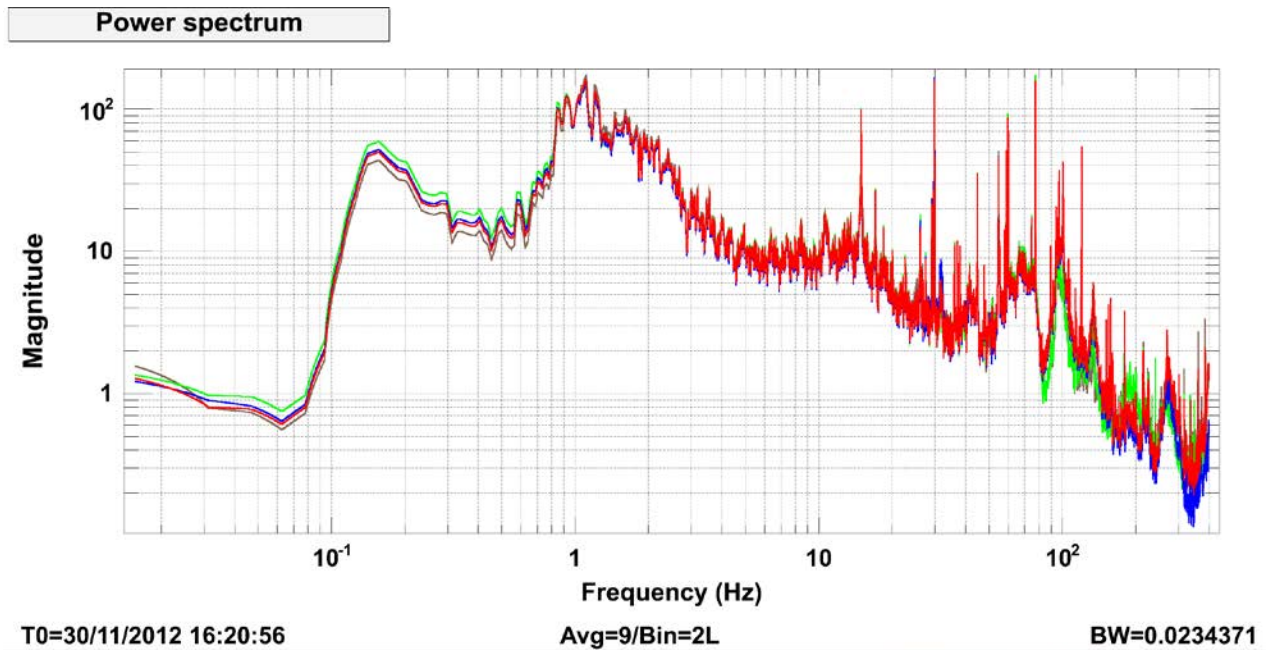
Figure 1: Power spectra of L1 HAM 5 horizontal L4Cs

Power spectrum

Figure legend:
- L1:HPI-HAM5_L4CINF_V1_IN1_DQ
- L1:HPI-HAM5_L4CINF_V2_IN1_DQ
- L1:HPI-HAM5_L4CINF_V3_IN1_DQ
- L1:HPI-HAM5_L4CINF_V4_IN1_DQ

T0=30/11/2012 16:20:56   Avg=9/Bin=2L   BW=0.0234371

Figure 2: Power spectra of L1 HAM 5 horizontal L4Cs

Assembly Validation

1.1 Load Cells assembly

- Spring attachment

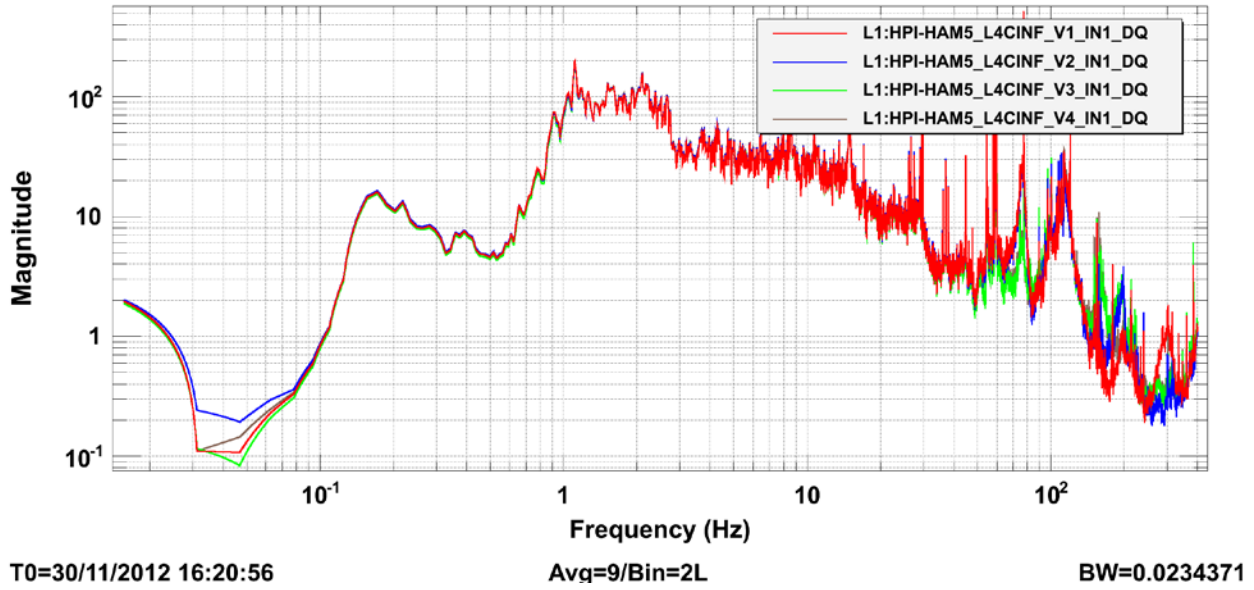For the HAM HEPI springs, check the assembly per D1003359.

- Load cell values

HAM HEPI load cell capacity → 2000 lbs
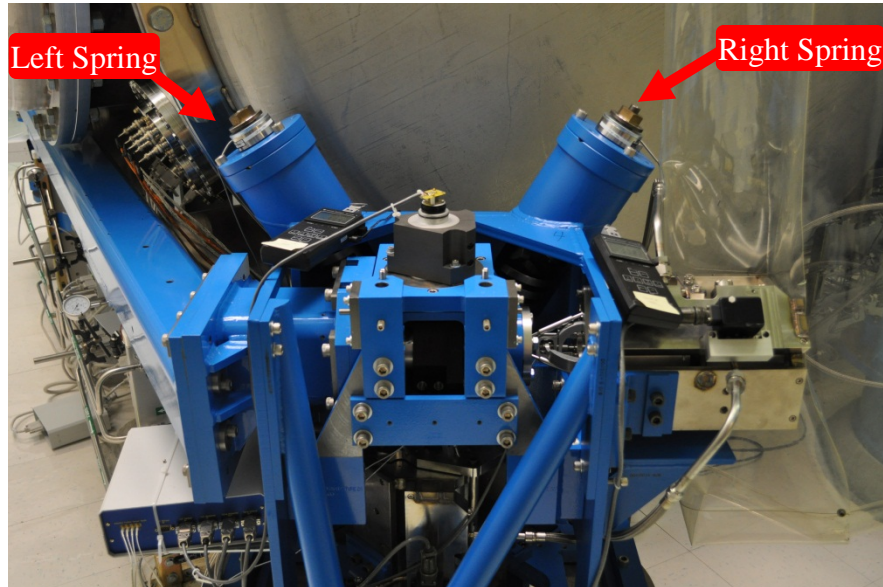
Figure 3: HAM-HEPI example at LASTI

	Left Spring (lbs)	Right Spring (lbs)
Pier 1		
Pier 2		
Pier 3		
Pier 4		

Acceptance criteria:
- The values must not exceed 80% of the load cell capacity (<1600lbs for HAM).

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

1.2 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.

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

1.3 Boot Location

	Pier 1	Pier 2	Pier 3	Pier 4	Nominal
Tangential Left	5.184	5.437	5.207	5.446	5.38
Tangential Right	5.462	5.218	5.454	5.225	5.38
Radial Back	1.233	1.172	1.196	1.127	1.17
Radial Front	1.302	1.352	1.393	1.188	1.42
Vertical	0.469	0.287	0.382	0.32	0.32

Acceptance criteria:

	Pier 1	Pier 2	Pier 3	Pier 4	Requirements
Tangential Left	-0.196	0.057	-0.173	0.066	+/- 0.20
Tangential Right	0.082	-0.162	0.074	-0.155	+/- 0.20
Radial Back	0.063	0.002	0.026	-0.043	+/- 0.10
Radial Front	-0.118	-0.068	-0.027	-0.232	+/- 0.15
Vertical	0.149	-0.033	0.062	0	+/- 0.20

Note: usually this test can be waived if step 1.10 Linearity Test/Range of motion in the local basis passes because it means that the system has a full range of motion and is, therefore, free to move.

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

1.4 Check Stops Gaps

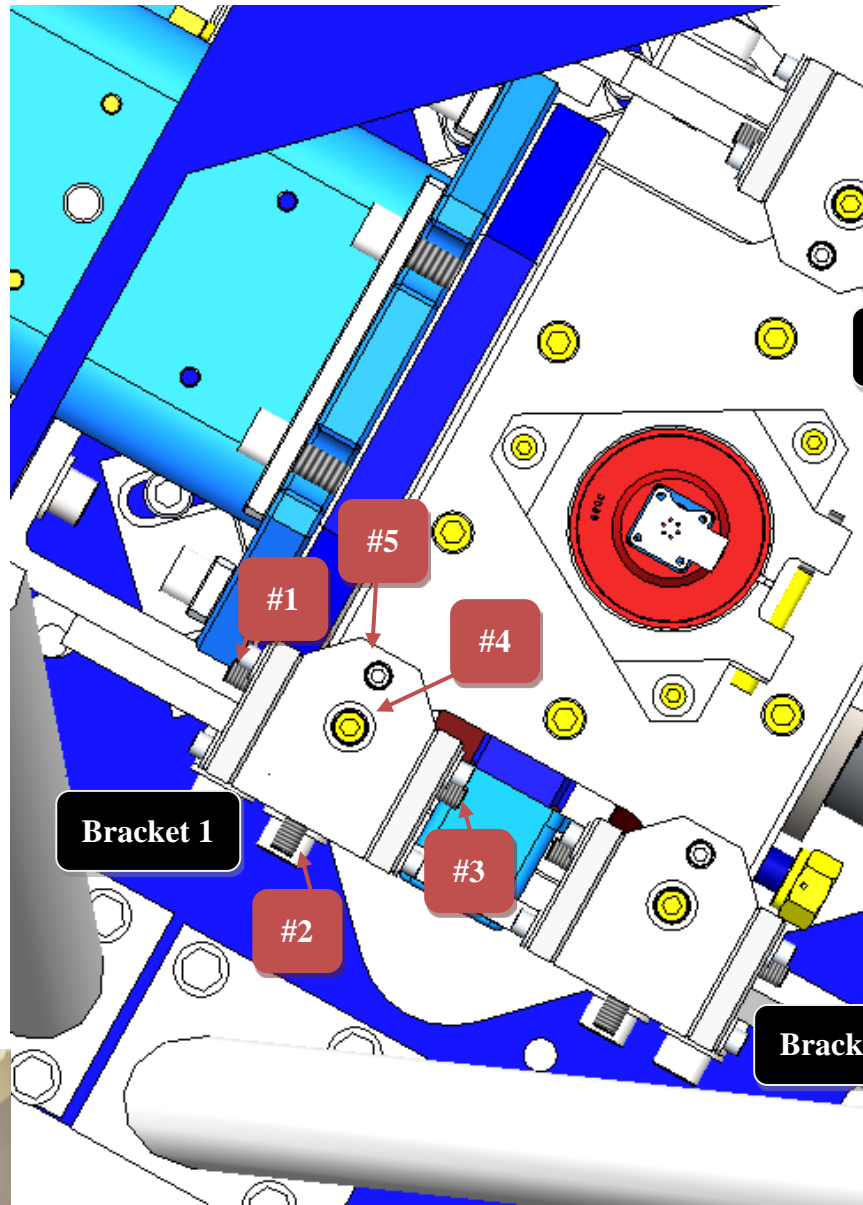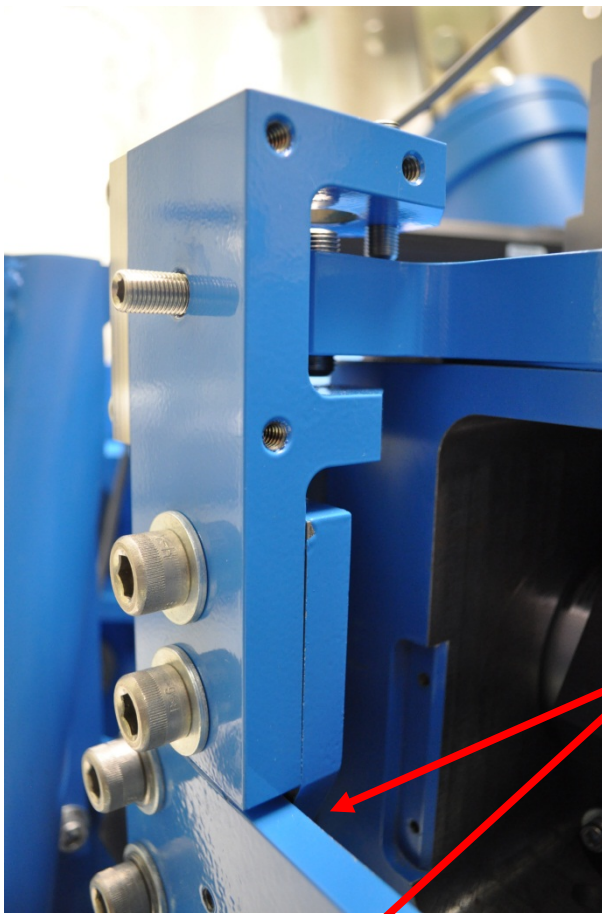The stops must not touch the boot. There are 15 stops per boot, 5 per F bracket.

Figure 4: Locations of the boot's stops

Acceptance criteria:
- A 0.062" shim must fit into the gaps
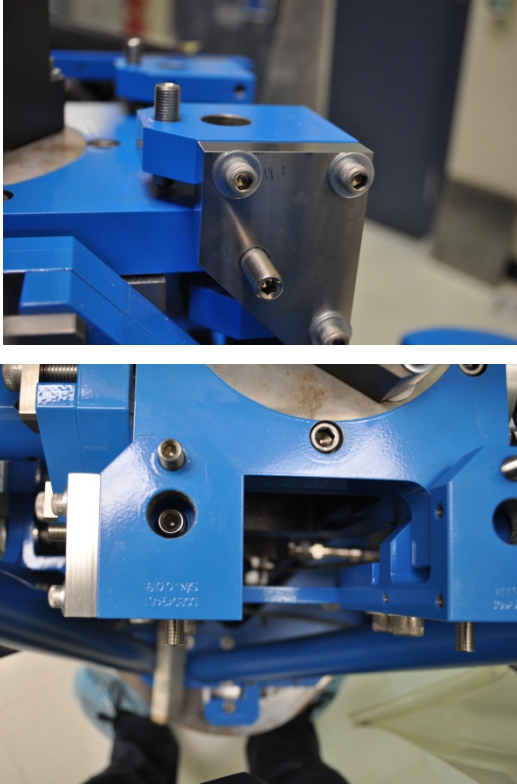
A 0.062" must fit into the gaps

Figure 5: Locations of the boot's gaps to measure

	Bracket 1						Bracket 2						Bracket 3					
	Gap 1	Gap 2	Gap 3	Gap4 above	Gap4 under	Gap 5	Gap 1	Gap 2	Gap 3	Gap4 above	Gap4 under	Gap 5	Gap 1	Gap 2	Gap 3	Gap4 above	Gap4 under	Gap 5
Pier 1	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go
Pier 2	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go	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

Note: HAM 4 is currently in the locked position so the measurement of these gaps is pointless at this time. Measurements will be taken when HEPI will be unlocked on HAM 4.

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

1.5 Gaps check

Four particular gaps need to be check.
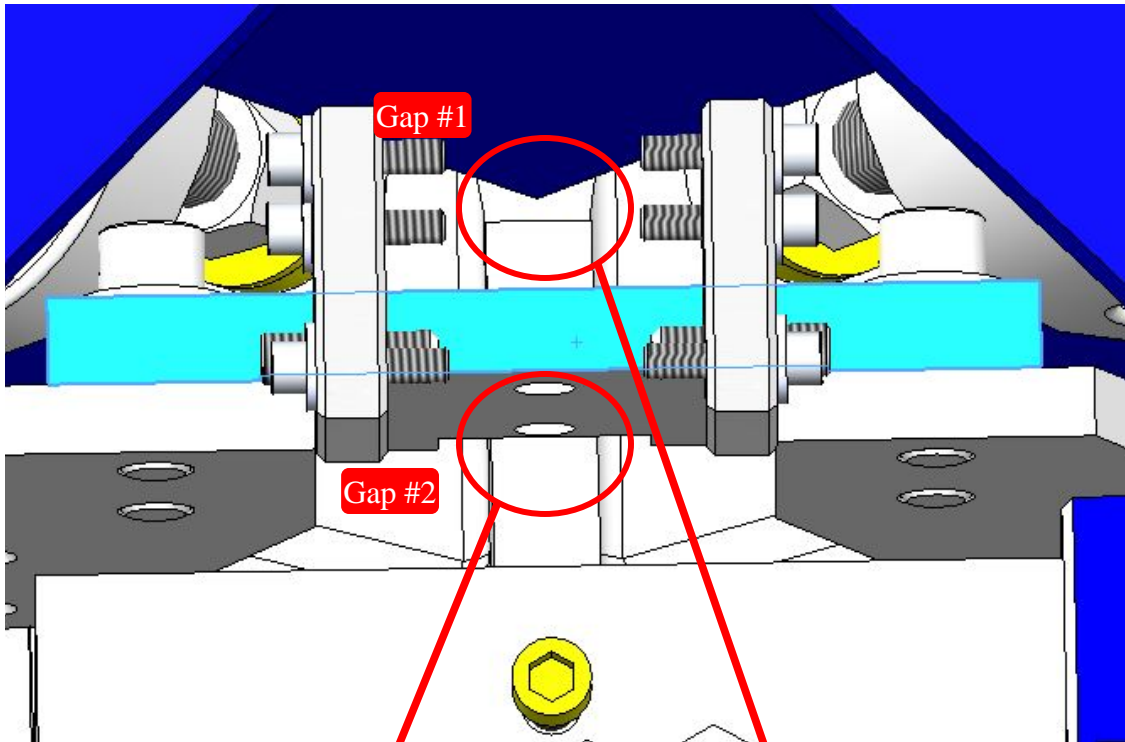
Note: **The F bracket has been removed for a better visibility**
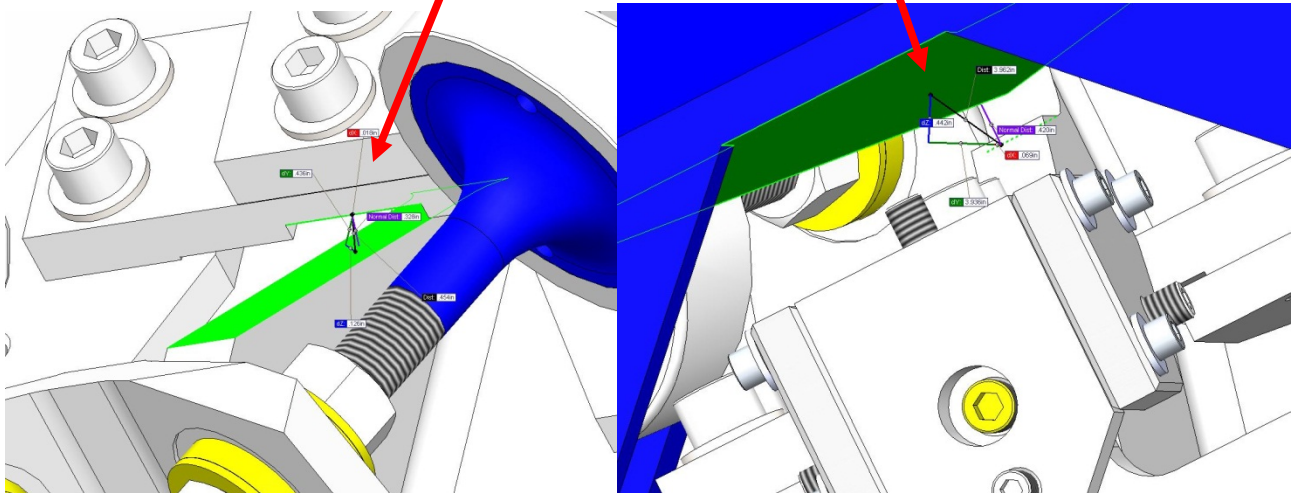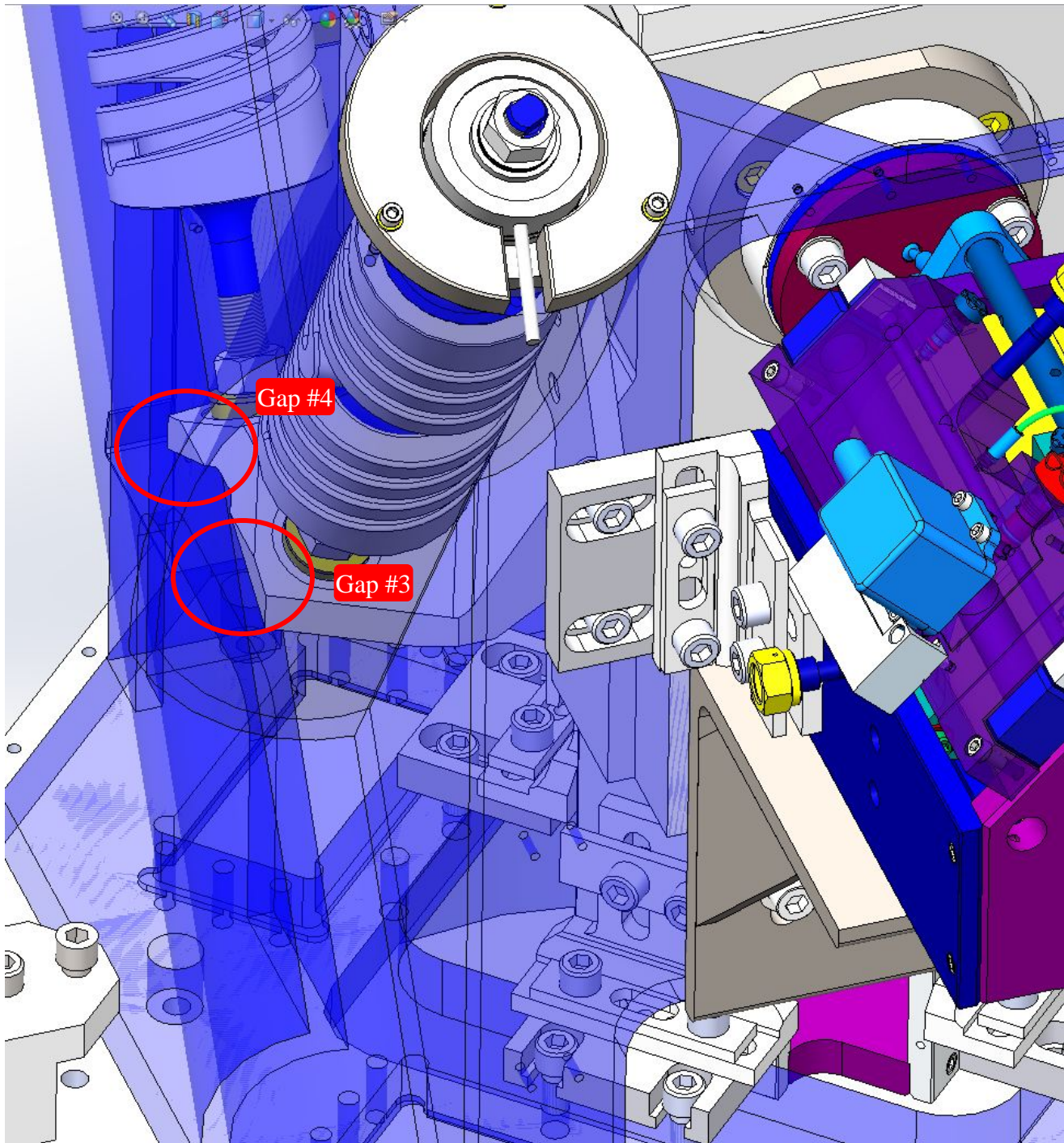
Figure 6: Gaps which need to be checked

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)

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Gap#1

Figure 7: First gap to measure (on the first picture, we can see the tool used to measure that gap)

Gap#2

Figure 8: Second gap to measure

	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

**Note:** usually this test can be waived if step 1.10 Linearity Test/Range of motion in the local basis passes because it means that the system has a full range of motion and is, therefore, free to move.

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

1.6 IPS Centering

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

**Note:** All the loops must be turned off during this test.

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

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

1.7 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/L1/HAM5/Data/Perf_Analysis/2013-06-24-HEPI_Level1-ISI_Level2/

Figures in SVN at:
/SeiSVN/seismic/HEPI/L1/HAM5/Data/ Figures/Perf_Analysis/2013-09-22-HEPI-locked/fig/

Figure 9: L1 HAM 2 HEPI Sensor spectra Horizontal L4Cs

Figure 10: L1 HAM 2 HEPI Sensor spectra Vertical L4Cs

Figure 11: L1 HAM 2 HEPI Sensor spectra Horizontal IPSs

Figure 12: L1 HAM 2 HEPI Sensor spectra Vertical IPSs

Issues/difficulties/comments regarding this test:

Acceptance criteria:

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

1.8 SUS-watchdogs interaction test

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

. Set up a zero value on the payload watchdogs.

. Check that the payload watchdog screen of HEPI tripped.

. In the payload watchdog screen, click on the OVERRIDE button and reset the watchdog.

. Do the same process for all the payloads

Acceptance criteria:

- The HEPI must trip when the payload watchdogs are tripped

- The HEPI watchdogs could be reset when the OVERRIDE button is ON

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

Note: When this test is done, reset everything (OVERRIDE button OFF, put back the value on the payload watchdog).

1.9 Static Test local drive

Scripts files for processing in SVN at:

/SeiSVN/seismic/HEPI/Common/Testing_Functions_HEPI/Static_Test_Local_Basis_HEPI.m

Data in SVN at:

SeiSVN/seismic/HEPI/L1/HAM5/Data/Static_Tests/

. 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 1: Main couplings and cross couplings for 100count offset

. 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 2: Main couplings and cross couplings for 1000 count offset

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

	H1	H2	H3	H4	V1	V2	V3	V4
H1								
H2								
H3								
H4								
V1								
V2								
V3								
V4								

Table 3: Main couplings and cross couplings for 5000 count offset

Issues/difficulties encountered during this test:

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

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

1.10 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/L1/HAM5/Data/Linearity_Test/

Figures in SVN at:
/SeiSVN/seismic/HEPI/L1/HAM5/Data/Figures/Linearity_Test/

	Slopes	Offsets	Average Slope	Difference / Average in %
H1				
H2				
H3				
H4				
V1				
V2				
V3				
V4				

Figure 13: Linearity Test

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

Data in SVN at:
SeiSVN/seismic/HEPI/L1/ HAM5/Data/Static_Tests/
  - *L1_HPI_HAM5_Range_Of_Motion_20130514.mat*

	Positive Drive	Negative Drive	Amplitude
H1	29365.74	-26446.4	55812.1
H2	32188.48	-23484.6	55673.06
H3	23490.39	-27781.9	51272.25
H4	31041.29	-27862.5	58903.8
V1	29177.26	-18673.7	47851
V2	28438.13	-13917.6	42355.72
V3	30154.86	-19951.5	50106.32
V4	27923.13	-23359.4	51282.51

Table 4: Range of Motion

Issues/difficulties encountered during this test:

Acceptance criteria:
  ▪ For the linearity test, the results in these three tables must be the same (within +/- 20% compared to the average slopes)

  ▪ For the range of motion, the sign must be positive for a positive drive and negative for a negative drive, and the amplitude must be bigger than 40000 counts.

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

1.11 Actuator Plate to Shields gap

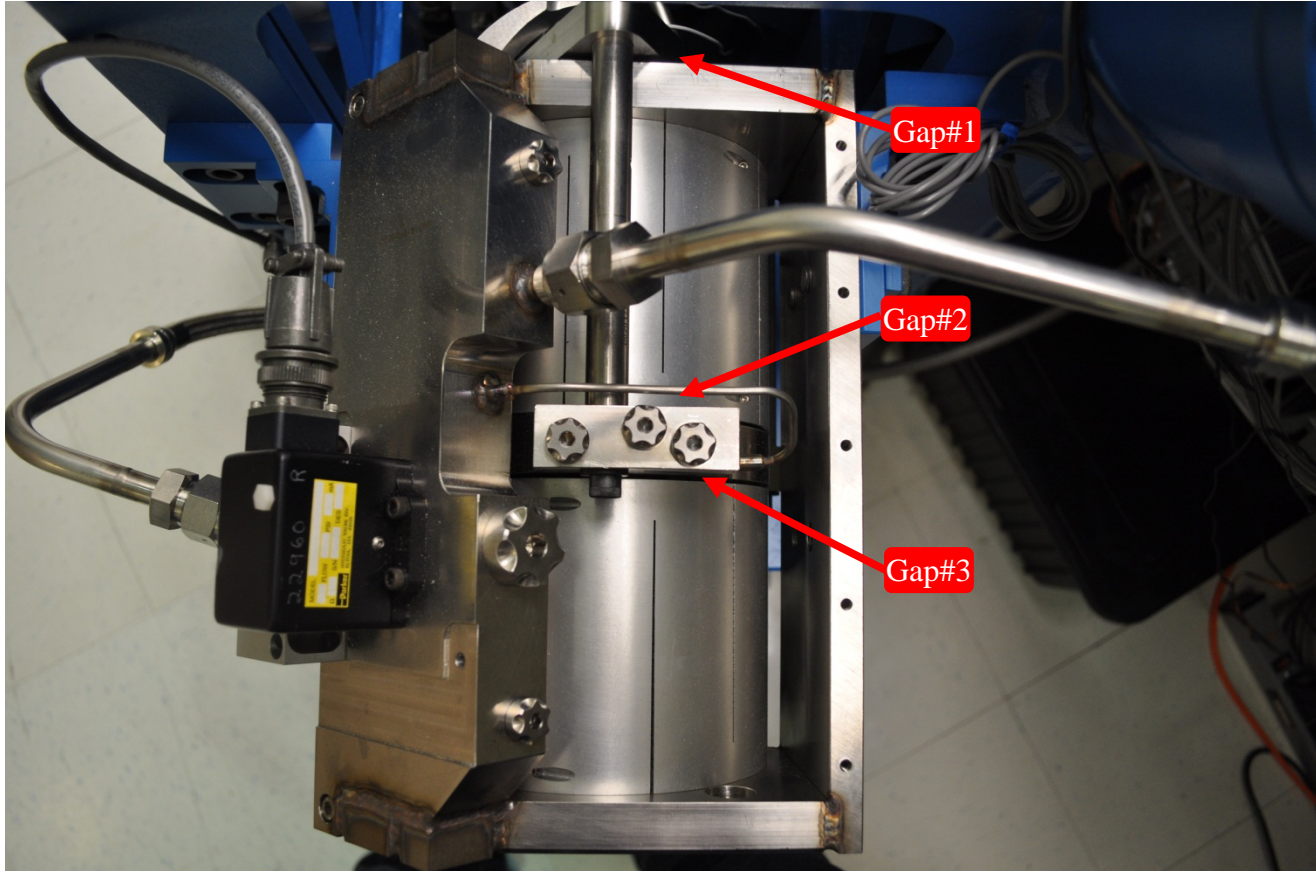*Note:* **Perform this test ONLY if the range of motion test failed.**

Figure 14: Locations of the actuator gaps to check if Step 1.10 Linearity Test/Range of motion in the local basis failed

Three gaps per actuator need to be checked as shown on Figure 19: Locations of the actuator gaps to check if Step 1.10 Linearity Test/Range of motion in the local basis failed .

	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

Acceptance criteria:
- A 0.1" shim must fit into the gap #1
- A 0.05 shim must fit into gap #2 and #3

Test result: Passed: ___   Failed: ___   Waived: __X__

1.12 Valve Check

Scripts files for processing and plotting in SVN at:
/SeiSVN/seismic/HEPI/L1/HAM5/Scripts/Valve_Check/plot_valve_check.m
/SeiSVN/seismic/HEPI/L1/HAM5/Scripts/Valve_Check

Figures in SVN at:
/SeiSVN/seismic/HEPI/L1/HAM5/Data/Figures/Valve_Check/Individual_Tests/Valve_Check_25-Jun-2013_09:08:16.fig
/SeiSVN/seismic/HEPI/L1/HAM2/Data/Figures/Valve_Check/Evolution/
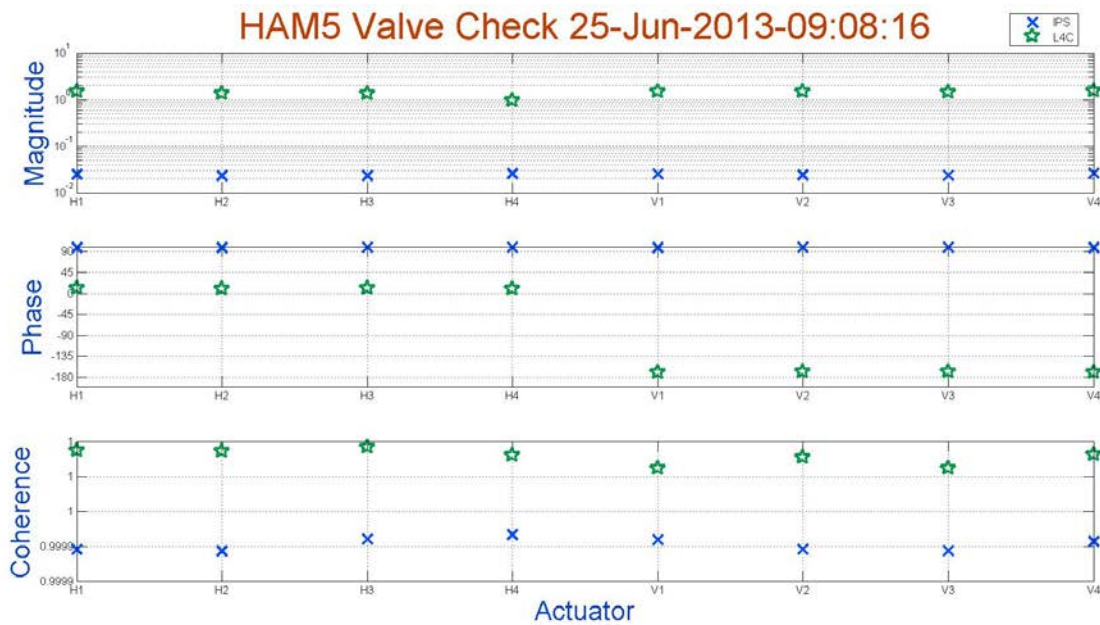*L1_HAM5_L4C_Valve_Check_From_09-May-2013_Until_25-Jun-2013.fig*

Figure 15: Valve check individual plot

L4C Valve Check Data for L1 HAM5 From 09-May-2013 Until 25-Jun-2013 09:08:16
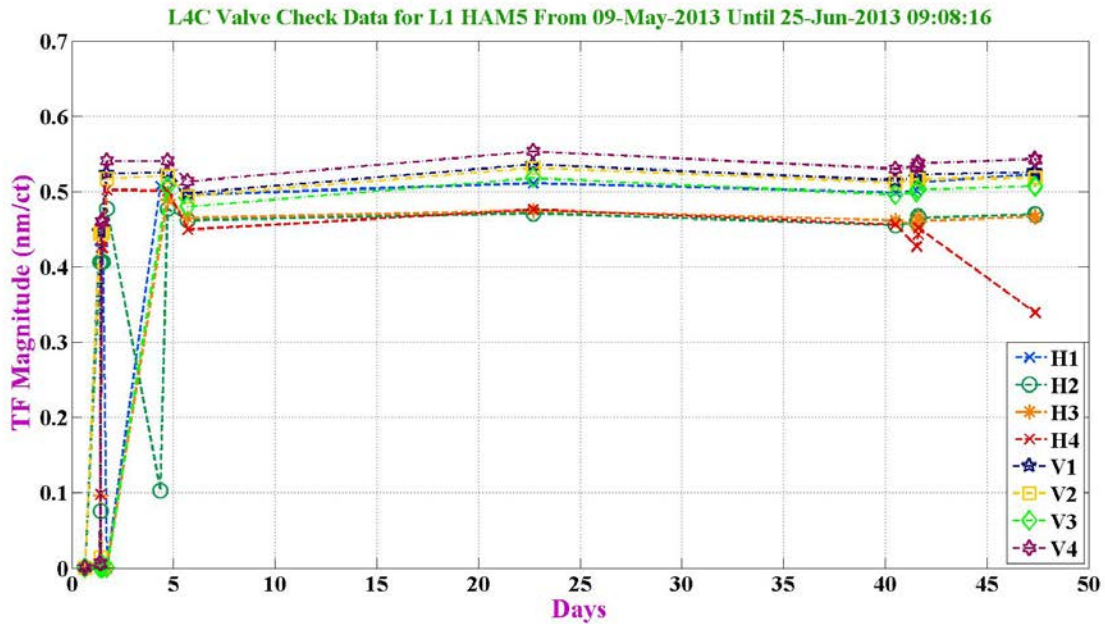

Figure 16: Valve check evolution plot

Note: On this last figure, we can see that H4 valve is faulty. This is confirmed by the Local to local measurements. The valve will be replaced when time permits and the failed tests will be redone.

Acceptance criteria:
-

- **Test result:**   **Passed:** ___   **Failed:** __X__   **Waived:** ___

1.13 Local-to-local measurements

Data files in SVN at:
/SeiSVN/seismic/HEPI/L1/HAM5/Data/Transfer_Functions/Measurements/Undamped/
- *L1_HEPI_HAM5_0p05_to_0p5Hz_20130619-164421.mat*
- *L1_HEPI_HAM5_0p5_to_2Hz_20130616-184207.mat*
- *L1_HEPI_HAM5_2_to_20Hz_20130619-015047.mat*
- *L1_HEPI_HAM5_20_to_100Hz_20130619-043806.mat*
- *L1_HEPI_HAM5_100_to_250Hz_20130620-063300.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/L1/HAM5/Scripts/Control_Scripts/Version_5/
- *Step_1_TF_Loc_to_Loc_L1_HEPI_HAM5.m*

Figures in SVN at:

/SeiSVN/seismic/HEPI/L1/HAM5/Data/Figures/Transfer_Functions/Measurements/Undamped/
- *L1_HPI_HAM5_TF_L2L_Raw_from_ACT_to_IPS_2013_06_19.fig*
- *L1_HPI_HAM5_TF_L2L_Raw_from_ACT_to_L4C_2013_06_19.fig*

Storage of measured transfer functions in the SVN at:

/SeiSVN/seismic/HEPI/L1/HAM5/Data/Transfer_functions/ Simulations/Undamped/
- *L1_HPI_HAM5_TF_L2L_Raw_2013_06_19.mat*

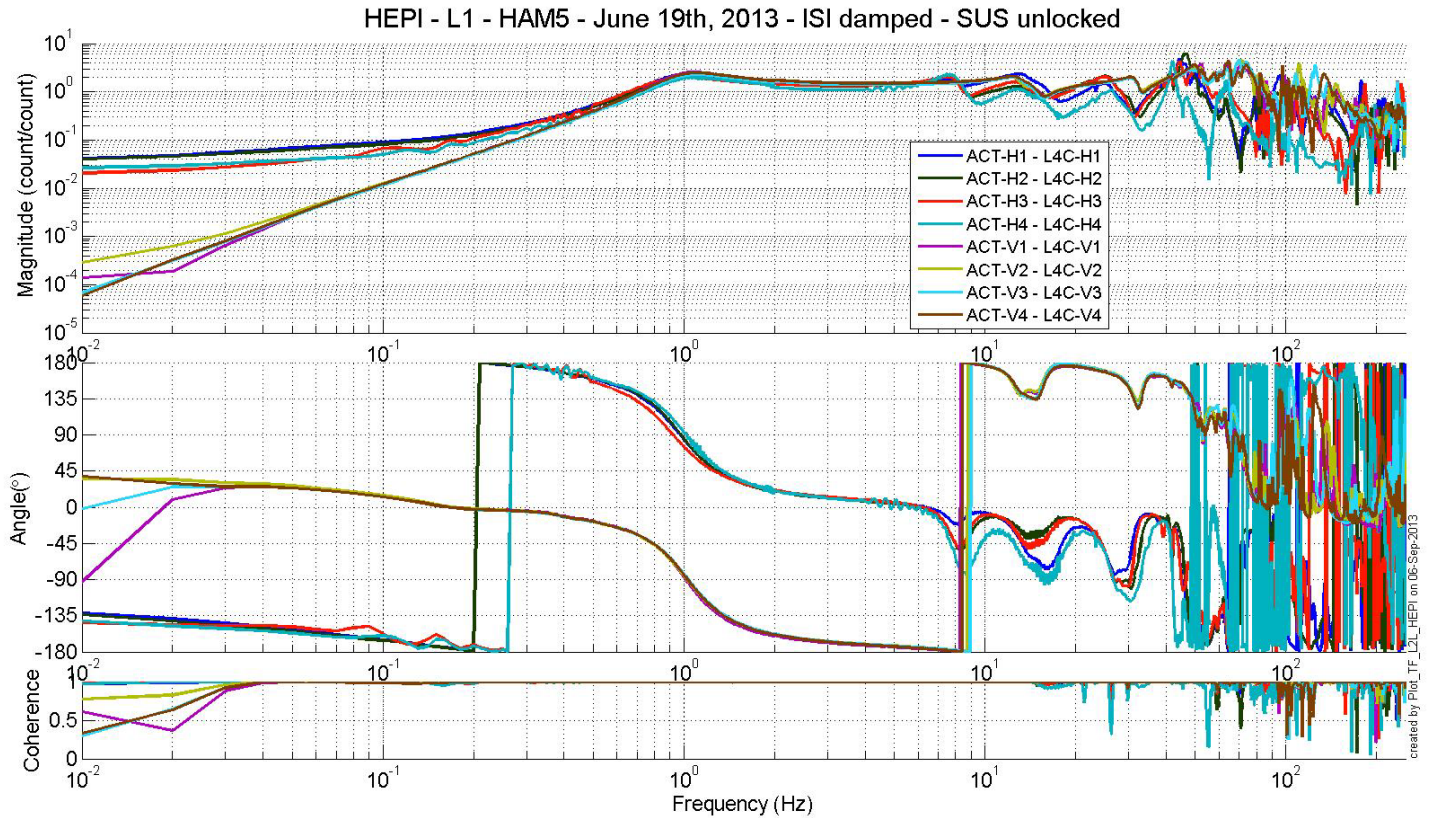The local-to-local transfer functions are presented below.

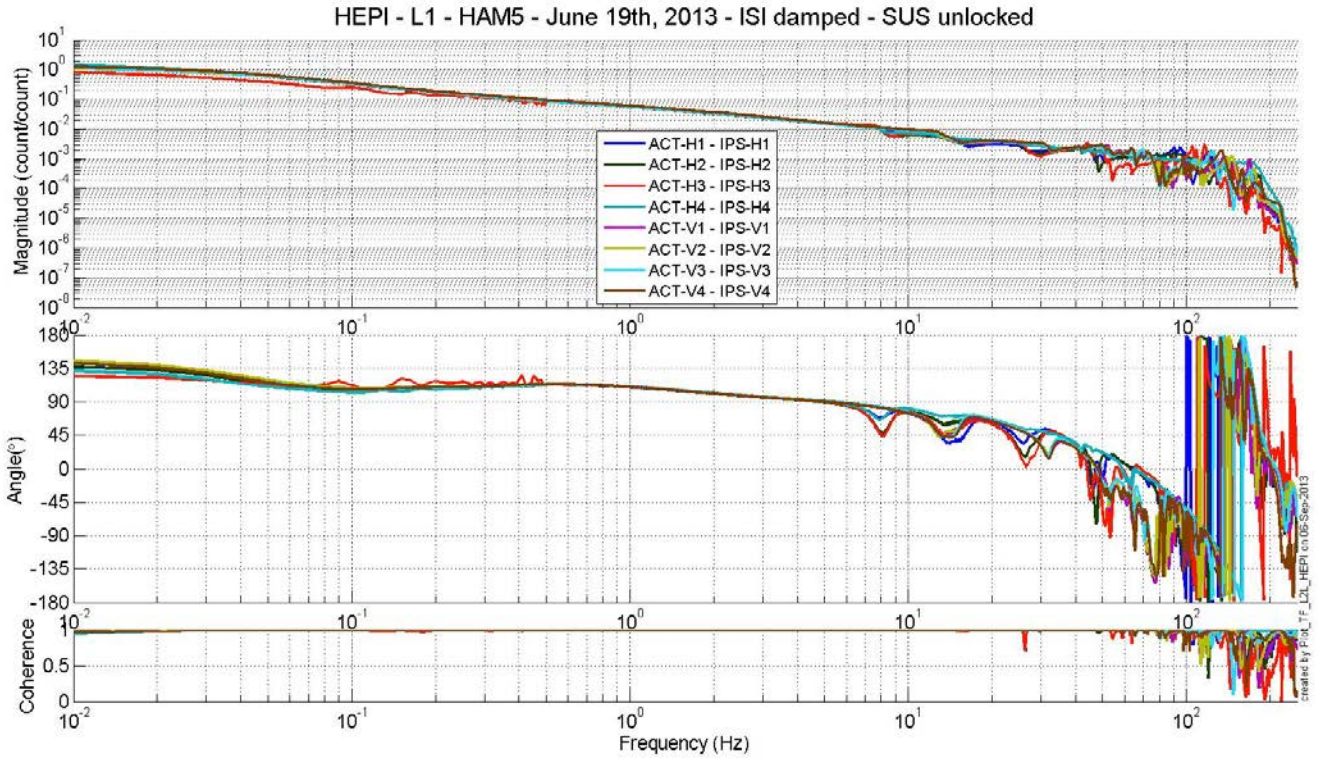**Figure 17:L1 HAM 5 HEPI Act to L4C Transfer Functions**

Figure 18: L1 HAM 5 HEPI Act to IPS Transfer Functions

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:** ___   **Waived:** ___

1.14 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 Readouts HEPI Locked	Offset Value
H1		
H2		
H3		
H4		
V1		
V2		
V3		
V4		

Acceptance criteria:
Offsets were recorded.

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

Conclusion

L1 HAM 5 HEPI seems good so far, we still have a few tests to run but should not have any issue with it. Here is a list of the tests that will be done:

- 1.1 Load Cell Assembly: the value will be recorded in this document
- 1.4 Check Stops Gaps: this test will be done when we unlock HEPI on L1 HAM 5
- 1.6 IPS Centering
- 1.7 Sensor ASD
- 1.9 Static Test Local Drive
- 1.10 Linearity Test
- 1.14 Alignment Offsets

Some of the tests have been waived:

- 1.2 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.
- 1.5 Gaps Check: this test can be waived if step 1.10 Linearity Test/Range of motion in the local basis passes because it means that the system has a full range of motion and is, therefore, free to move
- 1.11 Actuator Plate to Shield gap: this test was not performed because the Range of motion gave good results

So far, we have the 1.3 Boot Location that fails, but the requirements might be a little bit too strict for this test and our results are in the ballpark, the real issue with this HEPI is the H4 faulty actuator valve. This valve will be swapped and all the failed tests will be redone in order to approve this Unit.