SUBJECT: **Herschel/SPIRE Instrument Cold Vibration Test Report FM acceptance**

PREPARED BY: B. Winter and E. Sawyer

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CHANGE RECORD

ISSUE SECTIONS REASON FOR CHANGE

0.1	all	Draft Issue
0.1b		ESA comments added
1.0		Photographs added, appendix A, C, D, E completed

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1. SCOPE

This document lists the acceptance test results of the cold vibration test of the Herschel SPIRE instrument flight model (FM). This model is the flight model with a few exceptions as listed in section 5. The CQM model was tested in April 2004 with the stainless steel supports for the instrument itself as well as for the detector boxes. The FM test started with an all CFRP support. Halfway during the Z-axis vibration testing the instrument cone had to be replaced by a stainless steel one.

2. DOCUMENTS

AD (1)	Instrument Interface Document, part A	IID-A, issue 3
AD (2)	Technote 9 Random Vibration SPIRE February 2003 issue 3.doc	
AD (3)	Instrument Interface Drawing	5264-300 sheet 1 to 7, issue 18
AD (5)	As built status	SPIRE-RAL-DOC-002326 issue 2.2
AD (7)	HERSCHEL : SPIRE STM QUALIFICATION	AIV-2003-027-VIB
AD (8)	TRR1 minutes of meeting	SPIRE-RAL-MOM-001958
AD (9)	Cold vibration test plan	SPIRE-RAL-PRC-002524, issue 2.1
AD (10)	Cold vibration test procedure	SPIRE-RAL-PRC-002539, issue 2.2
AD (11)	SPIRE FPU Handling and integration procedure	SPIRE-RAL-PRC-001923
AD (12)	Cryo-vibration test report SPIRE FM 1	RP-CSL-CRYOV-05001, version 1

3. DEFINITIONS

3.1. Abbreviations

AD	Applicable Document
BSM	Beam steering mirror
CQM	Cold Qualification Model
EM	Engineering Model
FM	Flight Model
ICD	Interface Control Document
PFM	Proto-Flight Model
STM	Structural Thermal Model
S/C	Spacecraft
TBC	To be confirmed
TBD	To be defined
TRB	Test Review Board
TRR	Test Readiness Review
TML	Total Material Loss
VCD	Verification Control Document
VCM	Volatile Condensable Material

4. TEST PHILOSOPHY

The test item is the FM model of the SPIRE instrument as it will be flown, with the exception of the SMEC. The SMEC will be replaced at a later stage after which a workmanship cryo-vibration test may be performed. The instrument will be acceptance tested. That is at reduced levels compared to the CQM test and for shorter durations.

5. BUILD STANDARD

The instrument is the flight model with all parts up to flight standard with the exception of the SMEC. The SMEC will be replaced by the SMEC flight model at a later stage.
AD(5) As built configuration list applies.
Due to a degrading CFRP instrument main cone support the instrument mounting was changed between the Y and Z axis vibration.

Axis	Instrument Cone	Drawing	A-frames	Drawing
Y	CFRP 'A'	B3MD-00.20.022	CFRP No3 and No4	B3MD-00.20.017
Z*	CFRP 'A'	" "	CFRP	" "
Z	Stainless	5264-302-5	CFRP	" "
X	Stainless	" "	CFRP	" "

Table 5-1: Instrument support parts used during the test

6. TEST OBJECTIVES

- To acceptance test the SPIRE instrument.
- The test sequence was dictated by the cryo-vibration facility. It consisted of:
  - Cool down
  - complete Y-axis
  - shaker table/cryo-chamber rotation
  - complete Z-axis
  - warm up
  - reconfiguration
  - cool down
  - complete X-axis

After the sine vibration run in the Z axis it appeared the main structure response had degraded in such a way that it was decided to stop the test and inspect the instrument. Minor cracks were found in the CFRP instrument support cone. It was decided after an TRB meeting to replace the CFRP cone with the original stainless steel alternative as This was already qualified and the degradation to thermal performance was acceptable.

7. FIXTURE

The fixture for this cold vibration test was provided for by CSL

8. TEST REQUIREMENTS

8.1. SUMMARY

Resonance search, sine vibration test and random vibration tests were carried out in three axes. Resonance searches and intermediate random tests were performed in all three axes before the instrument was subjected to qualification runs.

8.2. Fixture qualification runs

Runs on just the bare fixture were carried out to prove that the fixture (and cold vibration facility) behaviour was suitable for the test. This was carried out before the instrument test. Test was successful.

8.3. Resonance search

A resonance search was performed between all major runs (qualification level), as the first and also as the last run in each axis.

8.4. Sine vibration test

See AD12 for all response curves.

The acceptance level sine testing was adjusted as not to exceed 1000 load cycles for the main structure and to accommodate the limitation of the shaker (stroke of ±1 mm)
As stated in AD (9) the acceptance levels are (here limited to the facility lower frequency 20 Hz and the 1000 maximum load cycles). Sweep rate was 4.0 oct/min. For each test the input was specified via the average response of the accelerometers located on the shaker table near the feet of the instrument.

X axis

Frequency Range Hz	Acceptance level
20 – 42.4	+/- 1mm
42.4 - 90	14.4 g (1000 cycles)
90-100	6.4 g (remainder)

Test sweep rate 4 Oct/min, the input was limited to the equivalent quasi static interface force.

Y and Z axis

Frequency Range Hz	Acceptance level
20 - 29	+/- 1mm
29 - 75	6.4 g (1000 cycles)
75-100	4.8 g (remainder)

Where applicable the input was limited to the equivalent quasi static interface force. For this, since no force cells were available for this test, accelerometer readings were used on or near the CoG of the instrument. During the X-axis sweep the SMEC response was capped to the specified input level since its first resonance is located at 110 Hz.

Note that the shaker system (including the cryostat) is responsible for some artefacts. One of these is a dip in the input at 50 Hz in the Y and Z-direction. After reconfiguring the shaker this artefact had shifted to 67 Hz (X axis).

Achieved Levels and discussion X-AXIS

The accelerometer at the top of the SPIRE optical bench was used as a control to limit the interface force to an equivalent 14.4 or 6.4 g static force where applicable. The number of maximum load cycles was limited to 1000. Based on the limitation of the CSL shaker (2 mm stroke maximum) maximum input could only be achieved at 42.4 Hz, continuing the maximum input to 90 Hz gives roughly 1000 cycles. After 90 Hz the input is lowered to 4.8 g with scaled limits accordingly. In order to protect the delicate spectrometer mechanism with a first resonance frequency at 110 Hz the the response of the top of the SMEC was limted to the input specification.

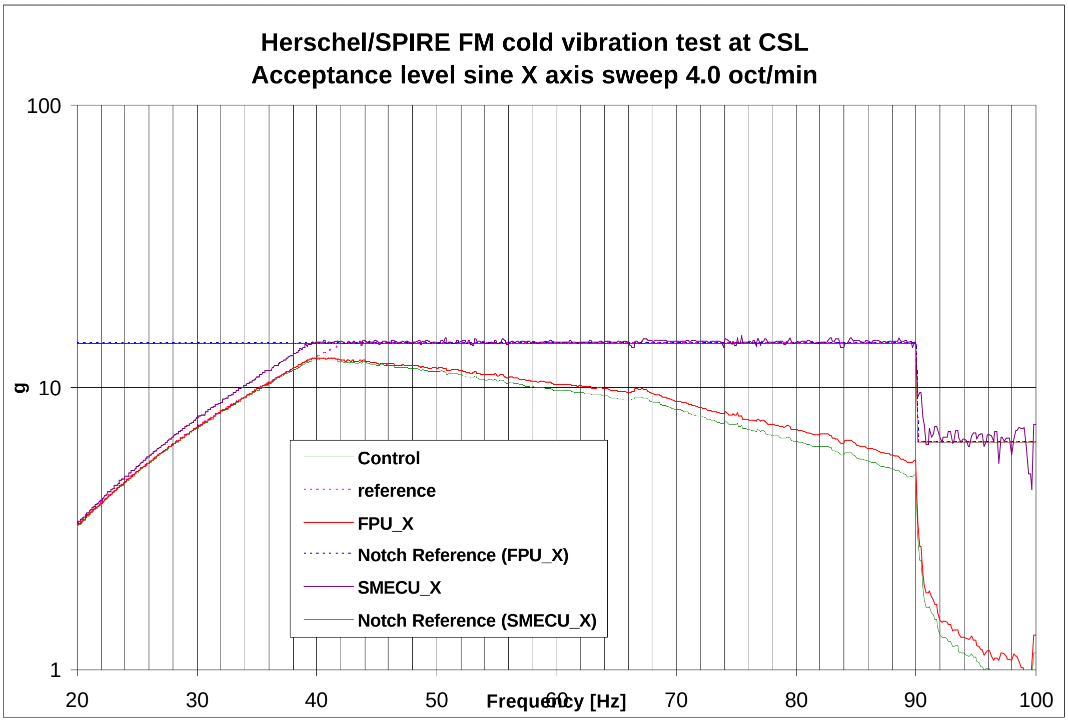


Figure 8.4-1 Achieved inputs for the X direction

Since during possible subsequent workmanship test no test instrumentation will be mounted internally the measured response of the FPU_X on the outside of the instrument will be used as a notch reference for future workmanship tests.

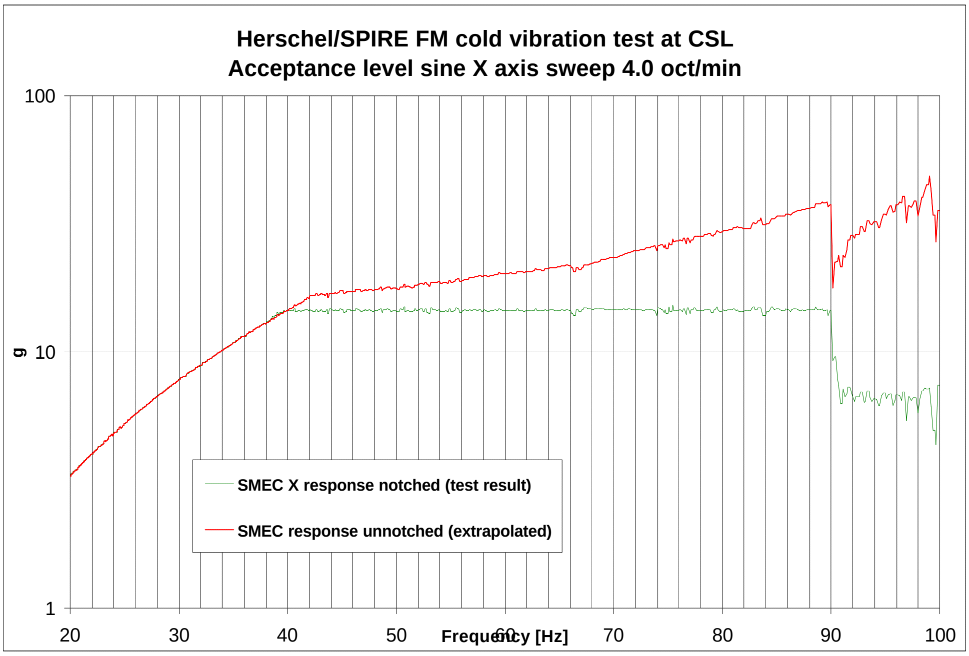


Figure 8.4-2 Measured and extrapolated X direction response of SMEC

Figure 8.4-2 shows the actual measured response (limited to the specified input, green bottom line) of the top part of the spectrometer mechanism and the extrapolated response of this mechanism if we had limited the response of the instrument just based on the CoG response. The SMEC response would have been too high, exceeding its qualified level of 20 g.

Achieved Levels and discussion Y-AXIS

A similar strategy was followed for the Y-axis. The Y-axis has a flat input of 6.4 g up to 75 Hz. Then it is lowered down to 4.8 g at 75 Hz and continued to 100 Hz. This was the first axis tested at CSL. Figure 8.4-3 shows the responses. The response of the CoG was limited to the specified input. The notch level for the CoG was set via the FPU_Y where the amplification factor between FPU_Y and CoG was taken into account.

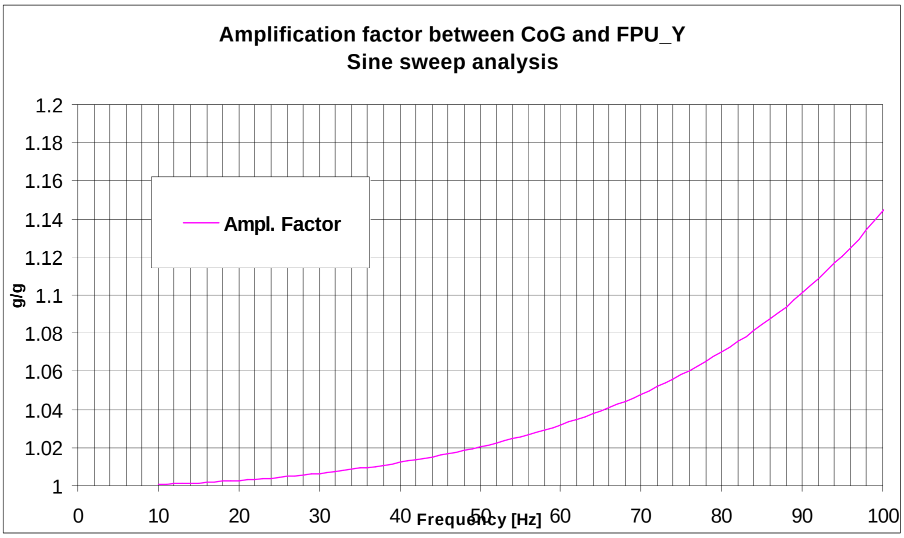


Figure 8.4-3: Amplification factor between CoG response and FPU_Y

The CoG response was limited to the specified input by notching the FPU_Y response to 6.7 g below 75 Hz and to 5.5 g above 75 Hz. The levels were set by the amplification as shown in figure 8.4-3.

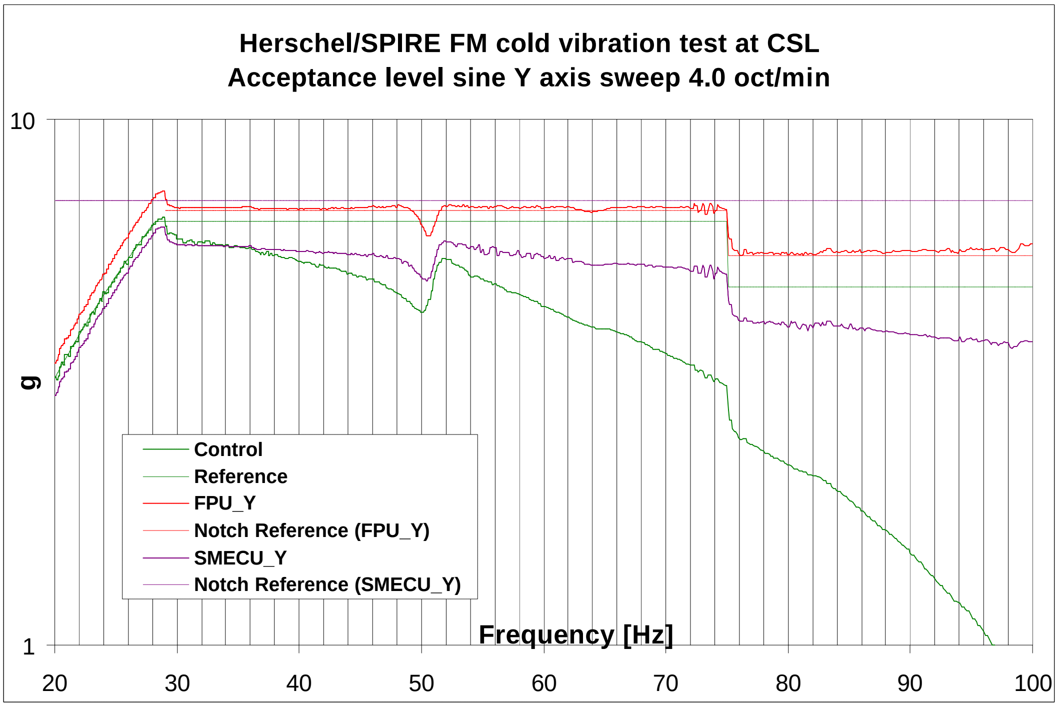


Figure 8.4-4 Achieved responses for the Y direction

Various points on detector boxes and SMEC.

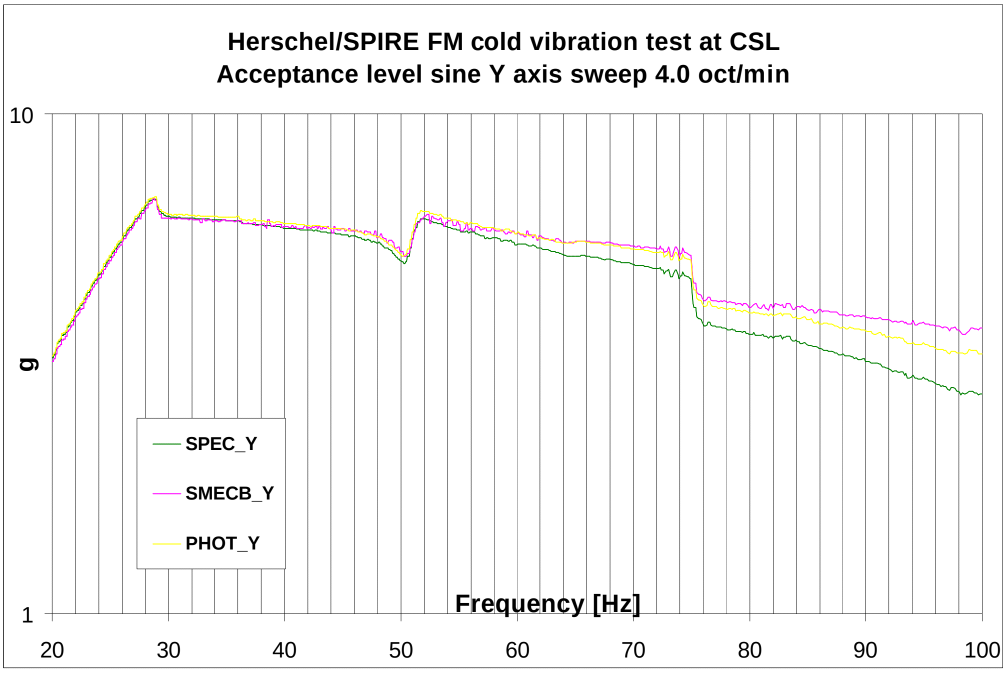


Figure 8.4-5 Achieved responses for the Y direction (continued)

Achieved Levels and discussion Z-AXIS

For the Z-axis the problem was to protect the Spectrometer mechanism. The SMEC_Z accelerometer showed during previous runs a significant amplification, shown in figure 8.4-6.

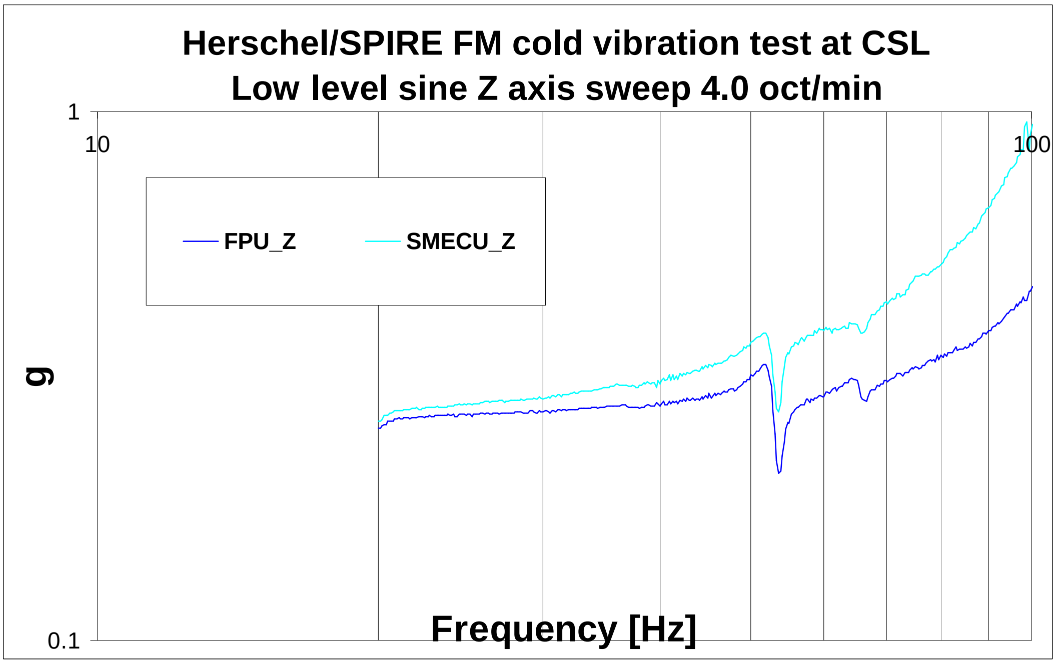


Figure 8.4-6 FPU_Z and SMECU_Z response (low level)

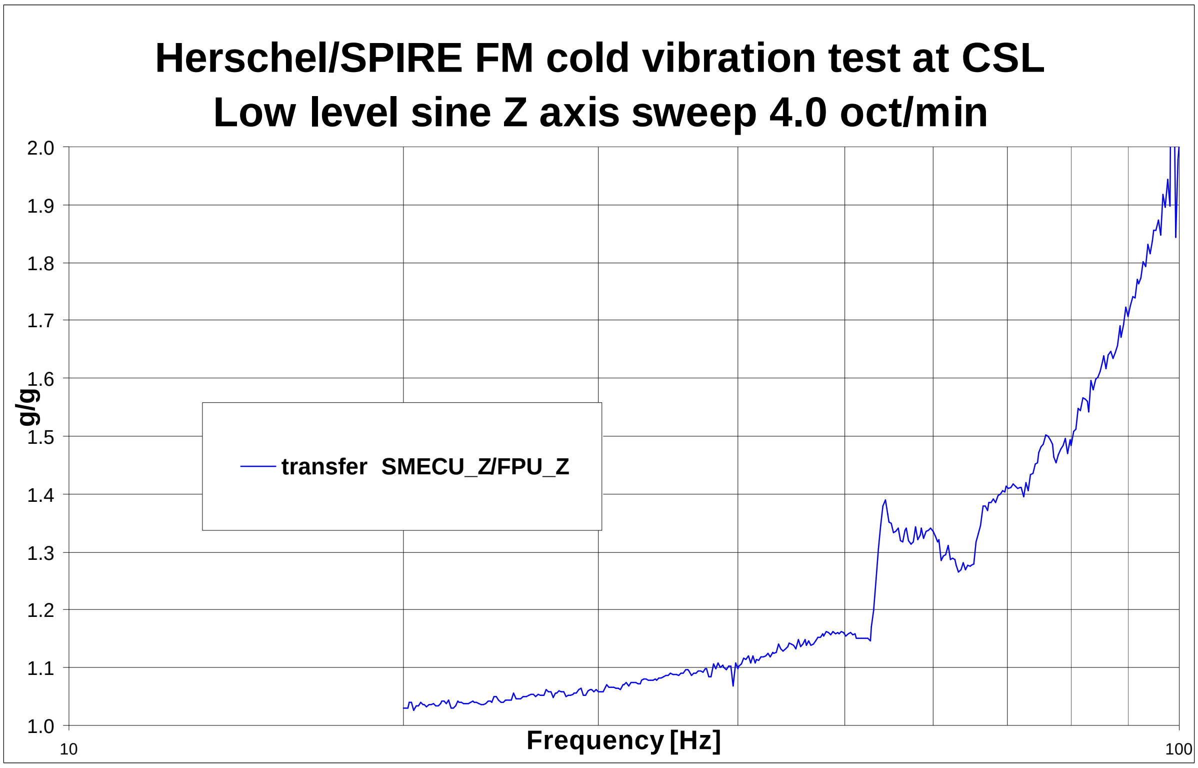


Figure 8.4-7 FPU_Z and SMECU_Z transfer function (low level)

After the first low level run the SMECU_Z signal was lost, in order to prevent subjecting the SMEC to loads higher than its acceptance levels the response of the FPU_Z was notched to protect the SMEC (indirectly) using the transfer function displayed in figure 8.4-6.

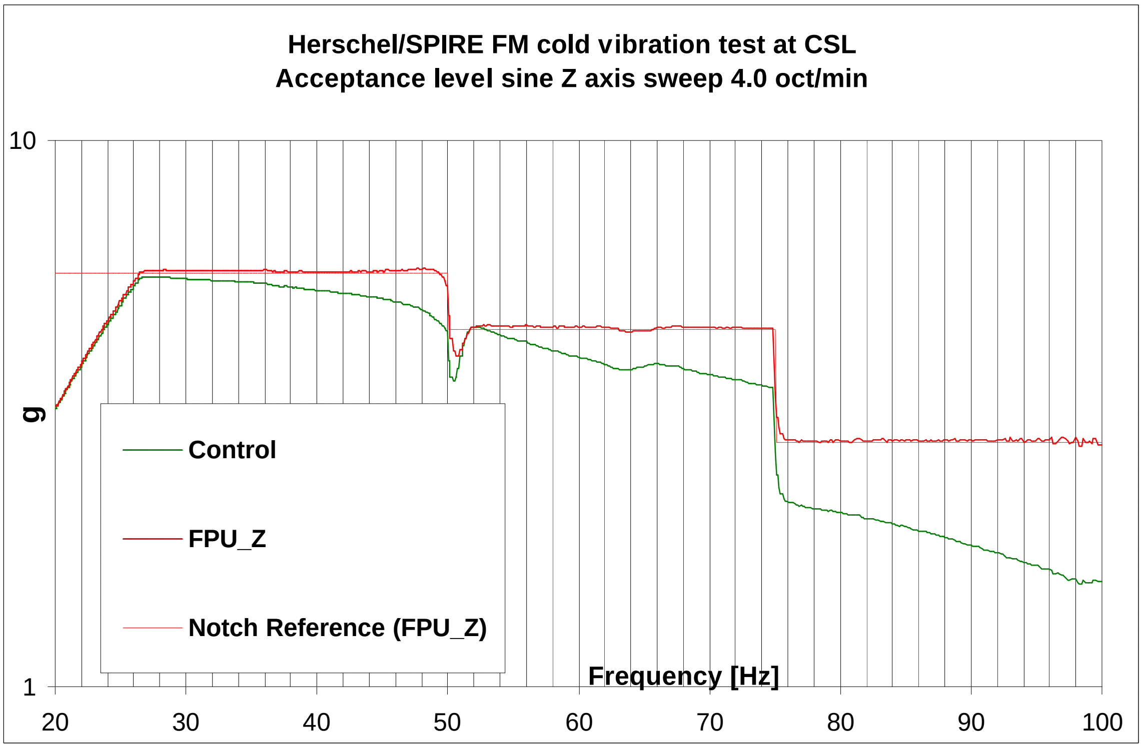


Figure 8.4-8 Achieved inputs for the Z direction

Figure 8.4-8 shows the achieved response of the FPU_Z. A third order interpolation function was used to approximate the transfer function (using the least square method), shown in figure 8.4-9. This was necessary (for this report) in order to display the achieved SMECU_Z response, based on this function. The interpolation needed to be carried out in order to account for different frequency samplings within the different recorded traces.

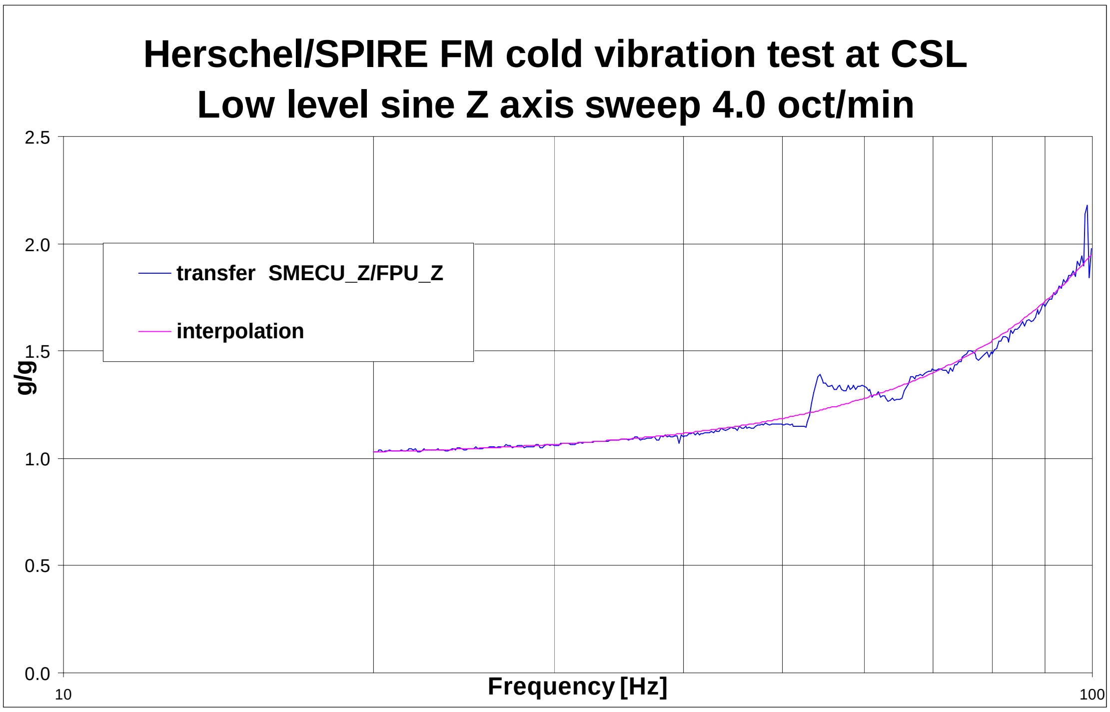


Figure 8.4-9: Transfer function and interpolation (required to scale functions with different frequency spacings)

The reconstructed SMECU_Z response is given in figure 8.4-10.

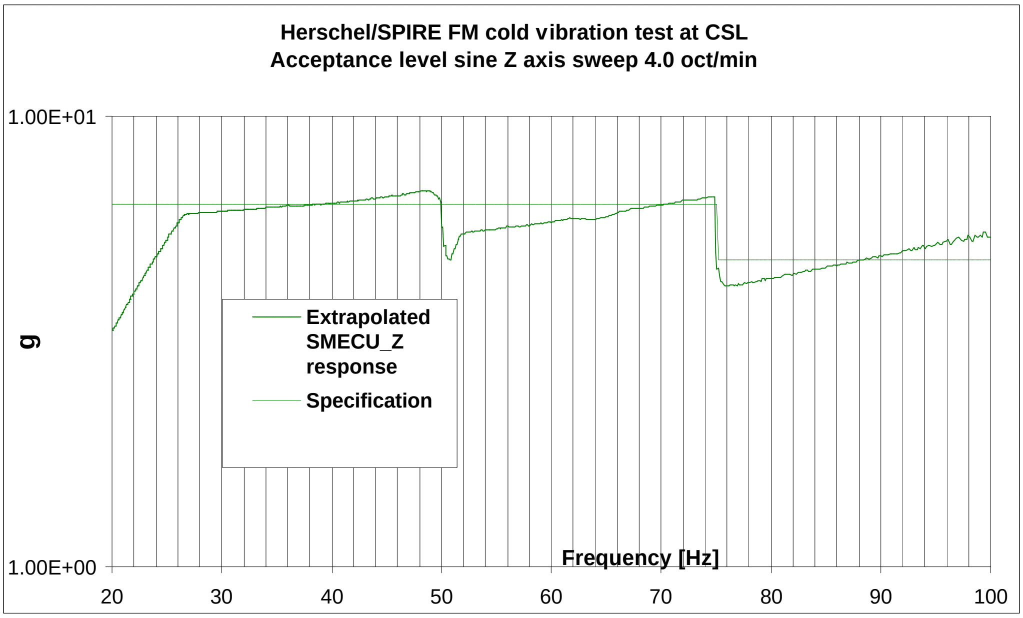


Figure 8.4-10 The reconstructed SMECU_Z response

The reconstruction in figure 8.4-10 shows that the SMEC did not exceed the acceptance level by more than 7% to 13%.

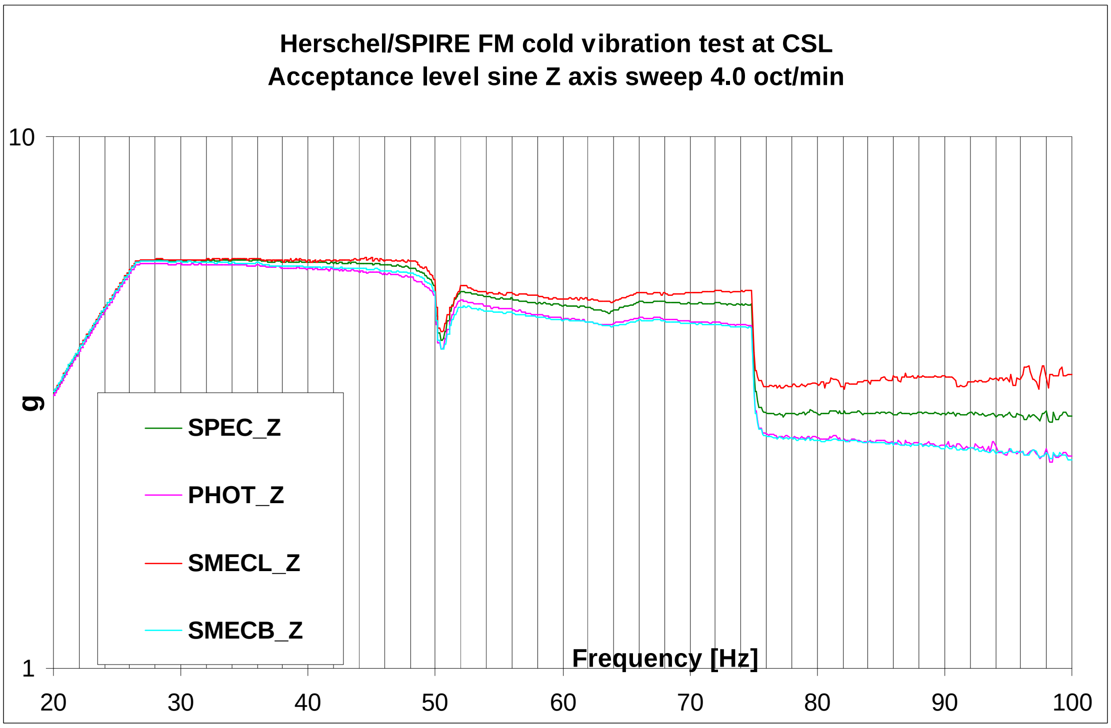


Figure 8.4-11 Achieved inputs for the Z direction (continued)

8.5. Random vibration test

See AD12 for all response curves.

As stated in AD(9) the acceptance levels were defined as follows.

Y and Z axis

Frequency Range Hz	Qualification level
20-100	+3dB/Oct
100-150	0.0128 g^2/Hz
150-300	0.008g^2/Hz
300-2000	-12 dB/Oct
Global	2.0 g-rms

Table 8.5-1: Y and Z axis input definition for random acceptance

Test duration 1 minutes in each axis

X axis

Frequency Range Hz	Qualification level
20-100	+3dB/Oct
100-150	0.032 g^2/Hz
150-300	0.0128g^2/Hz
300-2000	-12 dB/Oct
Global	2.8 g-rms

Table 8.5-2: X axis input definition random acceptance

Test duration 1 minute

Input definition (control)

For each test the input was specified via the average response of the accelerometers located on the shaker table near the feet of the instrument. For all tests this was the average over 3 accelerometers.

Notching

For all (but X-axis) random tests force notching was applied as well as notching on the responses of some of the components on the SPIRE optical bench.

Force Notching

Force notching was done indirectly via the instrument CoG response. As a minimum, a clear response should be present in the first mode indicating a significant amount of modal mass. Secondly notching on interface force is not allowed significantly beyond the first resonance frequency. In principle notching should be limited around the first eigenfrequency up to 1.5 times the first eigenfrequency (2.0 times if needed but not allowed to extend beyond twice the first eigenfrequency). When there is no clear first response mode present (effective mass spread out over the first few modes) indirect (by limiting the acceleration response) force notching is not allowed.

Detector response notching

Notching on the detector responses was performed indirectly, as was done during the CQM testing. The notching had to be done indirectly since it is not even close to practical to measure the detector responses directly. The notching was performed on a detector response as predicted by the miles equation. The internal (mechanical sensitive) part of each detector is a 300 mK Kevlar suspended stage with a mass between 0.1 to 0.3 kg.

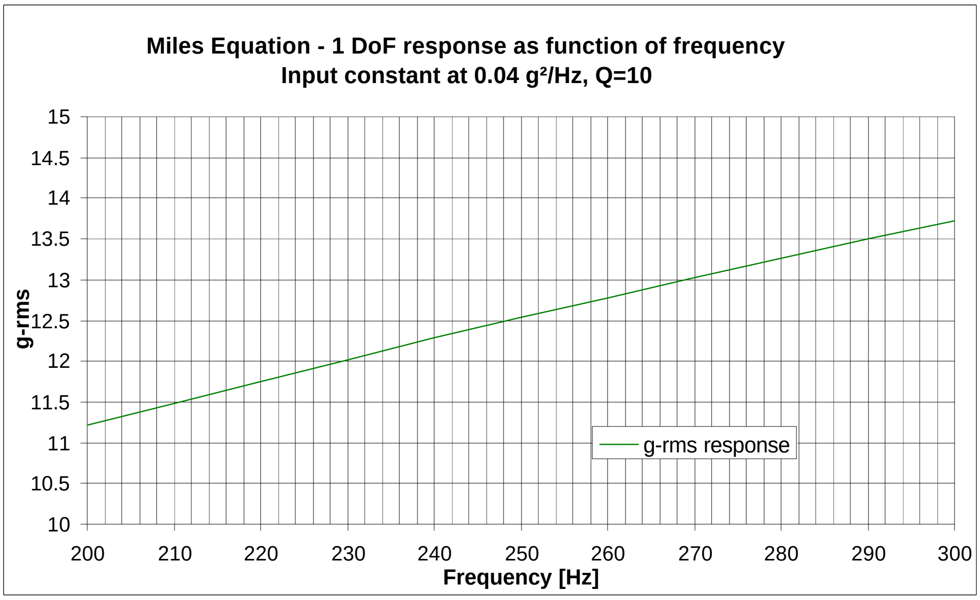


Figure 8.5-3: Miles response (as a function of frequency)

The graph shown in 8.5-3 shows extrapolated detector response as function of detector box response. The notching on detector response follows the curve shown in figure 8.5-3 limiting the response of the detector boxes to 0.04 g^2/Hz and indirectly the detectors to about 11 g-rms (1-sigma) where the detectors are qualified for 15 g-rms. The detectors have first resonances between 200 and 300 Hz. In the Z-axis a mistake was made where the input to the detectors was limited to 0.004 g^2/Hz, due to a wrong reference in a graph.

Spectrometer mechanism

The responses of the SMEC were measured directly and the responses were limited to around 8 grms. On top of that the quasi-static responses were limted to the input specification (which was important for the X-axis notching).

Achieved Levels and discussion X-AXIS

For the X axis it was decided not to notch on equivalent quasi-static interface forces since the overall response of the instrument at lower frequencies showed that the interface force would not exceed the equivalent QS-interface force (effective mass is spread out). The only notch applied was therefore to protect the detectors and the spectrometer mechanism.

Because in the future workmanship testing has to be performed without any accelerometers mounted on the inside of the instrument it was decided to actively notch on the FPU_X accelerometer only.

The notching applied on this accelerometer is to prevent over testing of the SMEC in particular. The SMEC has its first resonance frequency in the 110-120 Hz range. See figure 8.5-2 for comparison between FPU and SMEC_U response in X. The input is 0.25 g average over the three mounting points of the instrument.

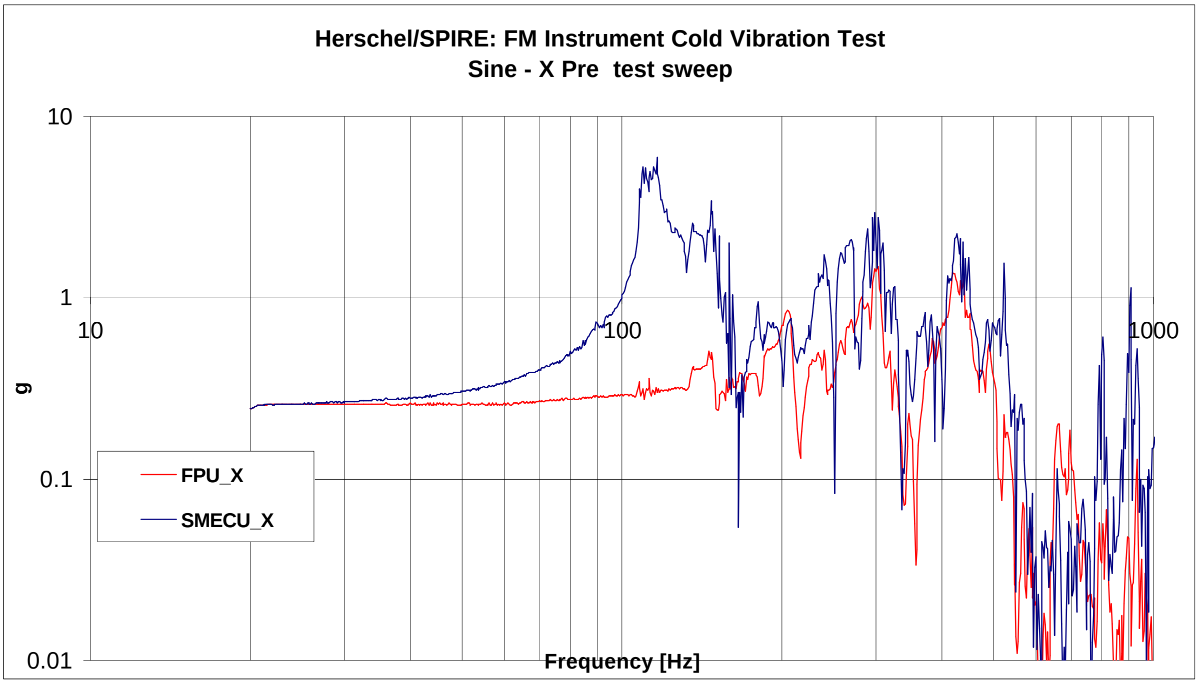


Figure 8.5-2: Filtered low level sine sweep response, note the (jagged) response of the SMEC between 110 and 120 Hz.

The SMECU_X response is strongly influenced by the play on the pinion that holds the moving part of the mechanism in place. As a result the response is not 'clean' and influenced by rattle/shockloads. Never the less, the first mode is clearly present and the loading of the SMEC as a result serious.

The low level random sweep gave the rms-levels listed in table 8.5-3.

Frequency range	FPU_X (g-rms)	FPU_Y (g-rms)	FPU_Z (g-rms)	SMECU_X (g-rms)	SMECU_Y (g-rms)	SMECB_X (g-rms)	SMECB_Y (g-rms)	SMECB_Z (g-rms)
20 - 300 Hz	0.99	0.98	1.18	5.91	1.72	1.05	0.82	0.84
20 - 700 Hz	1.09	1.02	1.21	6.76	2.05	1.10	0.89	0.88
20 - 2000 Hz	1.11	1.11	1.26	9.04	4.51	1.83	3.33	2.37

Table 8.5-3: Measured g-rms levels (at -12 dB), calculated over different frequency domains

From table 8.5-3 it can be concluded that there is no need for force notching in X direction during random vibration, maximum response of the main structure will be below 5 g-rms. There is however significant cross-coupling in Y and Z potentially exceeding the qualification levels in Y and Z.

The SMEC responses show significant responses in both X and Y. The SMECU_X response will be between 25-30 g-rms if no notching is applied. In order to protect the SMEC and to comply with the maximum response level for the SMEC in any direction of 8 g-rms the response has to be limited for the acceptance run. Notching in the 115 Hz region (first eigenmode for the SMEC) would not reduce the response enough and the response of the SMEC had to be limited all the way up to 700 Hz to stay within limits.

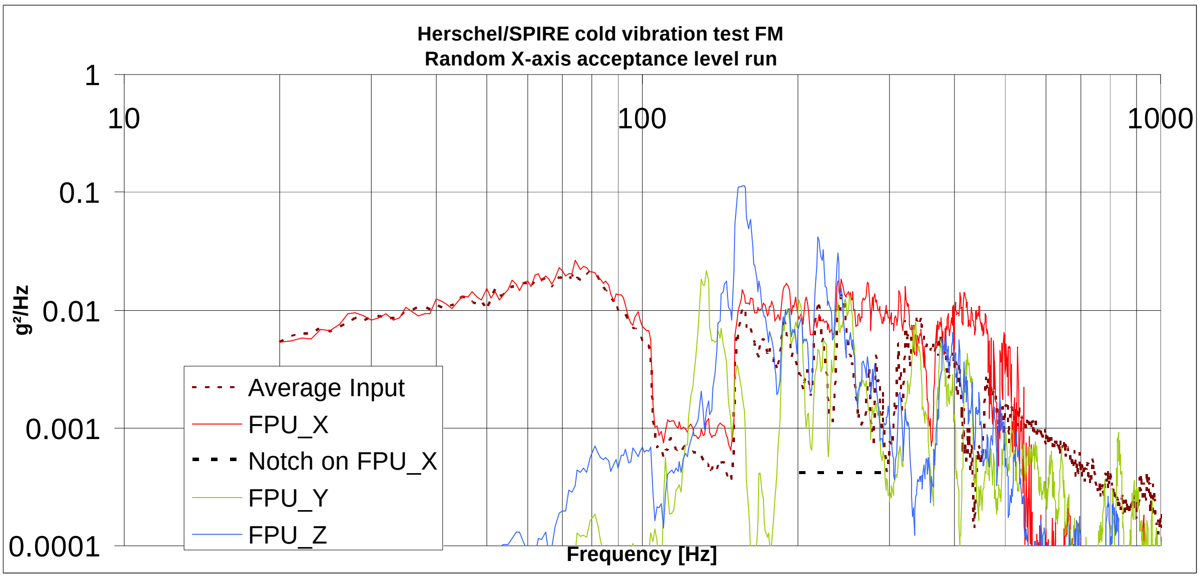


Figure 8.5-4 Achieved random responses in X main structure

Figure 8.5-4 shows the input and achieved levels for the main structure together with the applied notch. The notch was there to protect the spectrometer mechanism. As stated before, only responses on the outside of the instrument were limited for this axis only since the same control can be used during workmanship test.

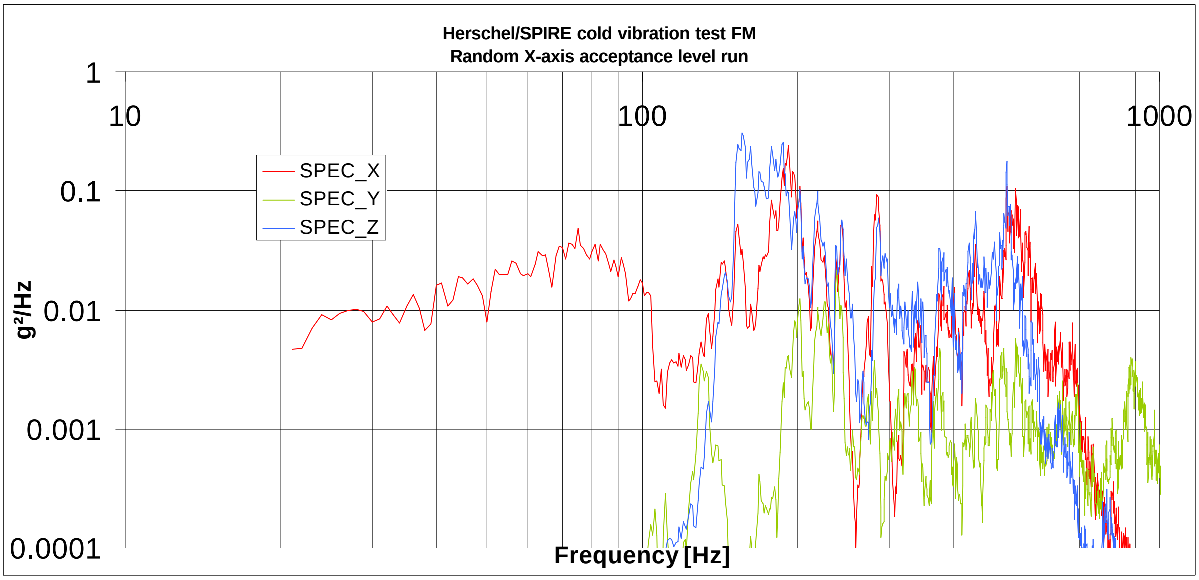


Figure 8.5-5 Achieved random input for spectrometer detector box

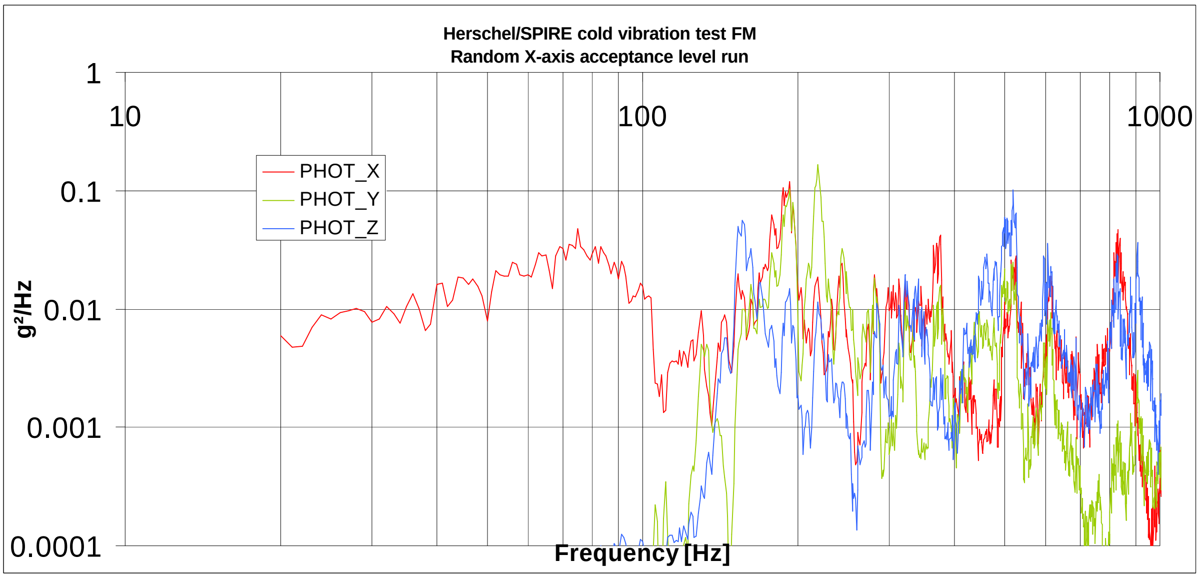


Figure 8.5-6 Achieved random input for photometer detector box

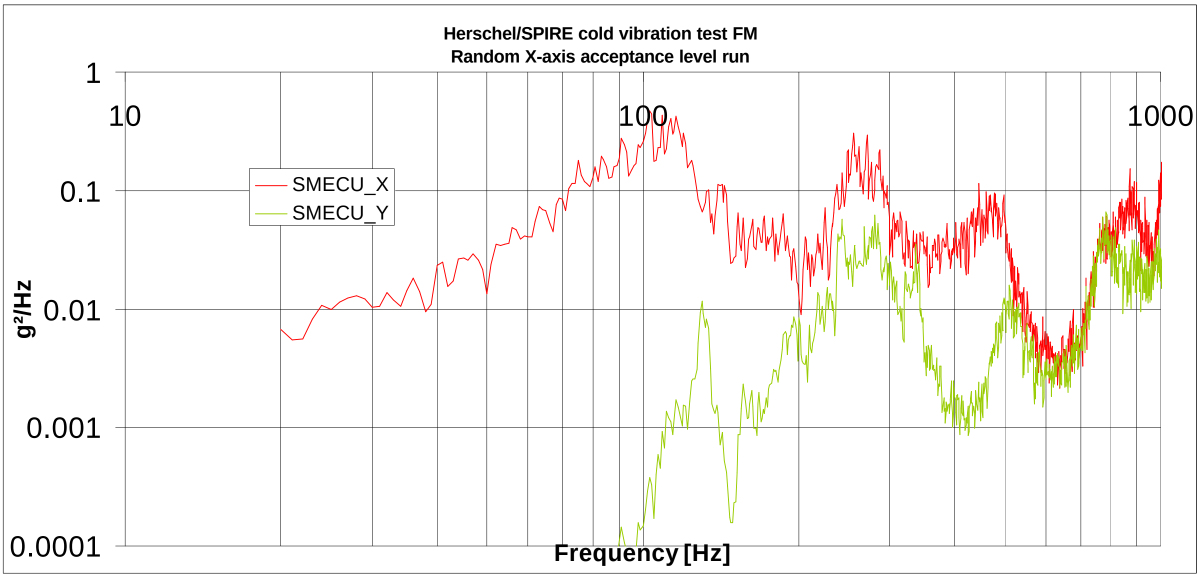


Figure 8.5-7 Achieved random input for the top of the spectrometer mechanism

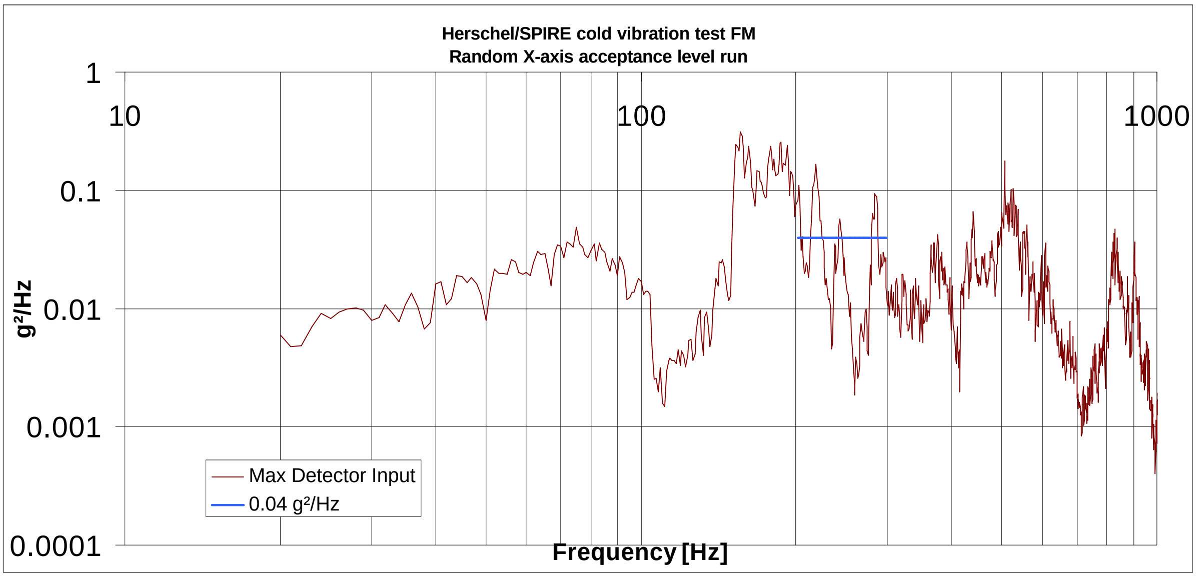


Figure 8.5-8 Maximum random input for (envelope) for the detectors

	Control		FPU_X	FPU_Y	FPU_Z	SPEC_X	SPEC_Z	SPEC_Y	PHOT_X	PHOT_Z	PHOT_Y
20-300 Hz	1.31		1.68	0.85	1.54	2.78	**3.20**	0.69	2.15	1.06	1.85
20-700 Hz	1.58		2.07	1.05	1.64	3.55	3.95	0.98	2.66	2.34	2.23
20-2000 Hz	1.63		2.08	1.25	1.72	3.56	3.96	1.22	2.96	2.70	2.34
			SMECL_X	SMECL_Y	SMECL_Z	SMECU_X	SMECU_Y	SMECU_Z	SMECB_X	SMECB_Y	SMECB_Z
20-300 Hz			**3.46**	1.57	**4.21**	**5.28**	1.63	*	1.62	0.78	0.99
20-700 Hz			4.55	2.56	**4.71**	**6.23**	2.19	*	1.81	1.00	1.10
20-2000 Hz			4.81	2.92	**5.16**	**8.77**	4.76	*	2.81	4.23	3.10

Table 8.5-9 Achieved g-rms over diffent frequency bands during X-axis vibration

Achieved Levels and discussion Y-AXIS

For the Y-axis a notch was implemented on the interface force as well on the spectrometer detector box to limit the input to the detectors at 0.04 g²/Hz. There was no need to limit the input to protect the SMec.

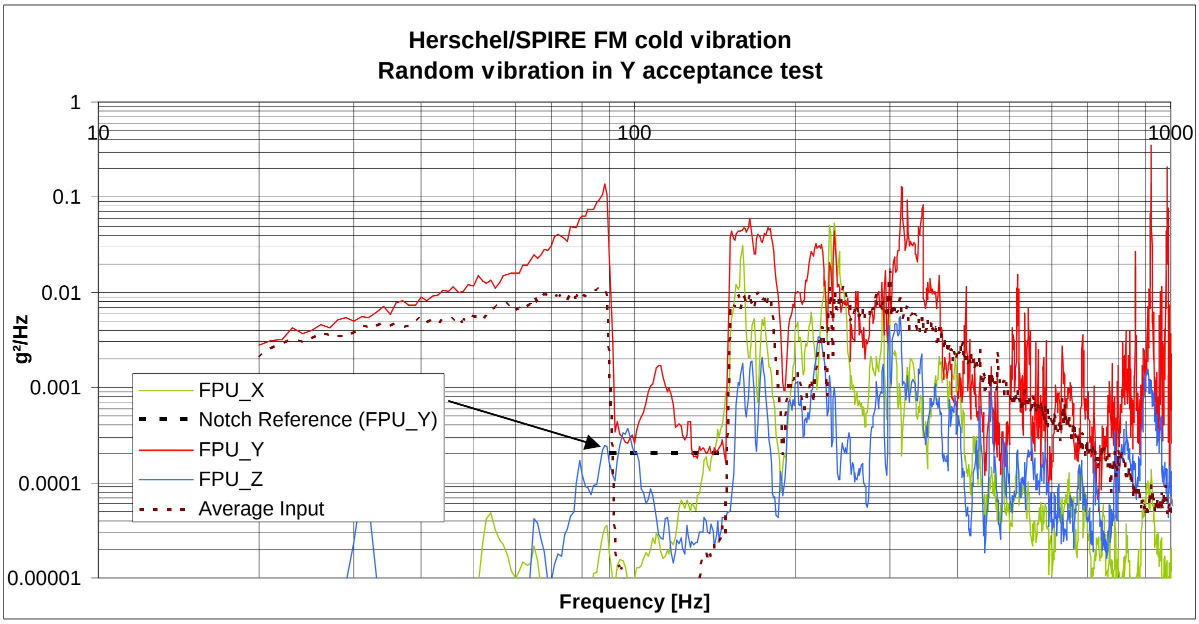


Figure 8.5-10 Achieved random responses in Ymain structure, arrow points to notch level

Figure 8.5-10 shows the FPY response with the FPU_Y response in 3-sigma well over the required 6.4 g equivalent.

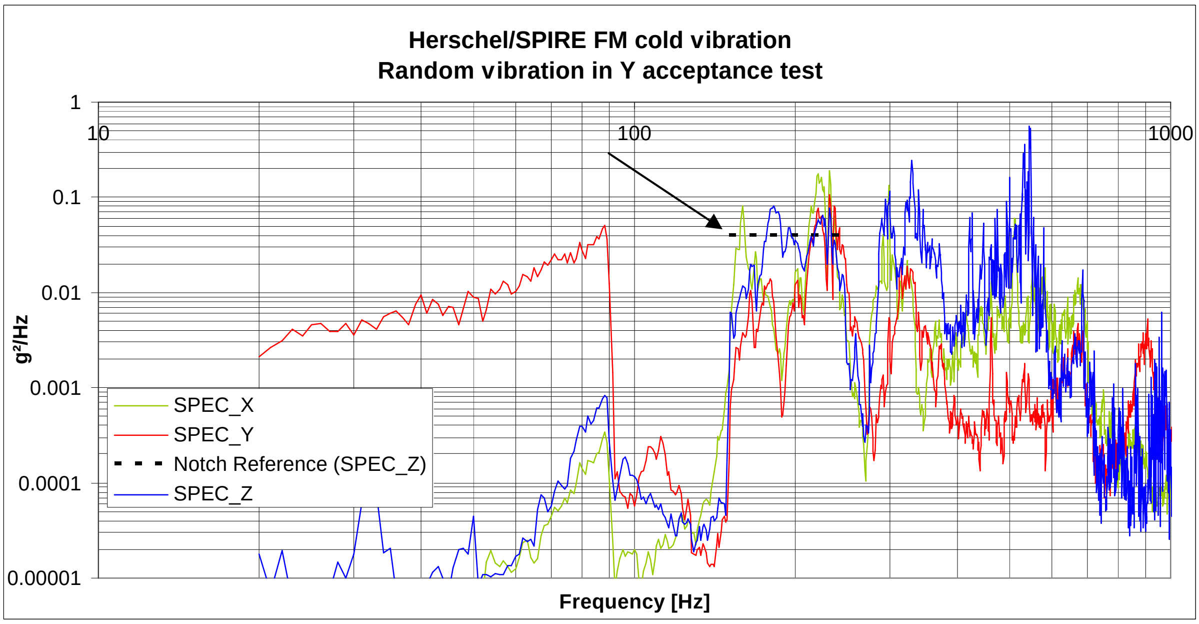


Figure 8.5-11 Y-axis response graph for spectrometer detector box, arrow points to notch level

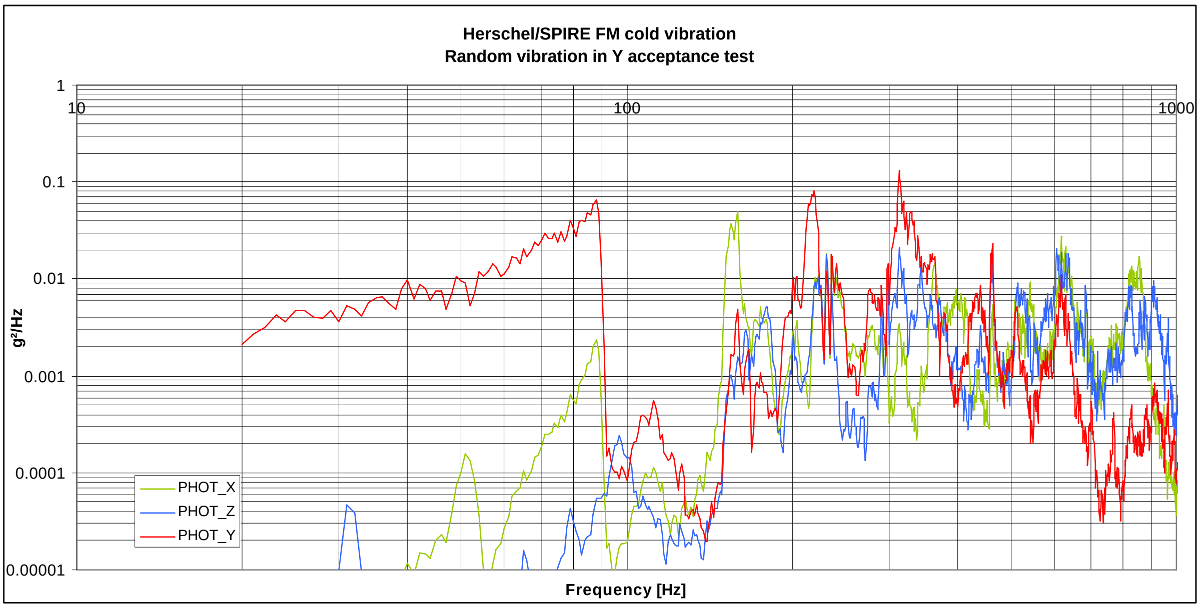


Figure 8.5-12 Y-axis response graph for photometer detector box

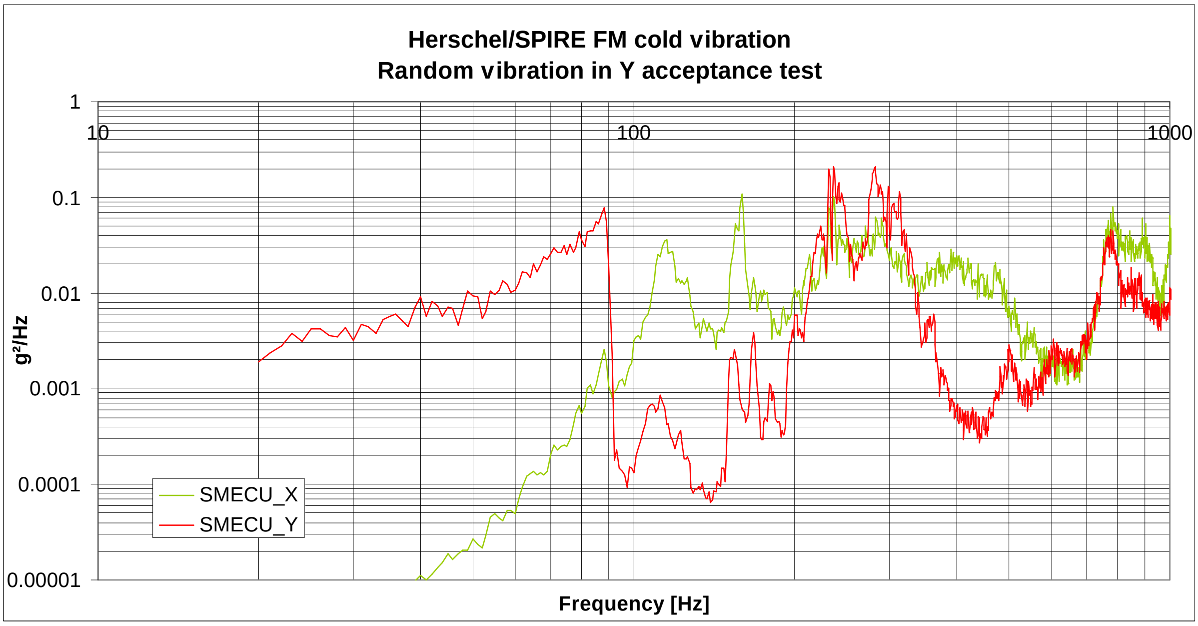


Figure 8.5-13 Achieved random input for the top of the spectrometer mechanism

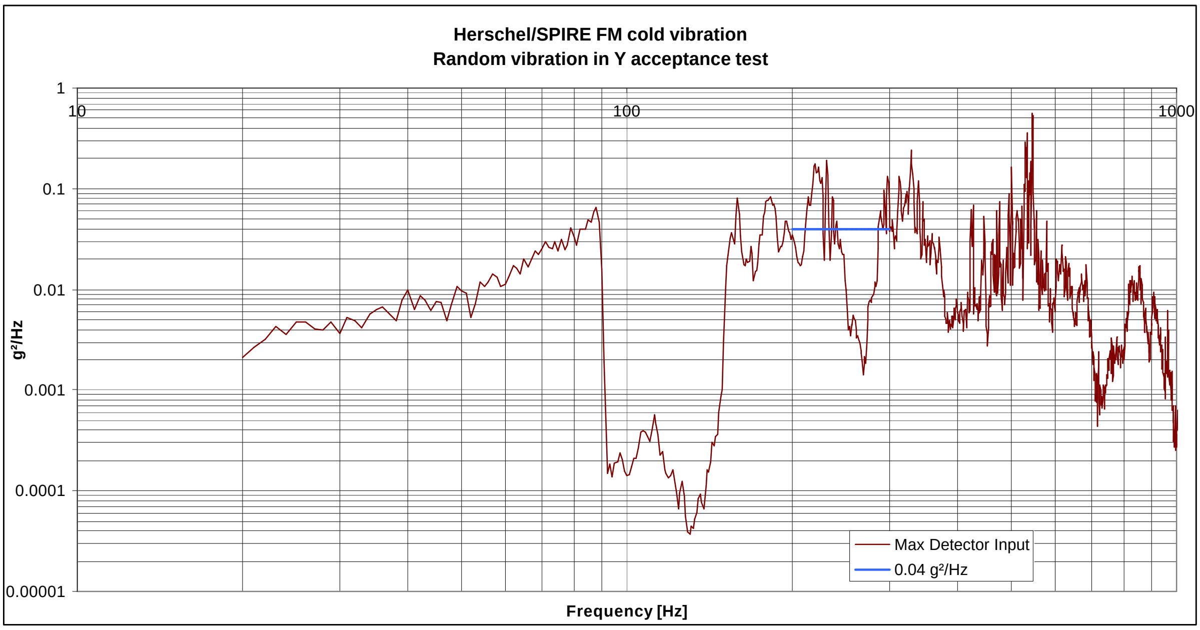


Figure 8.5-14 Maximum random input for (envelope) for the detectors

	Reference	FPU_X	FPU_Y	FPU_Z	SPEC_X	SPEC_Y	SPEC_Z	PHOT_X	PHOT_Z	PHOT_Y
20-250 Hz	1.63	0.95	2.38	0.43	2.11	1.85	2.41	0.92	0.75	1.97
20-700 Hz	1.79	1.00	2.64	0.52	2.61	1.98	3.89	1.54	1.47	2.30
20-2000 Hz	1.80	1.02	2.98	0.64	2.63	2.08	3.91	1.79	1.73	2.36
	SMECU_X	SMECU_Y	SMECB_X	SMECB_Y	SMECB_Z					
20-250 Hz	2.26	3.06	0.75	1.64	0.49					
20-700 Hz	2.89	3.20	0.84	1.70	0.55					
20-2000 Hz	4.79	4.21	1.53	3.37	2.15					

Table 8.5-15 Achieved g-rms over diffent frequency bands during Y-axis vibration

Achieved Levels and discussion Z-AXIS

As for the Y-axis force notching was applied at the CoG but now between 120 and 170 Hz. Trying to achieve 2.1 g-rms up to about 290 Hz. The achieved level was 1.8 g-rms, slightly below the goal.

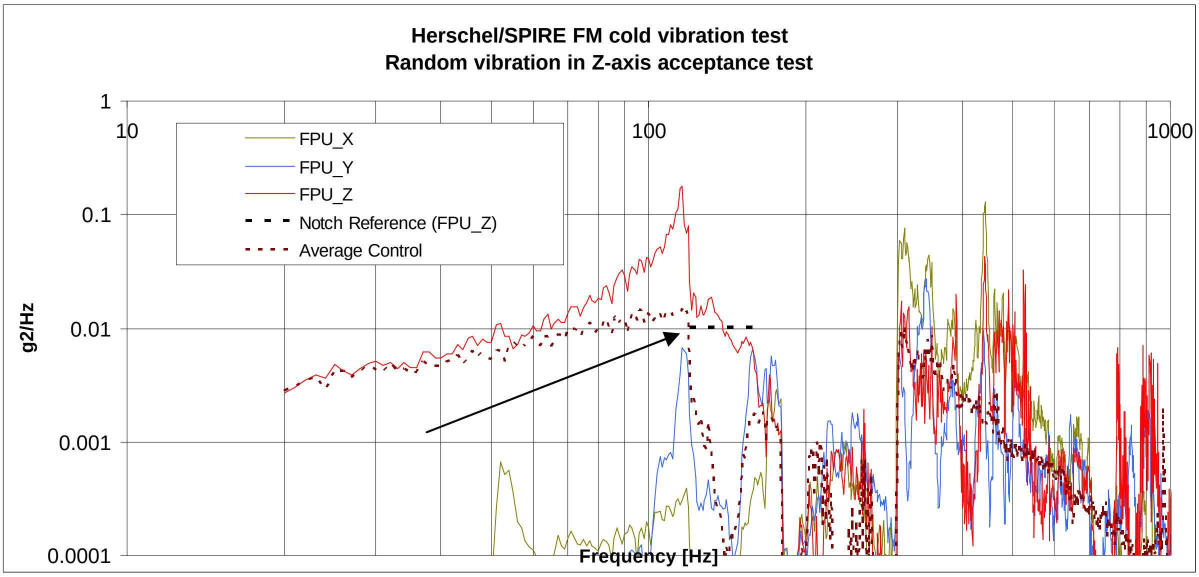


Table 8.5-16 Achieved random responses in Zain structure, arrow points to notch level

The detector box response was limited for botht the spectrometer and for the photometer detector box. During the assessment of the notching the wrong graph was used to set the notching levels for the detector boxes at 0.004 g^2/Hz instead of 0.04 g^2/Hz.

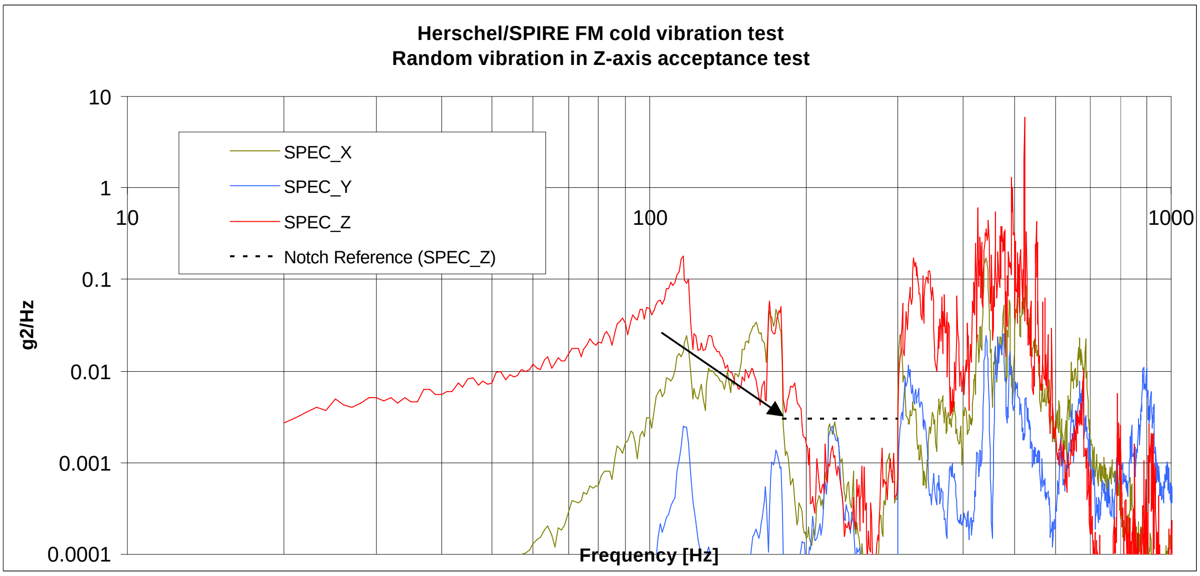


Table 8.5-17 -axis achieved spectrometer box levels

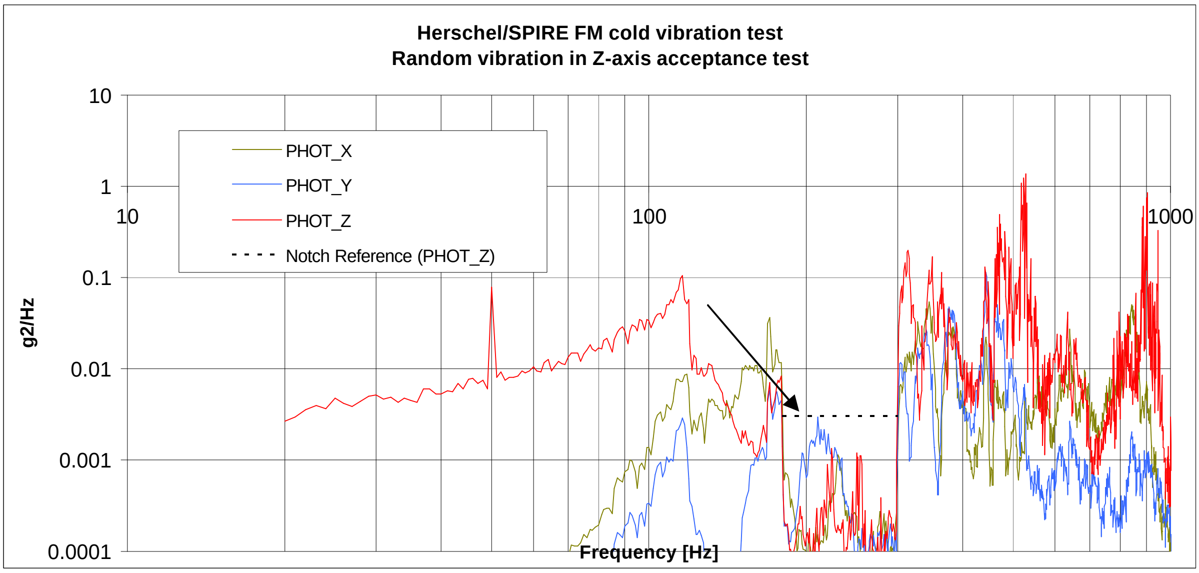


Table 8.5-18 Z-axis achieved photometer box levels

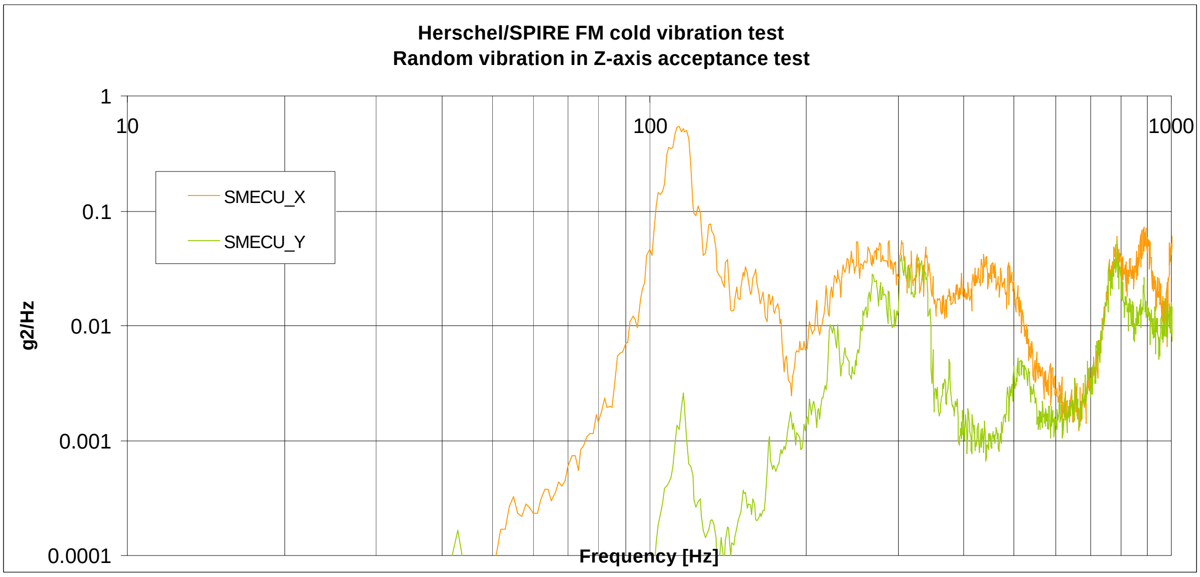


Table 8.5-19 Z-axis achieved photometer box levels

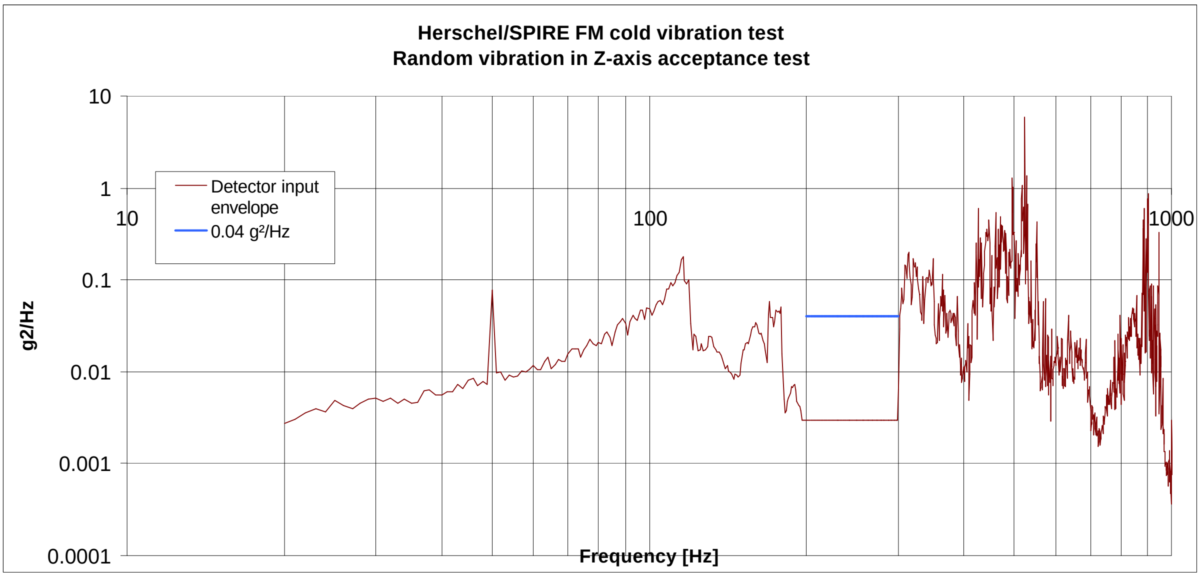


Table 8.5-20 Z-axis achieved detector input levels, too deeply notched between 200 ad 300 Hz

	Control	FPU_X	FPU_Y	FPU_Z			
20-300 Hz	0.98	0.31	0.47	1.77			
20-700 Hz	1.31	2.00	0.99	2.12			
20-2000 Hz	1.34	2.03	1.27	2.29			
	SPEC_X	SPEC_Y	SPEC_Z	PHOT_X	PHOT_Y	PHOT_Z	
20-300 Hz	1.18	0.26	2.04	0.79	0.41	1.58	
20-700 Hz	2.78	1.19	6.32	1.87	1.86	5.03	
20-2000 Hz	2.82	1.49	6.33	2.41	1.97	5.99	
	SMECL_X	SMECL_Y	SMECU_X	SMECU_Y	SMECB_X	SMECB_Y	SMECB_Z
20-300 Hz	1.55	1.95	3.43	1.04	0.55	0.34	1.43
20-700 Hz	2.68	3.15	4.20	1.75	1.14	0.73	1.68
20-2000 Hz	2.91	3.31	6.13	3.55	1.87	3.21	2.76

Achieved g-rms over diffent frequency bands during Z-axis vibration

Overall the response level during the Z-axis has been slightly below the goal of 6.4 g equivalent on interface force.

8.6. Measurement of subsystem levels

N.A.

8.7. Post test inspection

On return to RAL an incoming inspection was carried out, and is documented in SPIRE-RAL-REP-002579. No anomalies were found.
The SMEC DM was removed and the CQM fitted for the next cold test campaign.

8.8. Main resonance frequencies found

Main frequencies [Hz]		
X-axis		
Warm	Cold CQM	COLD FM
176	158	145
206	193	205
219	212	207
314	300	300
Y-axis		
Warm	Cold CQM	COLD FM
122	129	112
197	210	206
249	228	218
Z-axis		
Warm	Cold CQM	COLD FM
137	148	141
202	205	194

8.7-1: Main frequencies

The listed frequencies are from the warm STM test, the cold CQM test and the cold FM test. There are a few things that are different between the warm and the cold STM test. First of all the instrument mass went up with about 12%, but this is countered by the increase in stiffness due to the lower temperatures (typically 5% to 10%). The rest is the influence of the coupled vibration with the CSL shaker, which in general lowers the frequencies or clusters modes. The cold FM test has again slightly lower frequencies due to the slightly more flexible A-frames. The original stainless steel A-frames (CQM) were replaced by CFRP re-engineered frames (FM).

9. REJECTION AND RETEST

No test run was rejected or a re-test performed. Several attempts were made to continue an aborted low level sine-sweep. But because of the inherent problem of the shaker (flexibility of the table mounting) it was decided to accept sweeps up to 500 Hz as a minimum, but all sweeps were successful up to 2000 Hz.

During the Z-axis the FPU responses showed signs of degradation after the sine test. The test was aborted and the instrument warmed up. The CFRP cone showed small radial cracks around the top spigot and was replaced by a stainless steel cone (as used during CQM testing). The Z-axis acceptance test repeated the sine test and finished with the random tests following the test sequence, repeating the sine vibration test. The Z-axis was performed successfully.

Appendix A – Intrumentation specification

The instrumentation consisted of two types of accelerometers. The first type is the cold-vibration accelerometers provided for by CSL. The second type warm-vibration accelerometers provided for by RAL. The warm-vibration accelerometers were not calibrated at the structure temperature at which we vibrated. However cold-vibration accelerometer readings (pointing in the same direction) were used during the test within the quasi-static frequency range as a reference for in-situ calibration.

- At each mounting point of the instrument (interface with vibration fixture for control, 3 tri-ax cold-vibration accelerometers in total)
- Top of the optical bench in instrument coordinates: FPU X,Y and Z (tri-ax co-aligned with S/C coordinates)
- On the photometer detector box PHOT X,Y and Z (tri-ax co-aligned with S/C coordinates
- On the spectrometer detector box SPEC X,Y and Z (tri-ax co-aligned with S/C coordinates
- At various locations on the spectrometer mechanism (SMEC), top of mechanism, base and bottom.

The SMEC accelerometers used were not cryogenic accelerometers and were calibrated in situ. During the test it appeared that the SMECU_Z malfunctioned as well as all the SMECB accelerometers.

The implemented instrumentation:

The numbering used during the tests was as follows (only accelerometers mounted in/on the instrument are listed):

Accelerometer allocation

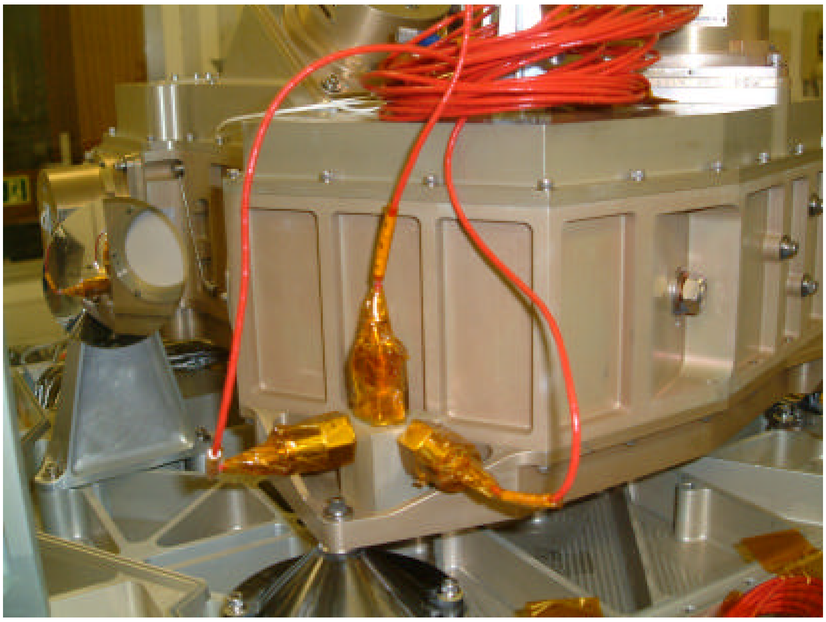
Channel No	Location	Type	Serial no	Code	Axis	Feed thro'
F65	Photometer detector box	7724	12376	PHOTX	X	1
F71	Photometer detector box	7724	12371	PHOTY	Y	2
F53	Photometer detector box	7724	12373	PHOTZ	Z	3
F66	FPU top of optics bench over cone	7724	12372	FPUX	X	4
F69	FPU top	7724	12381	FPUY	Y	5
F52	FPU top	7724	13433	FPUZ	Z	6
F68	Spectrometer detector box	7724	13424	SPECX	X	7
F73	Spectrometer detector box	7724	13416	SPECY	Y	8
F54	Spectrometer detector box	7724	13414	SPECZ	Z	9
*	SMEC moving	2222C	32974	SMECLX	X	10

	carriage 1.284pC/g					
*	SMEC moving carriage 1.606pC/g	2222C	32977	SMECLY	Y	11
*	SMEC moving carriage 1.627pC/g	2222C	32976	SMECLZ	Z	12
*	SMEC top 1.262pC/g	2222C	32975	SMECUX	X	13
*	SMEC top 1.692pC/g	2222C	26087	SMECUY	Y	14
*	SMEC top 1.373pC/g	2222C	AJC49	SMECUZ	Z	15
*	SMEC base plate 14.02 pC/g	2272	YG32	SMECBX	X	16
*	SMEC base plate 1.618pC/g	2222C	AADN7	SMECBY	Y	17
*	SMEC base plate 1.306pC/g	2222C	32978	SMECBZ	Z	18

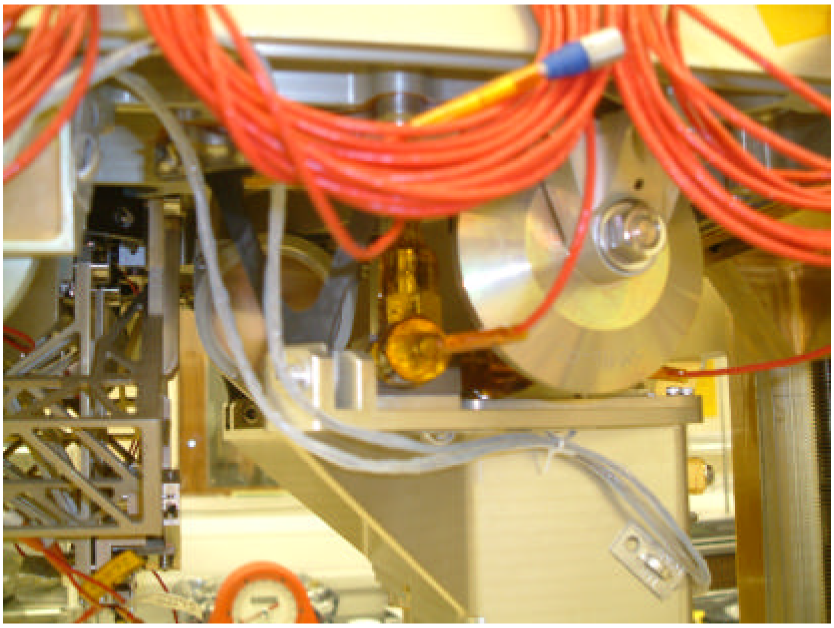
* are not cold-vibration accelerometers, they were calibrated during the tests

Not all accelerometers were working properly during all tests. Due to the extreme test environment and the routing between the accelerometer and the readout electronics this is not surprising.

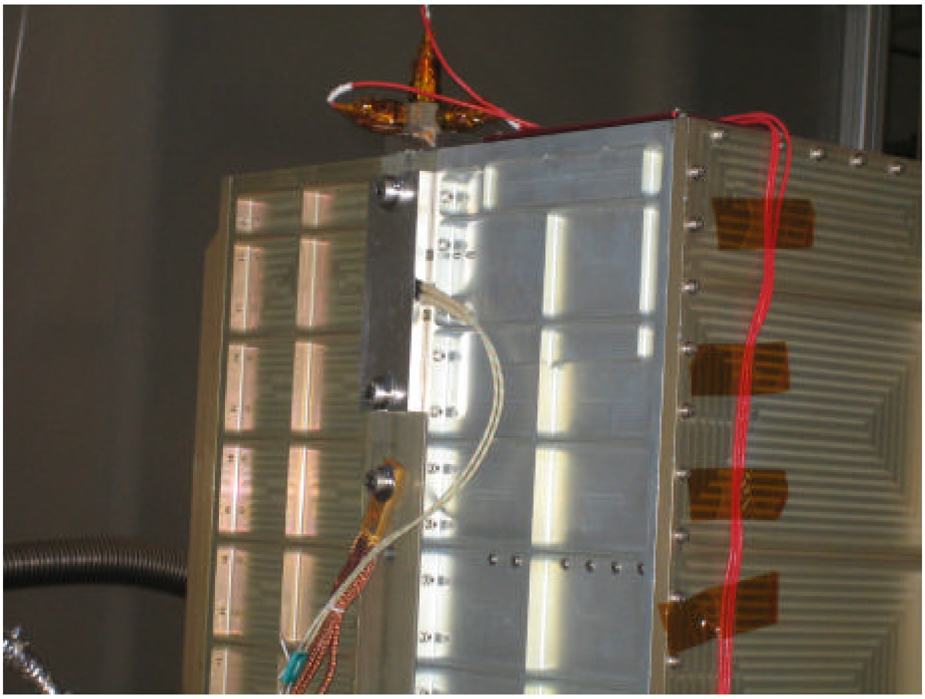
During the Y a Z axis vibration the SPECZ was not working properly (measuring in X) it was working properly during the X-axis vibration test.



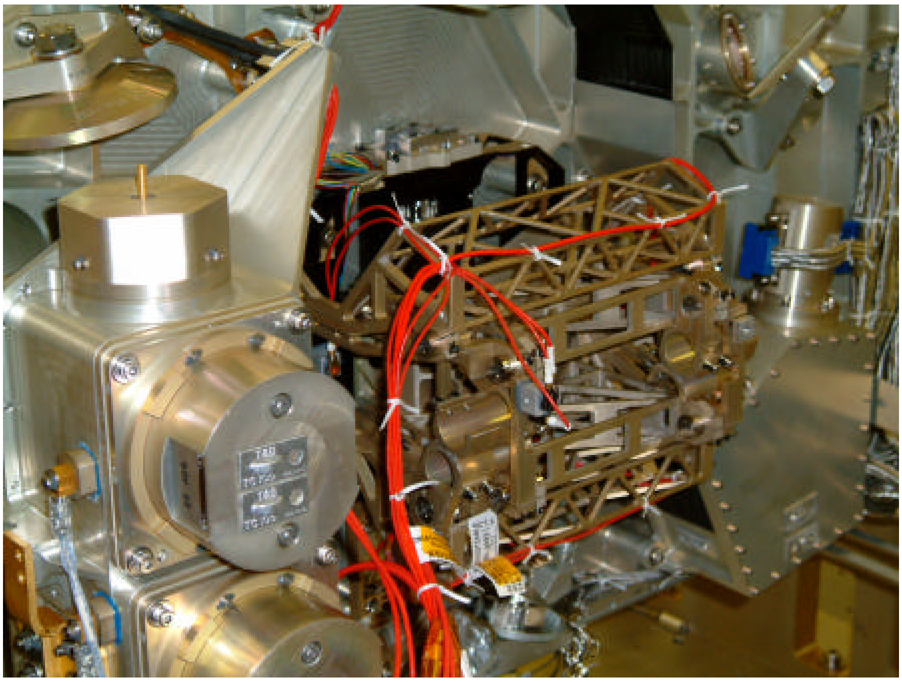
A-1: The triax on the photometer detector box



A-2: The triax on the spectrometer detector box

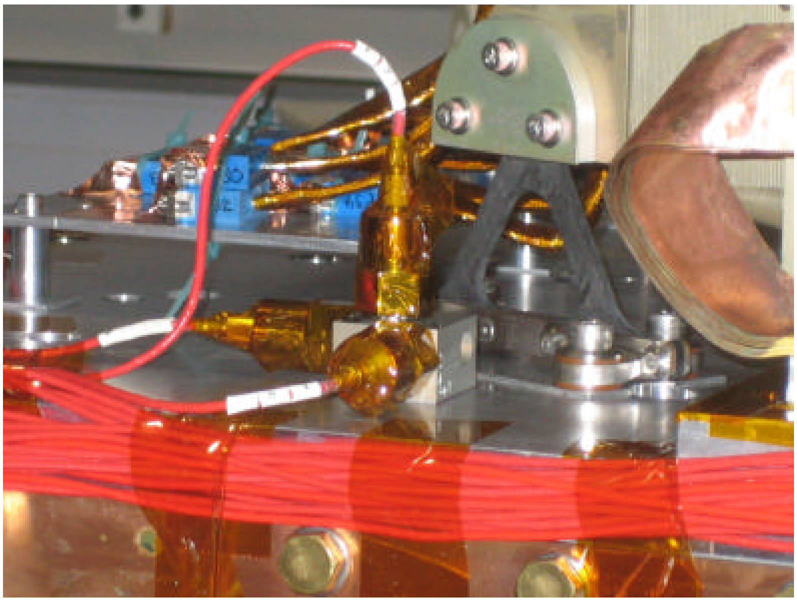


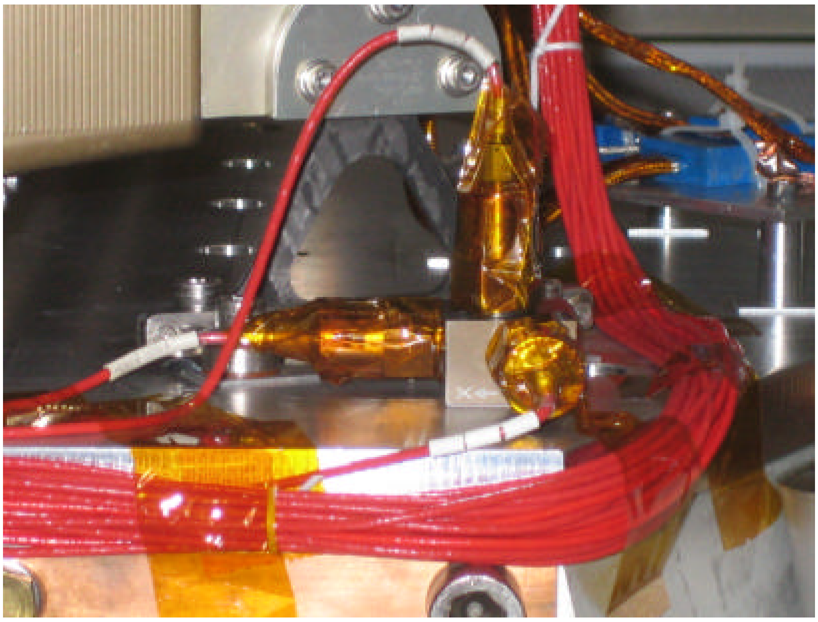
A-3: Triax on SOB outside (FPU)

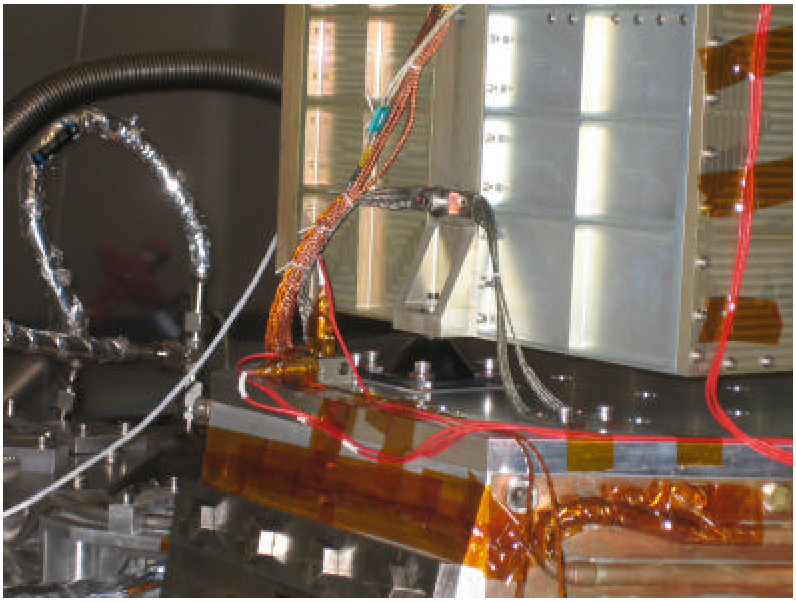


A-4: SMec

Additionally provided by the facility were accelerometers located at each interface point measuring out of plane at each interface point and in plane at two locations for each direction.



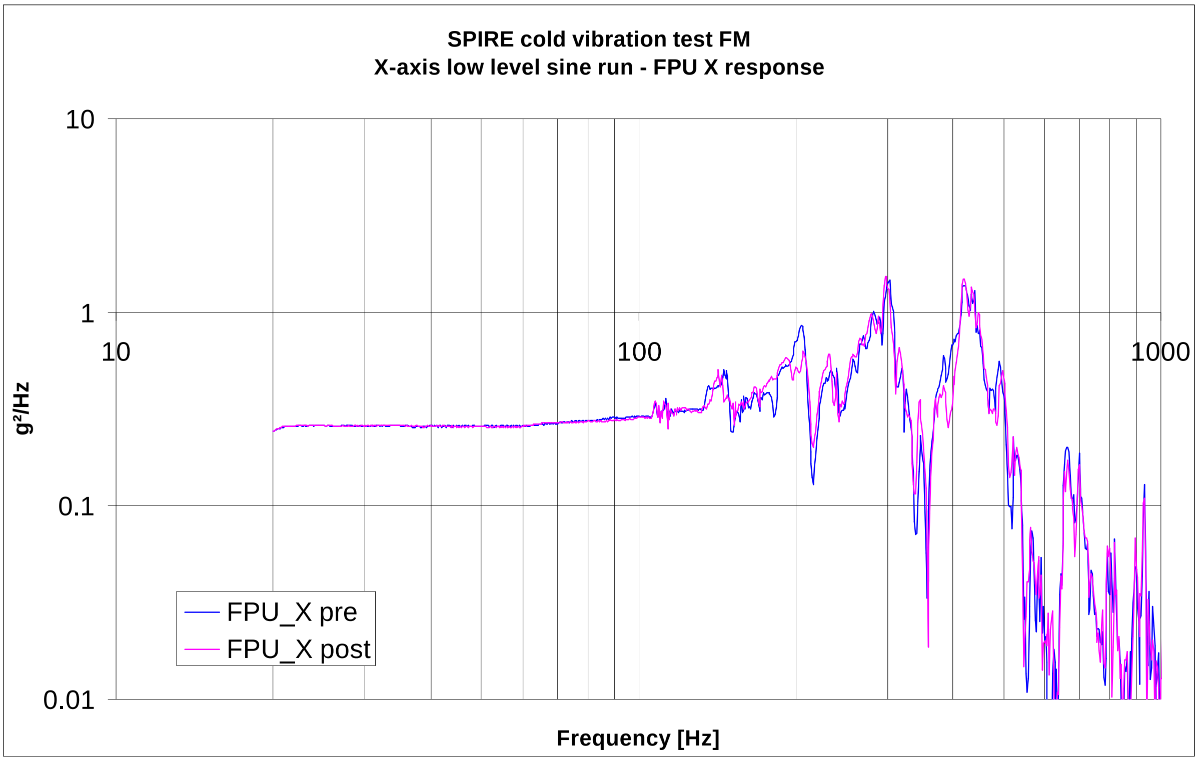


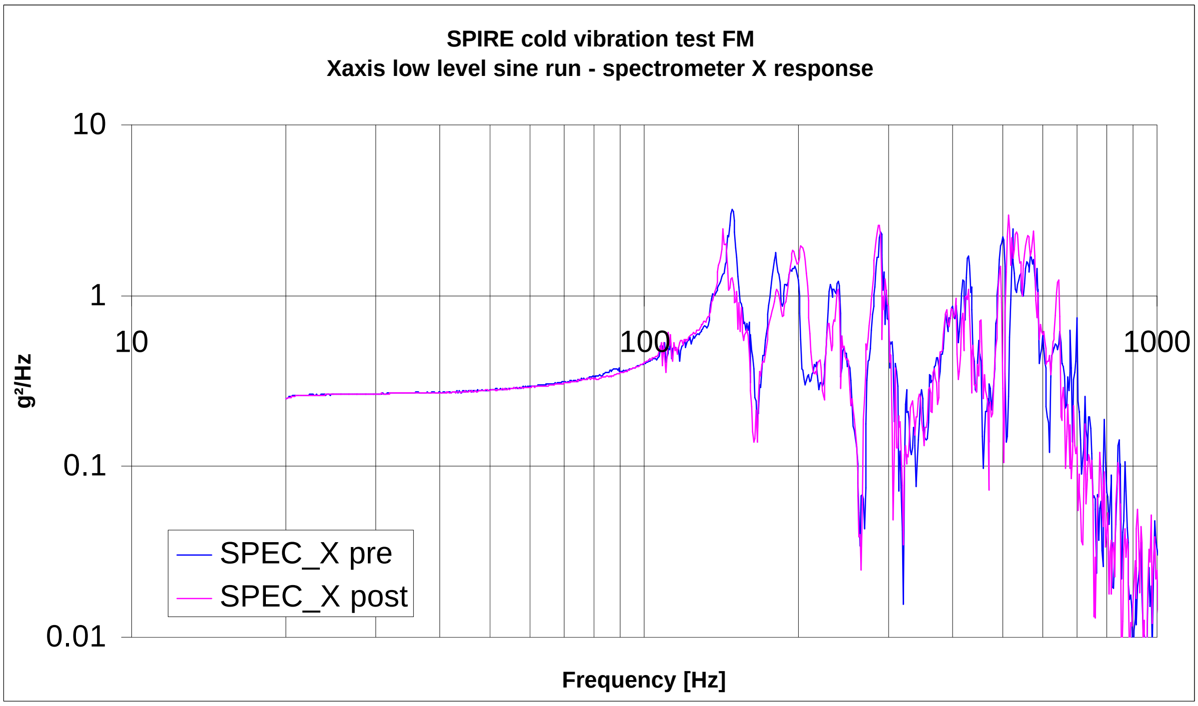


Appendix B – Pre-Post sine and random comparison

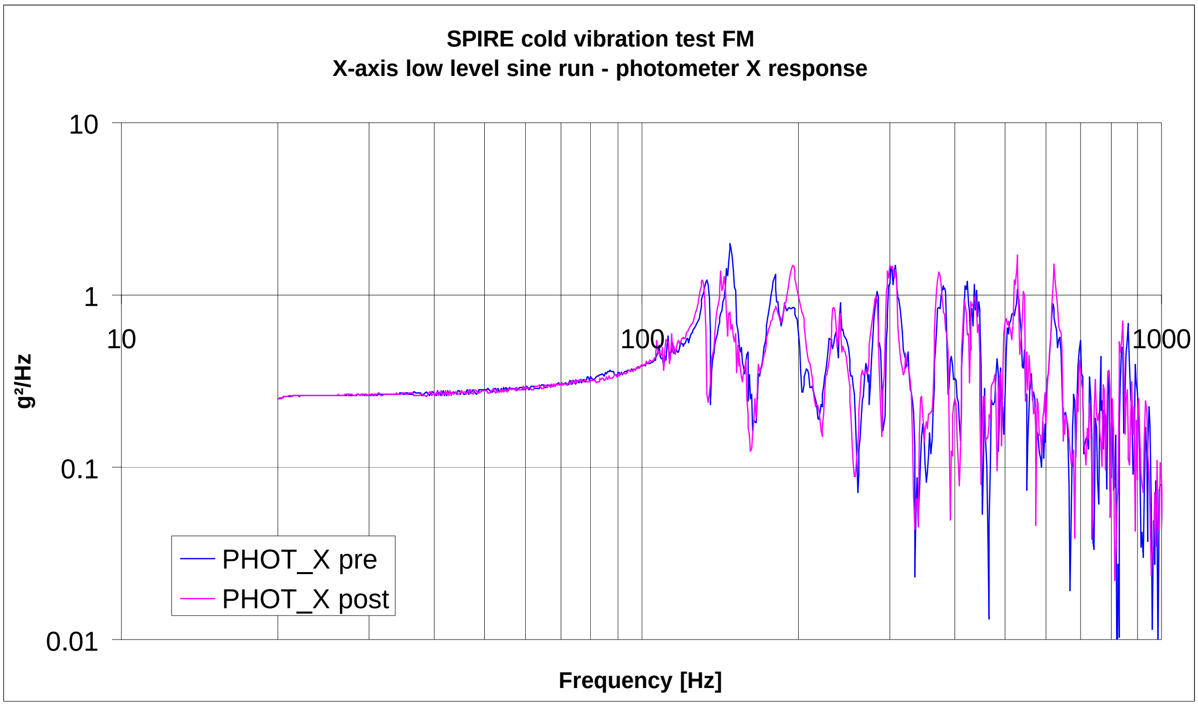
As for the CQM test programme all runs were controlled on the average of the accelerometers located nearest to the mounting points of the instrument. As a result of the cross-coupling of the shaker table itself with the cryostat the responses are biased. See the CQM cold vibration report.

Hereafter all pre-post test sequence sine responses are listed for the FPU, spectrometer detector box, photometer detectorbox and the SMEC in the excitation direction.

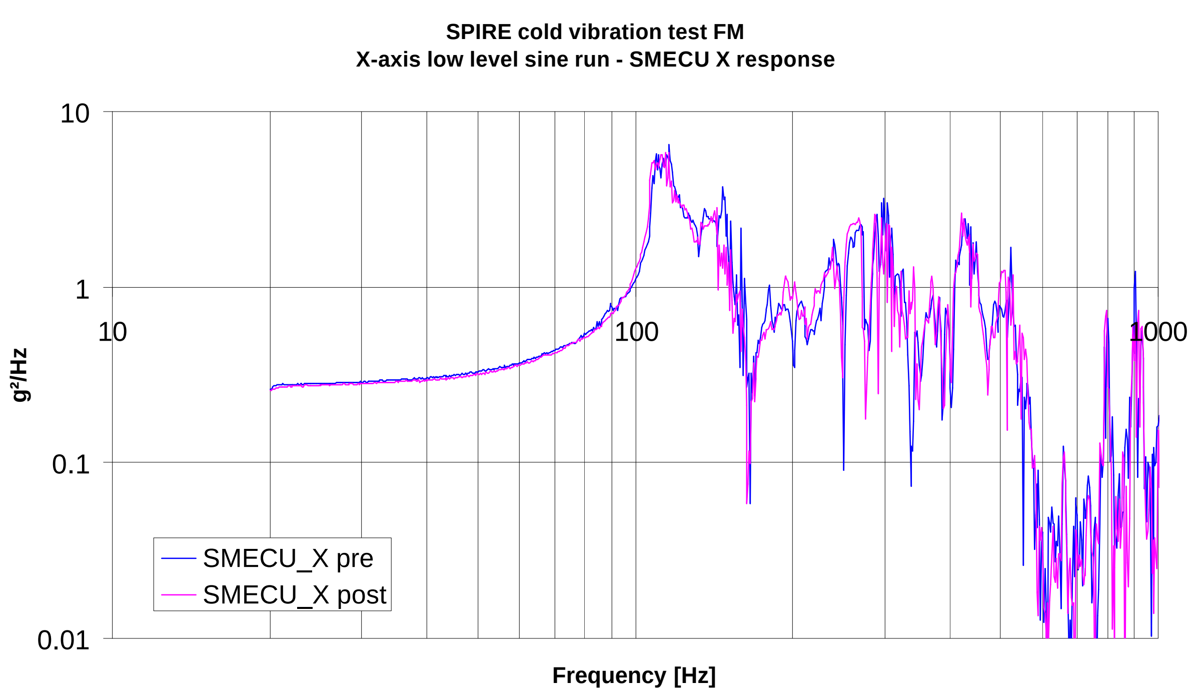




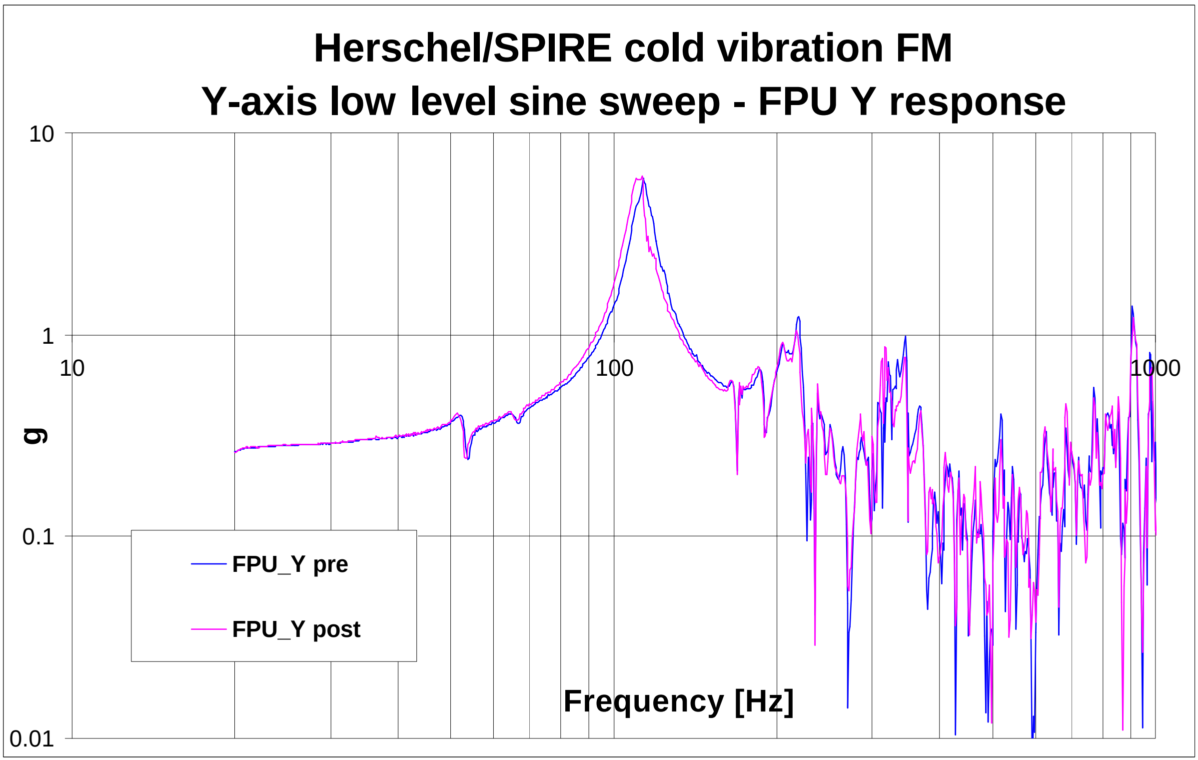
SPIRE cold vibration test FM
Xaxis low level sine run - spectrometer X response
g²/Hz
10
1
0.1
0.01
10
100
1000
Frequency [Hz]
SPEC_X pre
SPEC_X post



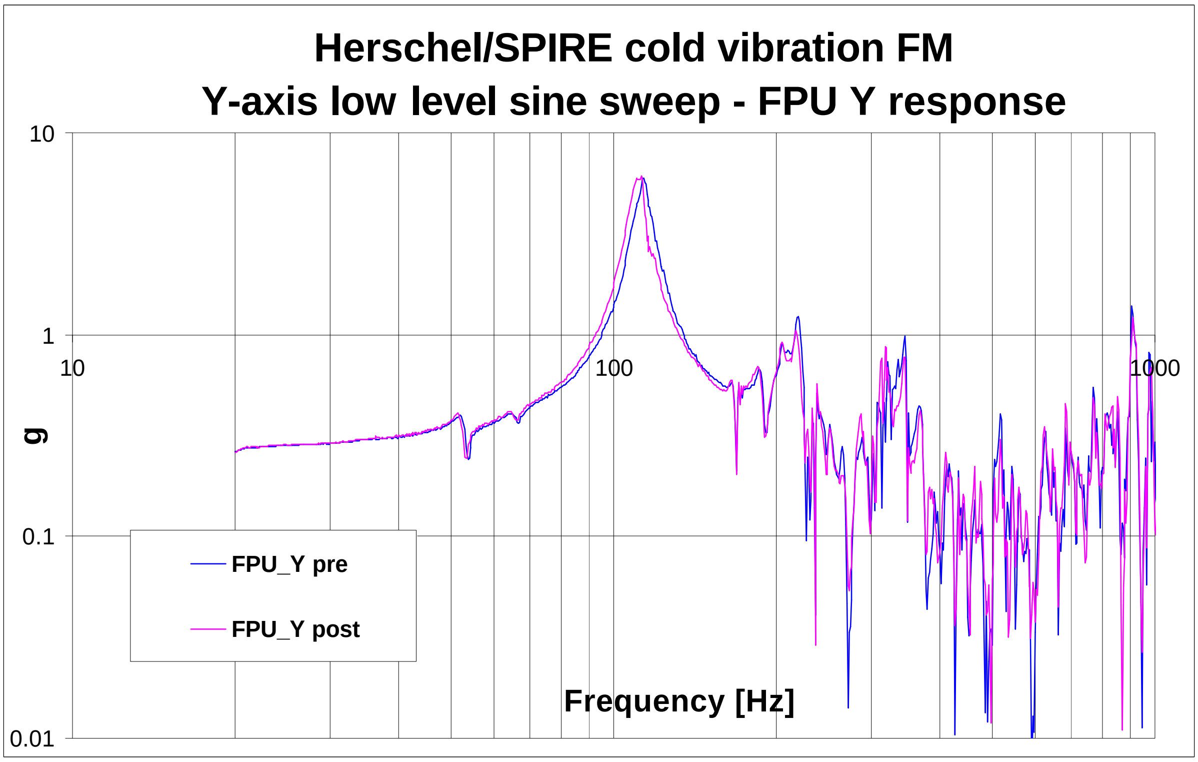
SPIRE cold vibration test FM
X-axis low level sine run - photometer X response
g²/Hz
10
1
0.1
0.01
10
100
1000
Frequency [Hz]
PHOT_X pre
PHOT_X post



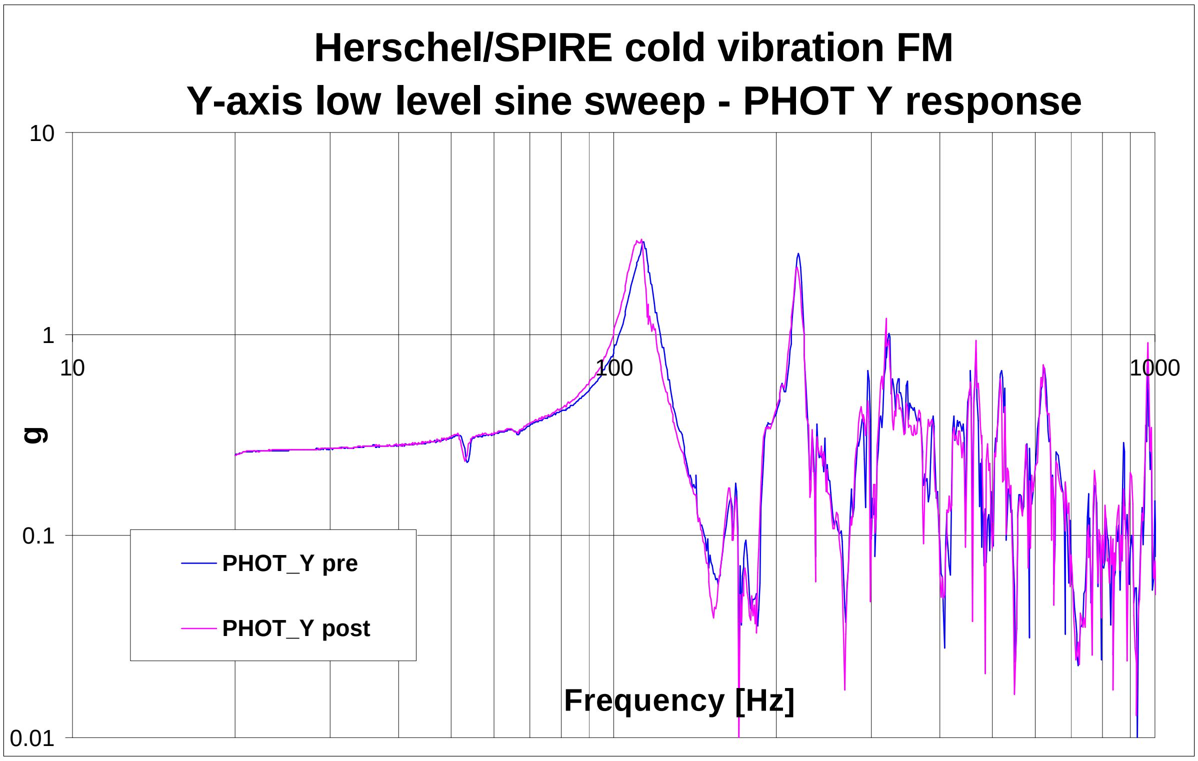
SPIRE cold vibration test FM
X-axis low level sine run - SMECU X response
g²/Hz
10
1
0.1
0.01
10
100
1000
SMECU_X pre
SMECU_X post
Frequency [Hz]



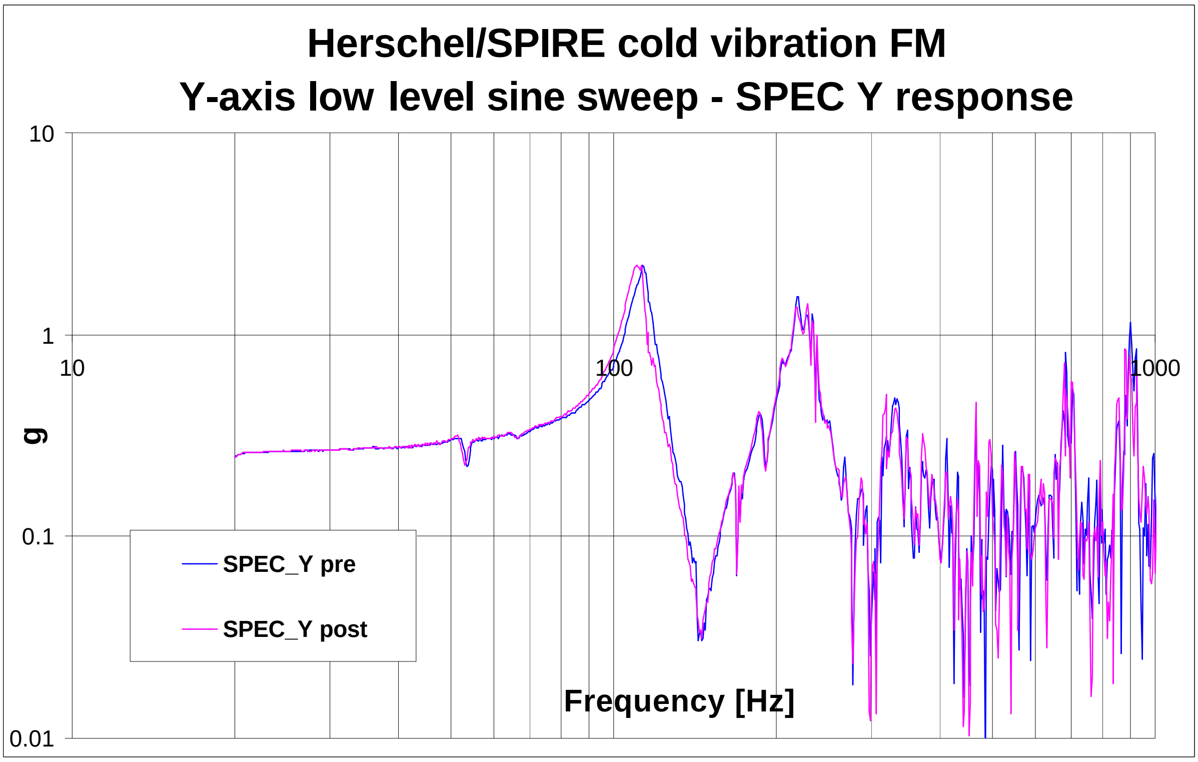
Herschel/SPIRE cold vibration FM
Y-axis low level sine sweep - FPU Y response
g
10
1
0.1
0.01
10
100
1000
FPU_Y pre
FPU_Y post
Frequency [Hz]



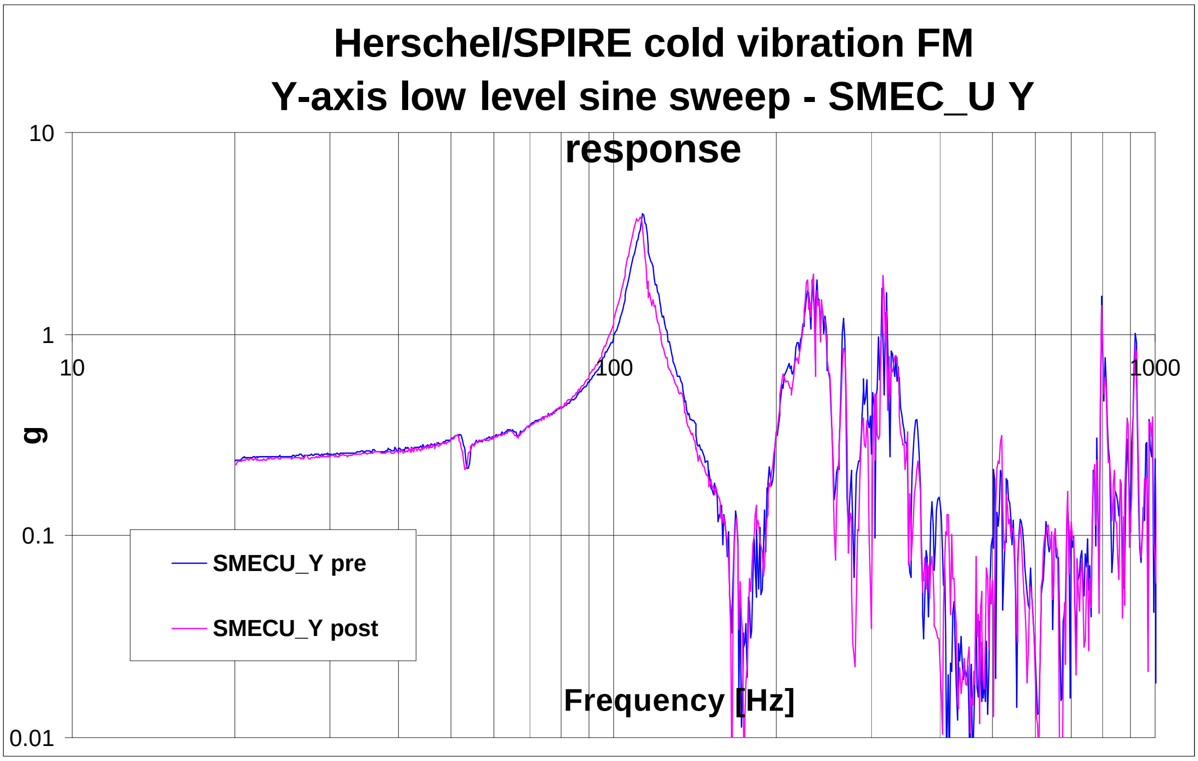
Herschel/SPIRE cold vibration FM
Y-axis low level sine sweep - FPU Y response
10
1
0.1
0.01
g
10
100
1000
FPU_Y pre
FPU_Y post
Frequency [Hz]



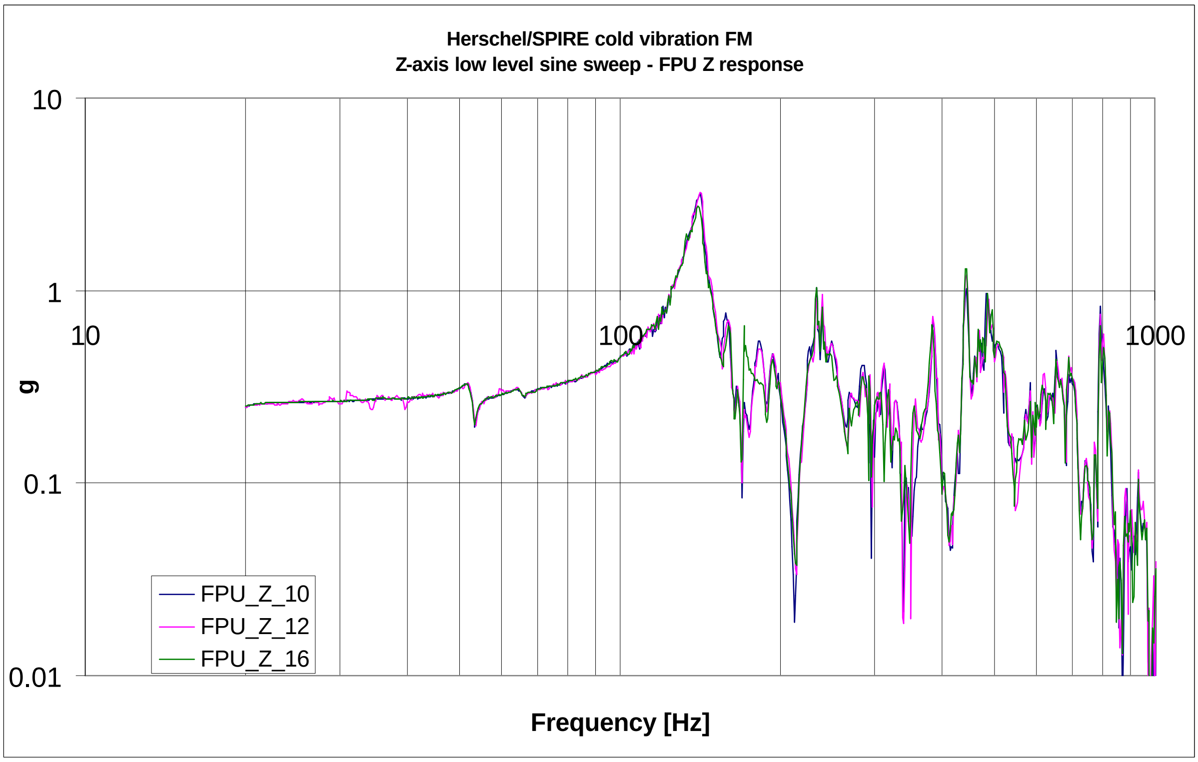
Herschel/SPIRE cold vibration FM
Y-axis low level sine sweep - PHOT Y response
10
1
0.1
0.01
g
10
100
1000
PHOT_Y pre
PHOT_Y post
Frequency [Hz]



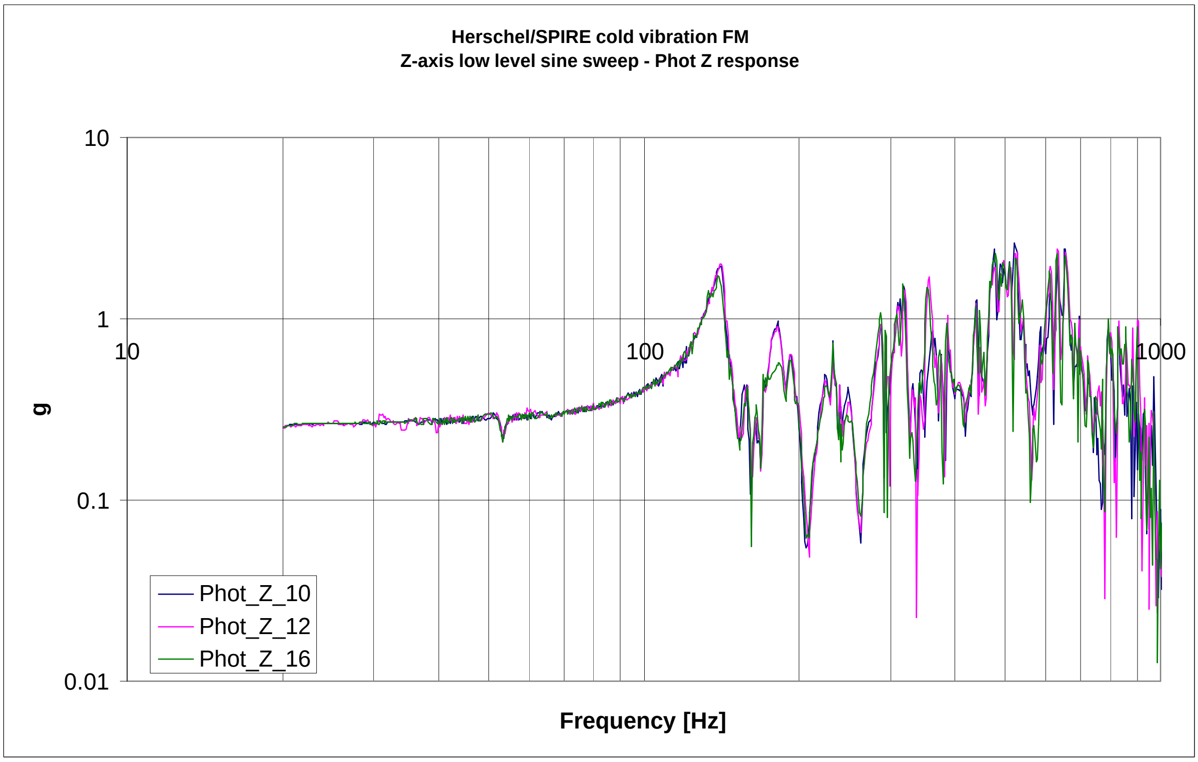
Herschel/SPIRE cold vibration FM
Y-axis low level sine sweep - SPEC Y response
10
1
0.1
0.01
10
100
1000
g
SPEC_Y pre
SPEC_Y post
Frequency [Hz]



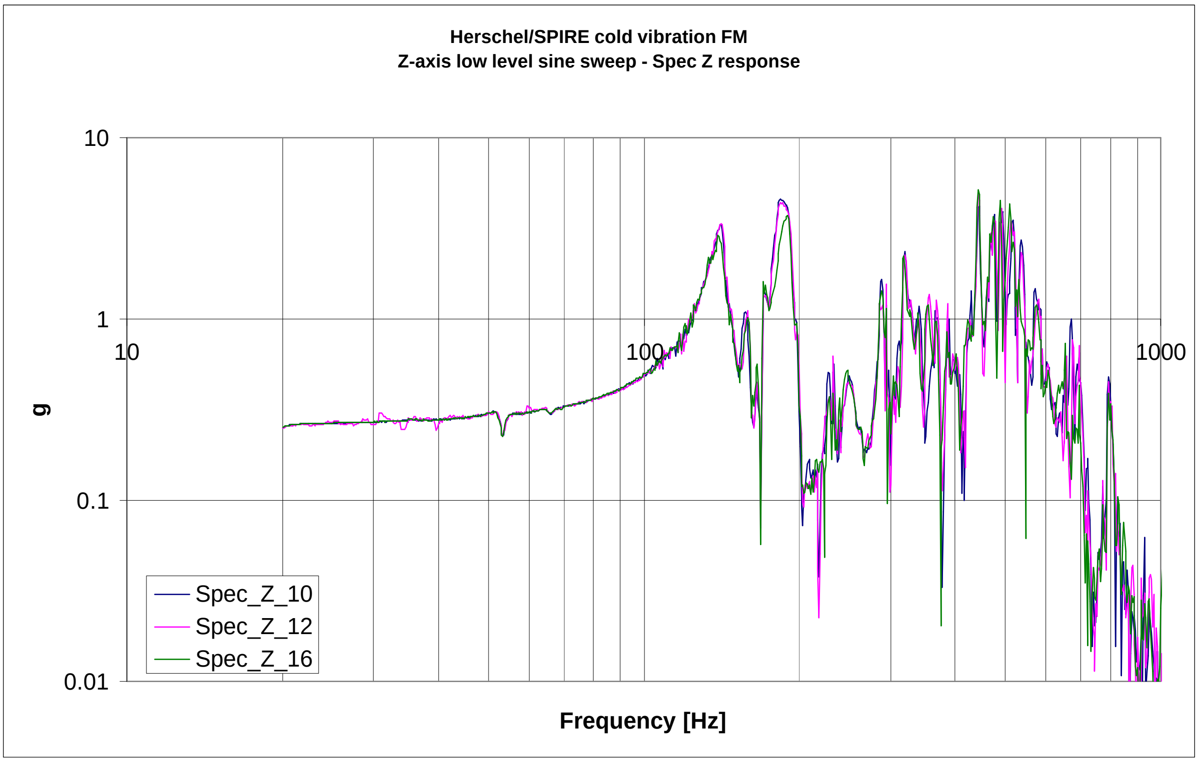
Herschel/SPIRE cold vibration FM
Y-axis low level sine sweep - SMEC_U Y response
10
1
0.1
0.01
10
100
1000
g
SMECU_Y pre
SMECU_Y post
Frequency [Hz]

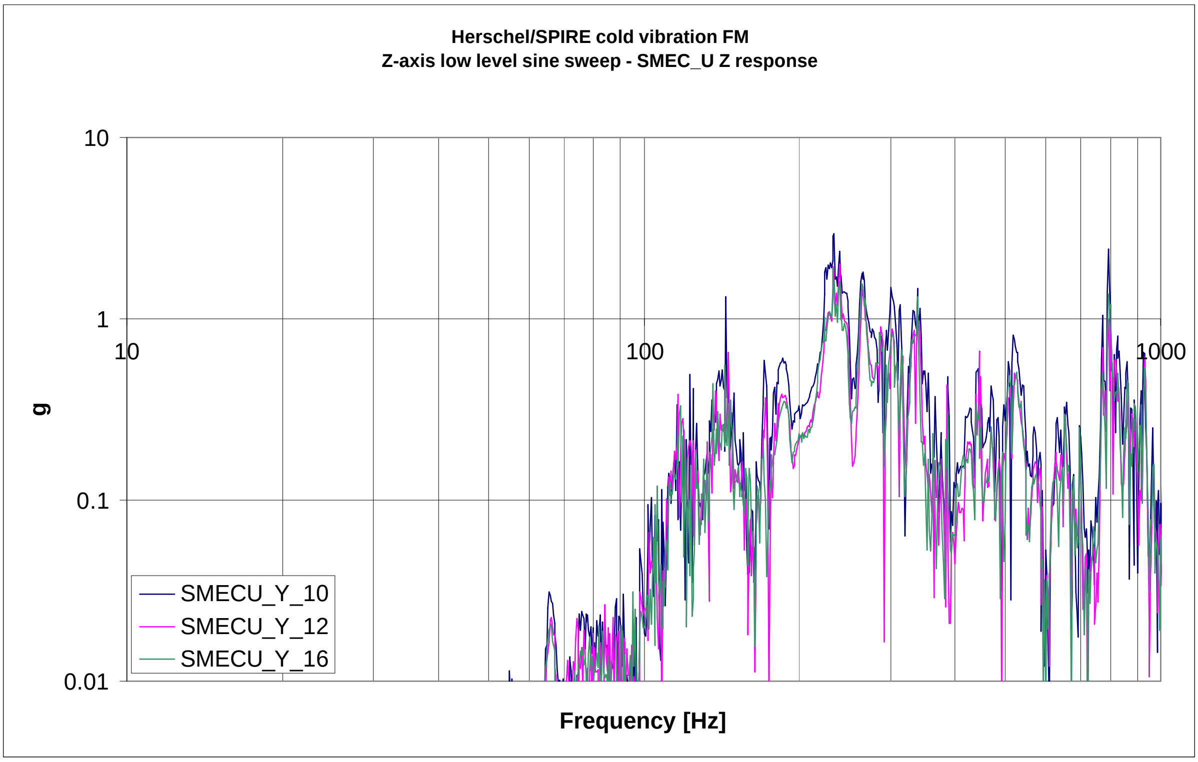


Herschel/SPIRE cold vibration FM
Z-axis low level sine sweep - FPU Z response
10
1
0.1
0.01
10
100
1000
g
FPU_Z_10
FPU_Z_12
FPU_Z_16
Frequency [Hz]



Herschel/SPIRE cold vibration FM
Z-axis low level sine sweep - Phot Z response
10
1
0.1
0.01
10
100
1000
g
Phot_Z_10
Phot_Z_12
Phot_Z_16
Frequency [Hz]





Appendix C – Run list

See AD12 for a complete overview.

Below is a list of vibration runs and their identification code.

Run	Date	Time	Axis	Description
BNS01Y.rsn	22/11/05	17:35	Y	Resonance search warm
BNS02Y.rsn	22/11/05	18:05	Y	Resonance search warm 1400 to 2000
BNS03Y.rsn	29/11/05	09:30	Y	Cold sensor cal run 20 to 70 Hz, 0.25g
BNS04Y.rsn	29/11/05	10:00	Y	Cold resonance search, aborted
BNS05Y.rsn	29/11/05	10:20	Y	Cold resonance search,
BNS06Y.rsn	29/11/05	11:25	Y	Sine test intermediate level
BNS07Y.rsn	29/11/05	11:35	Y	Sine test repeat
BNS08Y.rsn	29/11/05	11:40	Y	Sine test full level
BNS09Y.rsn	29/11/05	11:35	Y	Resonance search
BNS10Y.rrn	29/11/05	14:15	Y	Random test low level
BNS11Y.rrn	29/11/05	15:45	Y	Random test intermediate level
BNS12Y.rrn	29/11/05	17:15	Y	Random test intermediate level
BNS13Y.rrn	29/11/05	17:30	Y	Random test full level
BNS14Y.rsn	29/11/05	17:50	Y	Resonance search

Run	Date	Time	Axis	Description
BNS01Z.rsn	30/11/05	14:00	Z	Resonance search
BNS02Z.rsn	30/11/05	15:10	Z	Sine test intermediate level
BNS03Z.rsn	30/11/05	15:15	Z	Sine test full level
BNS04Z.rsn	30/11/05	15:20	Z	Resonance search
BNS05Z.rsn	30/11/05	15:45	Z	Low level sine 0.05g 1 oct/min
				Warm up for inspection
BNS06Z.rsn	5/12/05	17:15	Z	Resonance search warm
BNS07Z.rsn	15/12/05	17:15	Z	Resonance search cold
BNS08Z.rsn	15/12/05	18:00	Z	Sine test intermediate level
BNS09Z.rsn	15/12/05	18:10	Z	Sine test full level
BNS10Z.rsn	15/12/05	18:15	Z	Resonance search
BNS11Z.rrn	15/12/05	18:30	Z	Low level random
BNS12Z.rsn	16/12/05	07:20	Z	Resonance search
BNS13Z.rrn	16/12/05	07:30	Z	Low level random
BNS14Z.rrn	16/12/05	09:20	Z	intermediate level random
BNS15Z.rrn	16/12/05	10:40	Z	full level random
BNS16Z.rsn	16/12/05	10:50	Z	Resonance search

Run	Date	Time	Axis	Description
BNS01X.rsn	16/01/06	17:50	Z	Resonance search
BNS02X.rrn	16/01/06	18:10	Z	Low level random
BNS03X.rsn	17/01/06	08:30	Z	Sine test, intermediate level
BNS04X.rsn	17/01/06	08:50	Z	Resonance search
BNS05X.rsn	17/01/06	09:00	Z	Sine test, full level
BNS06X.rsn	17/01/06	09:10	Z	Resonance search
BNS07X.rrn	17/01/06	10:50	Z	Low level random
BNS08X.rrn	17/01/06	11:10	Z	intermediate level random
BNS09X.rrn	17/01/06	11;20	Z	Full level random aborted

BNS10X.rrn	17/01/06	11:30	Z	Full level random
BNS11X.rsn	17/01/06	11:45	Z	Resonance search

Appendix D - Summary of events

Date	Activity
21/11/05	Delivery of SPIRE to CSL
22/11/05	Mount FPU on VTA in Y axis
	Warm low level run
29/11/05	SPIRE cold, Y axis test
30/11/05	Change axis to Z
30/11/05	Z axis vibration test Change of signature
1 to 5 Dec	Warm up
5 Dec	Dismount SPIRE
6 Dec	NRB
7 Dec	Reintegrate SPIRE with one SS cone and two CFRP A frames
8 Dec	Close cryostat
11 Dec	Pump down
12-14 Dec	Cool
15 Dec	80K calibration run for SMEC sensors
16 Dec	Z axis repeat test
16 to 19	Warm up
20 Dec to 5 Jan	Store in Nitrogen inside the cryostat
5 Jan	Remove SPIRE
11 Jan	Refit SPIRE
12 Jan	Close cryostat
13 -15 Jan	Cool down
16/17 Jan	X axis test
18-20 Jan	Warm up
24 Jan	Remove SPIRE, Pack
25 Jan	Ship to RAL

Appendix E - NCR HR-SP-RAL-NCR-136

Spacecraft / Project	**Herschel / SPIRE**	**Originator's Name**	Eric Sawyer	
Experiment / Model	SPIRE / PFM	**Signature**		
Sub-System	FPU	**Date**	5th December 2005	
Assembly		**Level** (Highlight if applicable)	**Major**	Minor
Sub-Assembly				
Item		**NRB Reference**		
Serial Number				

NCR Occurred During (Highlight if applicable)	Manufacture	Inspection	**Test**	Integration	Other

NCR Title	**Cryo-vibration test Z axis**

NCR Description

After the high level sine test in the Z axis, the post test resonance search indicated a 20% drop in the frequency of the first mode.

Cause of NCR

Detailed inspection of the FPU is required before the cause can be confirmed. It is likely to be damage to the CFRP mounting cone for the following reasons.

Y axis test results appear to be ok with not indication of damage.

Z axis excitation applied more load to the cone then testing in Y axis.

Disposition / Corrective Action

Inspection first then decide on course of action, options are:

1. Stop test and return SPIRE to RAL for further assessment/possible redesign of mounts.
2. Replace CFRP cone with stainless steel cone which has already been qualified, and continue test – repeat Z axis test then do X axis.

Option 2 Above was selected and all Corrective actions have now been completed Cold Vibration test's completed,

NCR Closed

Document or Drawing Affected (Title, Number & Issue)	**Estimated COST OF NCR** (cost of : correction, Materials, Resource, and delay to Project etc.)

NCR CLOSED	**Name**	**Sign & Date**	
		Approved	**Rejected**
Project Manager	**Eric Sawyer**		
Product Assurance:	**Eric Clark**		
CCB-Chairman:			
Principle Investigator			
Product Assurance:			
Co-Investigator			
Prime Contractor			
ESA Project Office			