SUBJECT: **Instrument Vibration Test Report**
CQM Qualification (Cold)

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CHANGE RECORD

ISSUE	SECTIONS	REASON FOR CHANGE
1.0	all	New issue
1.1		Additional input from Eric Sawyer
1.2	8.5	Minor comments from ESA included, ref DRB
1.3	Appendix A	Images of accelerometer locations added
	10	New section added
	Appendix F	NCR updated following test results

Table of contents

1. SCOPE

This document lists the main results of the cold vibration test of the Herschel SPIRE instrument structural thermal model (CQM). This model is structural representative 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 and the detector boxes.

The notching philosophy for this cold vibration test is outlined in Appendix A

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)	Drawing of interface fixture for head expander	A1-5264-404-30
AD (4)	Drawing of interface fixture for slip table	A1-5264-404-31
AD (5)	As built status	
AD (6)	Instrument Vibration Test Specification – STM Qualification	MSSL/SPIRE/SP007.1, issue 2.0
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-PL-001955
AD (10)	Cold vibration test procedure	SPIRE-RAL-PRC-001956
AD (11)	SPIRE FPU Handling and integration procedure	SPIRE-RAL-PRC-001923
AD (12)	TRR2 minutes of meeting	SCI-PT-25866

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 design of the CQM of the SPIRE instrument is identical to the flight model except as stated in section 5. This model will be used to qualify the structural design of the SPIRE instrument.

5. BUILD STANDARD

The CQM of the SPIRE instrument is identical to the PFM with the following exceptions:-

- Mass thermal dummies of the following subsystem are fitted in place of the Flight units:-
- Beam Steering Mirror (and support)
- Spectrometer Mechanism (full structure but no electronics and dummy flex-pivots)
- I Flight standard suspended Detector
- 4 Detector mass dummies (mass representative and with tri-axial accelerometers at two locations)
- The instrument and detector boxes are supported by stainless steel parts, currently being re-designed.

The interface to the spacecraft is identical to the flight unit. The mass of the CQM model of the SPIRE instrument is 45 kg.

6. TEST OBJECTIVES

- To qualify the structural design of the SPIRE instrument and to recover response spectra at critical internal interfaces between system structure and subsystem structures.
- To measure the input levels of the subsystems.
- 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
  - warm up

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

The qualification 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 IID-A, AD (1) the qualification levels are:

X axis

Frequency Range Hz	Qualification level
5 - 20.1	+/- 11mm
20.1 - 100	18 g

Test sweep rate 2 Oct/min, the input was limited to the equivalent quasi static interface force.

Y and Z axis

Frequency Range Hz	Qualification level
5 - 13.5	+/- 11mm
13.5 - 100	8 g

Test sweep rate 2 Oct/min, 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.

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 18 g static force. 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 50 Hz, continuing the maximum input to 75 Hz gives roughly 1000 cycles. After 75 Hz the input is lowered to 8 g with scaled limits accordingly.

During the test (see next graph) the 18 g equivalent notch kicked in at 58 Hz and continued to act till 75 Hz. Then the second notch kicks in at 90 Hz and continues up to 100 Hz (8 g equivalent). The black line is the control accelerometer and the red line the CoG equivalent accelerometer.

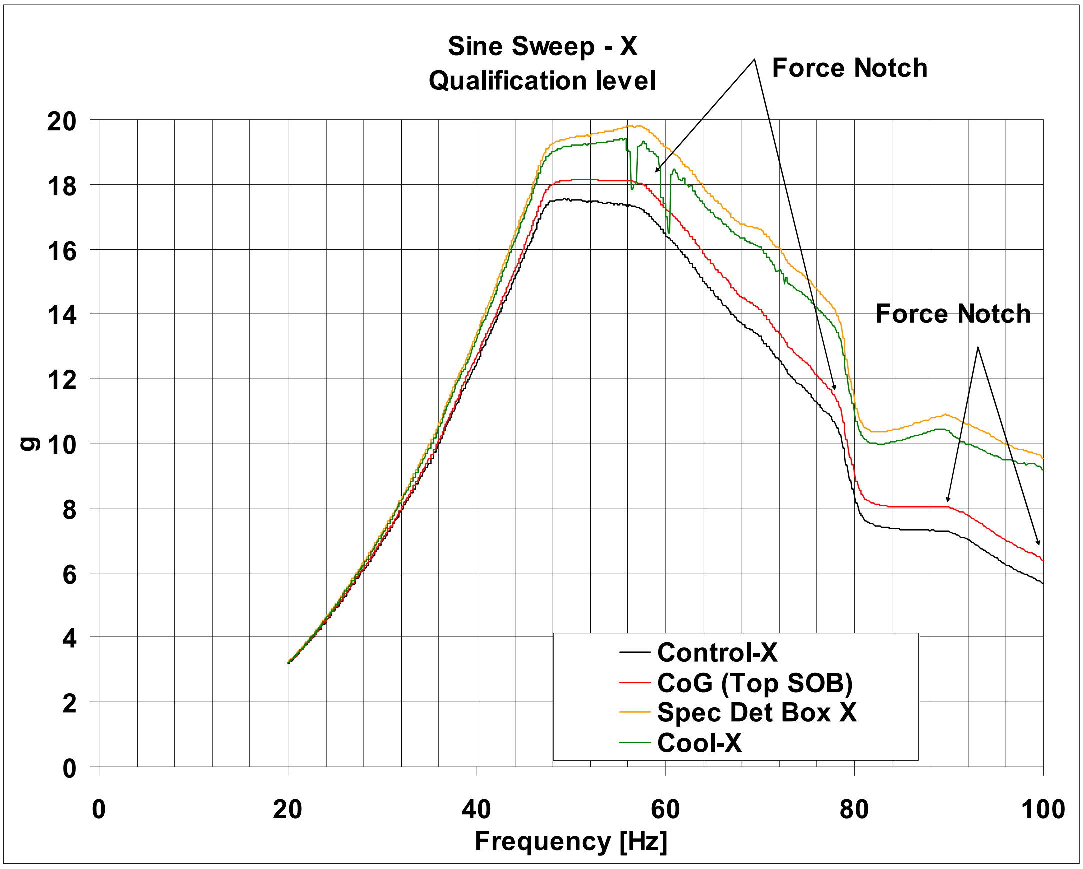


Figure 8.4-1 Achieved inputs for the X direction

The achieved levels show the top of the Spire Optical Bench (Top SOB) above the instrument mounting cone as the minimum response in X. The elements mounted more in the middle of the instrument and closer to the real CoG are also plotted (Cooler-X and Spec. Det. Box X)

Achieved Levels and discussion Y-AXIS

A similar strategy was followed for the Y-axis. The Y-axis has a flat input of 8 g up to 50 Hz. Then it is lowered down to 6 g at 60 Hz and continued to 100 Hz at 6 g. This was the first axis tested at CSL. The force notch was only limited to 8 g equivalent, hence the over test above 74 Hz.

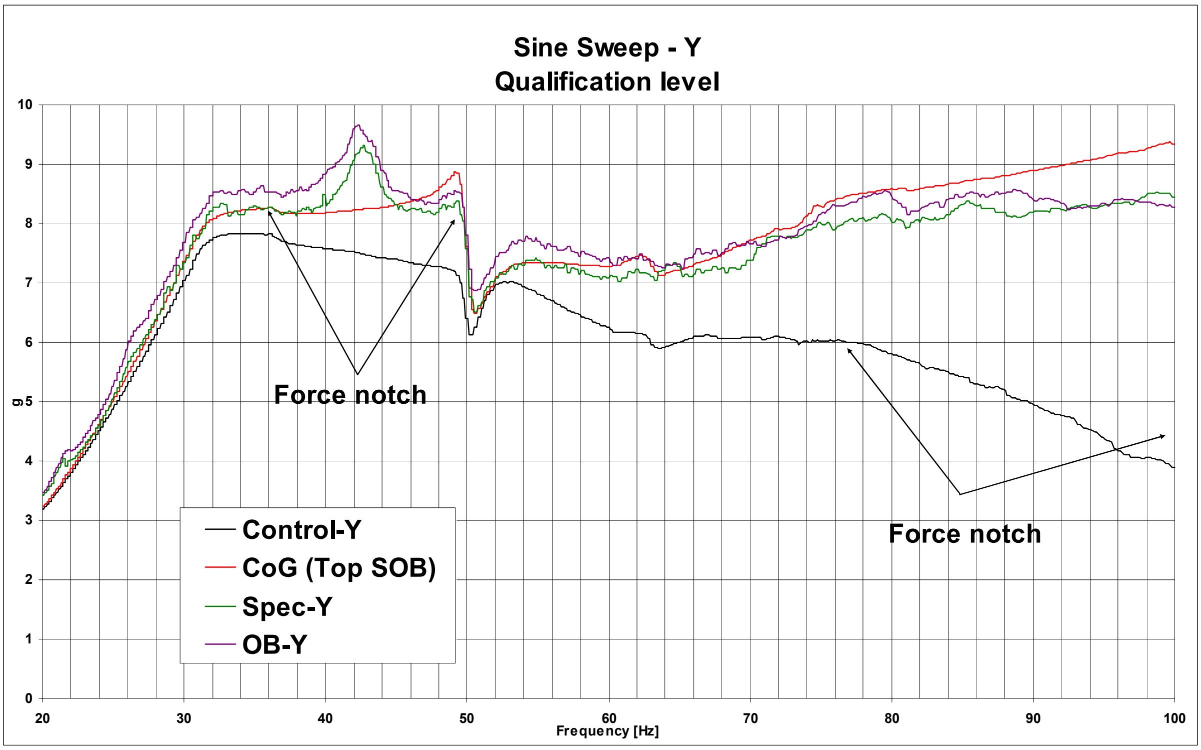


Figure 8.4-2 Achieved inputs for the Y direction

Achieved Levels and discussion Z-AXIS

For the Z-axis the same approach as for the Y-axis was followed with an additional scaled notch above 75 Hz. Additional was the scaled force notch above 75 Hz, preventing an over test at higher frequencies.

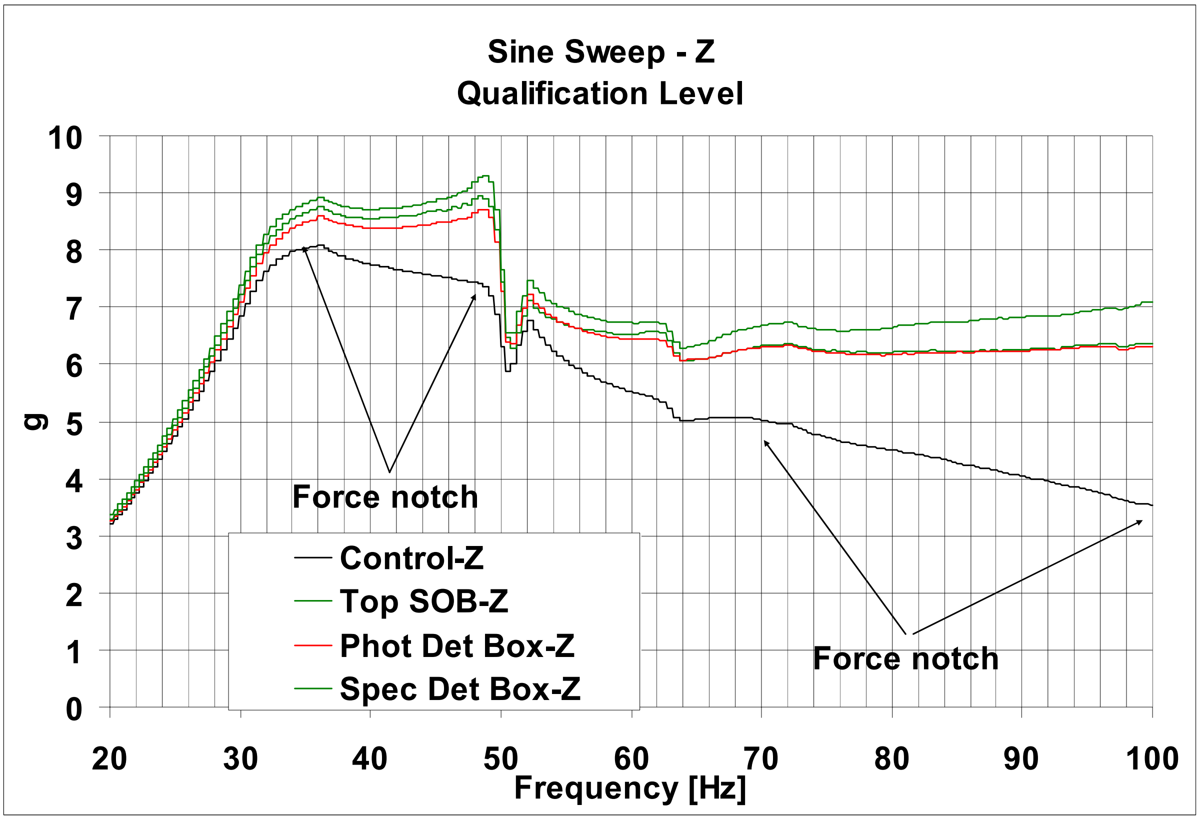


Figure 8.4-3 Achieved inputs for the Z direction (Top-Z is in Z at top of instrument)

8.5. Random vibration test

As stated in IID-A, AD (1) the qualification levels were:

Y and Z axis

Frequency Range Hz	Qualification level
20-100	+3dB/Oct
100-150	0.02 g^2/Hz
150-300	0.0125g^2/Hz
300-2000	-7 dB/Oct
Global	…. g-rms

Test duration 2 minutes in each axis

X axis

Frequency Range Hz	Qualification level
20-100	+3dB/Oct
100-150	0.05 g^2/Hz
150-300	0.02g^2/Hz

300-2000	-7 dB/Oct
Global	…. g-rms

Test duration 2 minutes

For all (but X-axis) random tests force notching was applied as well as notching on the responses of components on the SPIRE optical bench. Either by direct measurement or via a reference analysis. For the analysis a detailed coupled model was used (instrument and shaker) and response ratios were used to (indirectly) notch on the moving masses of the detectors. See following table for applicable ratios.

X-excitation	PLW	PMW	PSW	SLW	SSW	average
X	**2.21**	**2.17**	**2.66**	**2.22**	**2.41**	**2.34**
Y	5.89	2.65	1.71	0.95	1.23	-
Z	1.21	2.72	**1.65**	**0.58**	**0.64**	0.96

Y-excitation	PSW	PMW	PLW	SSW	SLW	average
X	2.83	2.84	**2.53**	**2.61**	0.47	**2.57**
Y	**1.75**	**1.46**	**1.19**	**1.29**	**0.57**	1.25
Z	1.50	5.20	1.49	1.53	**0.39**	0.39

Z-excitation	PLW	PMW	PSW	SLW	SSW	average
X	1.71	2.53	**2.75**	**2.61**	**2.92**	**2.76**
Y	3.74	3.69	1.41	2.05	1.64	-
Z	**1.22**	**1.82**	**2.20**	**1.23**	**1.23**	1.54

Table 8.5-1 g-rms/g-rms ratios for detectors and detector boxes (analysis)

The numbers listed in table 8.5-1 are the analysed g-rms ratios between detector box response and the response of the suspended mass inside each detector. The averages are taken over the ratios printed in bold, the ratios with a significant detector box response. It is considered that high ratios with minor inputs should be ignored. Since none of the suspended detector masses were present during the cold vibration test and because a direct measurement of their response if they were would be impossible, the ratios are used to notch the suspended mass response indirectly. The notch is applied using the detector box response (which is measured in 3 directions) and multiply the response with the above listed ratios. The resulting response should not exceed 10 g-rms (excluding analysis uncertainty) following the notch criterion set out by ESA.

The force notching was limited to responses up to twice the first resonance frequency in this case. It is common to limit the force notching to lower frequency response only, especially if the first mode has a lot of effective mass (50% or more). If the effective mass is spread out notching up to higher frequencies can be considered.

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. The only notch applied was therefore on the suspended masses on the detector boxes and the spectrometer mechanism.

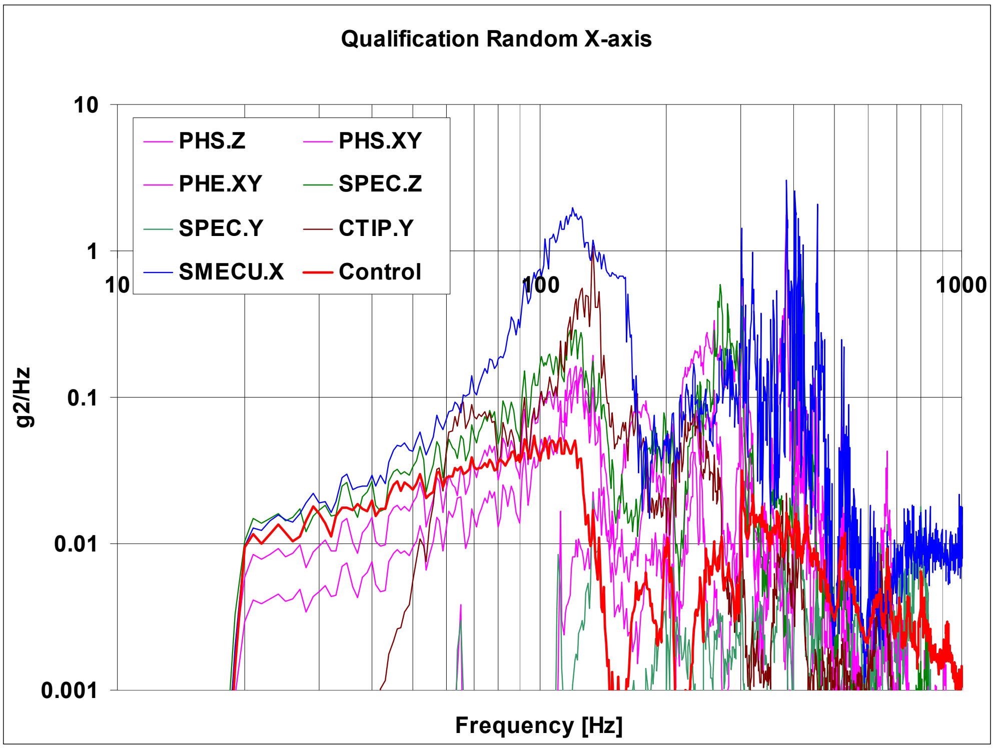


Figure 8.5-2 Achieved random input in X

Note in figure 8.5-2 the violent response of the spectrometer mechanism, it is the blue trace above all others. Green is the spectrometer box, magenta the photometer box.

	Direct	Det-equiv
ID	g-rms	g-rms
PHS.Z	6.2	14.3
PHS.XY	3.8	8.8
PHE.XY	3.5	8.1
SPEC.Z	6.5	14.9
SPEC.Y	1.6	3.6
CTIP.Y	5.1	
SMECU.X	13.3	
Control	2.9	

Table 8.5-3 Achieved random responses in X

Analysis has shown that the average amplification (in g-rms) between detector box and detector suspended mass for the X-axis is about 2.3 (see table 8.5-1). In table 8.5-3 the accelerometers g-rms are multiplied in the second column with this factor to arrive at the maximum expected level. This has to be done since these accelerations can not be measured directly (cold). The requirement is that the accelerations do not need to exceed 10 g-rms for any component mounted inside the structure during random vibration testing. (Ref ESA). Clearly both based on analytical considerations and direct measurements some detectors do exceed that value as well does the top of the spectrometer mechanism.

Achieved Levels and discussion Y-AXIS

For the Y-axis force notching was applied controlling the CoG acceleration to about 2 g-rms (4 sigma value gives 8 g equivalent static). The force notch was introduced between 90 and 150 Hz.

This is rather wide, but the only way of limiting the force was widening up the notch since it was already quite deep and nothing much was to be gained from deepening it further. For the force notch the response up to 2 times the first resonance frequency were taken into account. The applied notch gave a response at the top of the structure 3 g-rms. Correlation between CoG and this accelerometer shows a 1:1 response in this frequency range. If we take 10% uncertainty into account we reached 2.7 g-rms. This exceeds the required 2 g-rms comfortably.

Next to the notch on interface force two more were applied to suppress the responses of the detector boxes. This to limit the response of the boxes to a value of 10% above 10 g-rms equivalent for the suspended masses. There was no need to limit the input to protect the SMec.

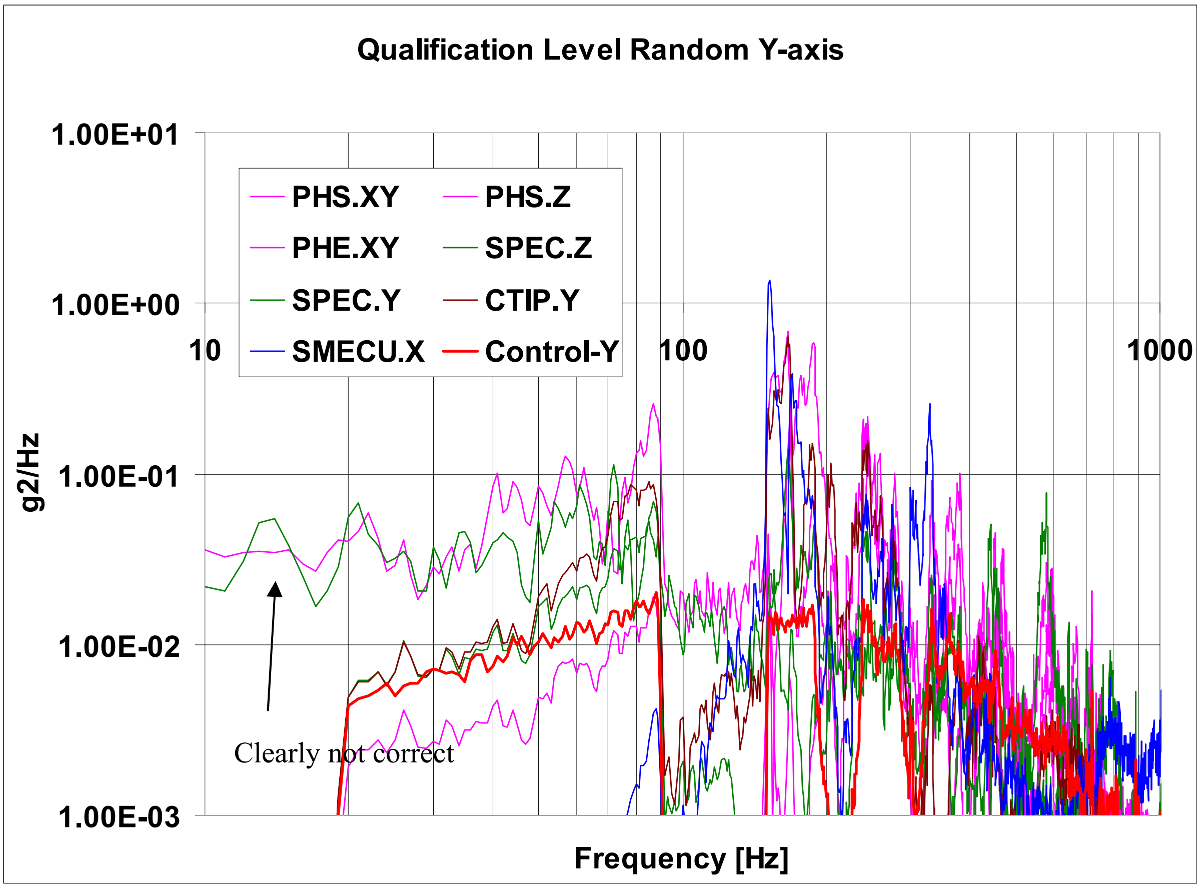


Table 8.5-4 Y-axis response graphes

	PHS.XY	PHS.Z	PHE.XY	SPEC.Z	SPEC.Y	CTIP.Y	SMECU.X	Control-Y
	3.03	2.71	5.70	2.98	2.56	4.41	4.65	2.12
susp equiv	7.0	6.2	**13.1**	6.9	5.9			

Table 8.5-5 Achieved responses, PHE.XY exceeding the required 10 g-rms (but suspect)

Note that for the detector box notches the response is limited for all detector box responses at the same time (both photometer and spectrometer). So it is not possible to discriminate between the 5 detector box responses and boost some of them whilst maintaining the 13.1 g-rms for PHE.XY. **However, after analysing the qualification level and low level sine sweep runs the response of PHE.XY it appeared to be suspect. It probably overestimates the actual response of the detector box.**

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 2.0 g-rms up to about 290 Hz. The achieved level was 2.6 g-rms, exceeding the required 2.0 g-rms with a comfortable margin.

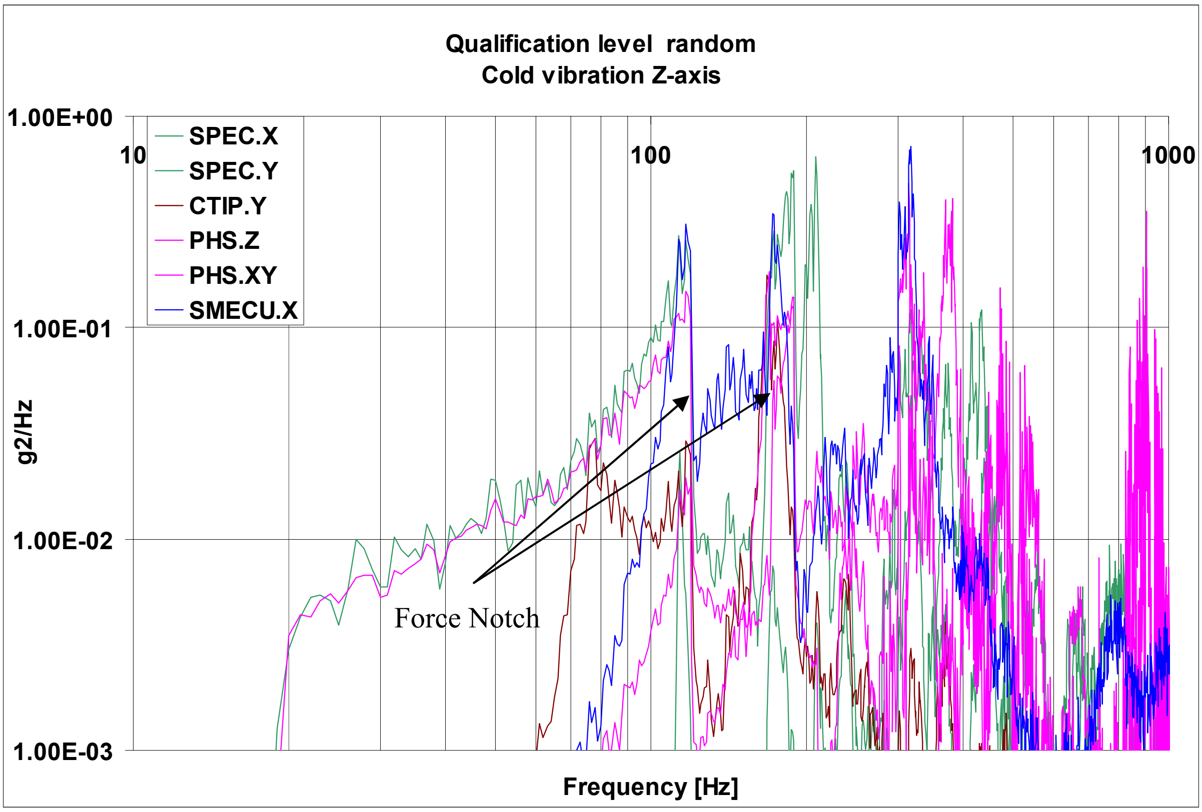


Table 8.5-6 Z-axis response graphs

And again the levels for the detector boxes were limited to reach a maximum of more than 10 g-rms for the equivalent acceleration of the detector's suspended masses. The multiplication factor applied for the Z-axis is according to the table 8.5-1, 2.76 9 due to a strong cross-coupling in X-direction.

	SPEC.X	SPEC.Y	CTIP.Y	PHS.Z	PHS.XY	SMECU.X
	4.93	1.67	1.91	4.98	4.03	5.08
susp. equiv	**13.61**	4.62		**13.74**	**11.11**	

Table 8.5-6 Z-axis achieved levels

And here the 10 g-rms level was reached for the Spec-X, PHS.XY and PHS-Z.

8.6. Measurement of subsystem levels

N.A.

8.7. Main resonance frequencies found

Main frequencies based on pre-post interface force measurements [Hz]		
X axis	Y axis	Z axis
	129 (122)	
	(141)	148 (137)
		154 (147)
158 (176)		
	210 (197)	
193 (206)		202 (205)
212 (219)		
	228 (249)	
270 (314)		

8.7-1: Main frequencies (test mass 45 kg)

The listed frequencies are from the cold test and warm test (XXX). There are a few things that are different between the warm and the cold 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.

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.

9.1. Sine overtest.

During the intermediate level (2g) sine test in the Y axis, the test was carried out up to 200Hz in error. HR-SP-RAL-NCR-0075 was raised and is attached as annex F

10. POST TEST INSPECTION AND TEST

10.1. Inspection.

When the instrument was returned to RAL a post test inspection was carried out. This is fully reported in SPIRE-RAL-REP-002007.
This involved a partial dismantelling of the FPU and the remopval of some subsystems.
Seven minor NCRs were raised.

10.2. Test.

The cooler was returned to CEA Grenoble for tests. Functional tests were carried out, all performance was nominal.
Electrical tests were carried out on the BDA and JFET. All tests were nominal.
Metrology measurements were carried out on the BDA to check for movement. The results were inconclusive as the before tests carried out at JPL used a different measurement technique. No significant movement had occurred.
The post vibration cold performance test was carried out from 10/9/04 to 8/10/04.

This is fully reported in a separate test report. No performance changes were identified. The SPIRE FPU and JFETs are now considered qualified.

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)
- Top of the optical bench in instrument coordinates: +X,+Z tri-axial or near that location. (3 channels) named FPU (3 channels)
- On each detector box, one of the detector dummy masses was replaced with a tri-axial accelerometer.
- At the foot of He3 cooler in Y direction (1 channel)
- At the foot of the SMec in Y direction (1 channel)
- At the foot of the BSM in Y direction (1 channel)

The implemented instrumentation:

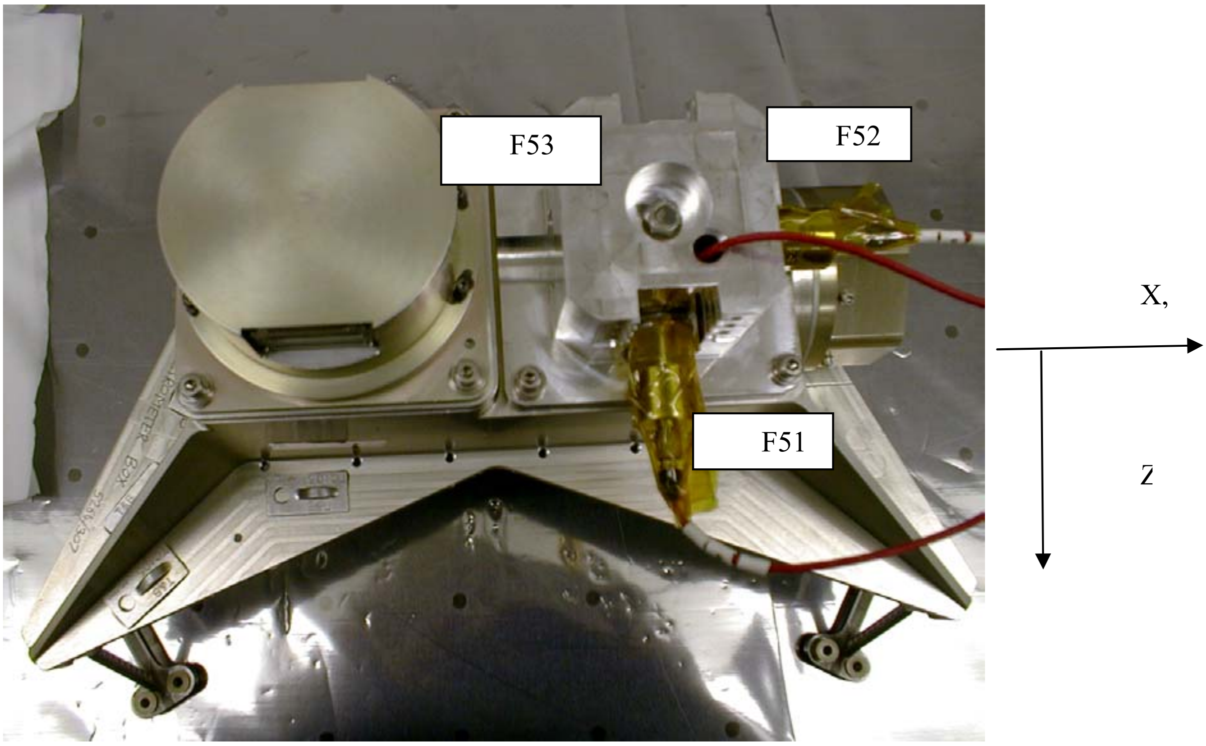
The numbering used during the tests was as follows (only accelerometers mounted in/on the instrument are listed):

Channel No	Location	Code	Measures axis
F66	Photometer detector (side)	PHS.XY	X and Y
F72	Photometer detector (side)	PHS.Z	Z
F58	Photometer detector (end)	PHE.XY	X and Y
F56	Cooler	COOL	X
F73	FPU top of optics bench over cone	FPUX	X
F71	FPU top	FPUY	Y
F63	FPU top	FPUZ	Z
F51	Spectrometer detector	SPECX	Z[2]
F52	Spectrometer detector	SPECZ	X[2]
F53	Spectrometer detector	SPECY	Y
F61	Optics bench near SMEC	OBY	Y
F54	SMEC moving carriage	SMECLX	X
11030	Cold tip	CTIPY	Y[1]
11606	SMEC top	SMECUX	X[1]

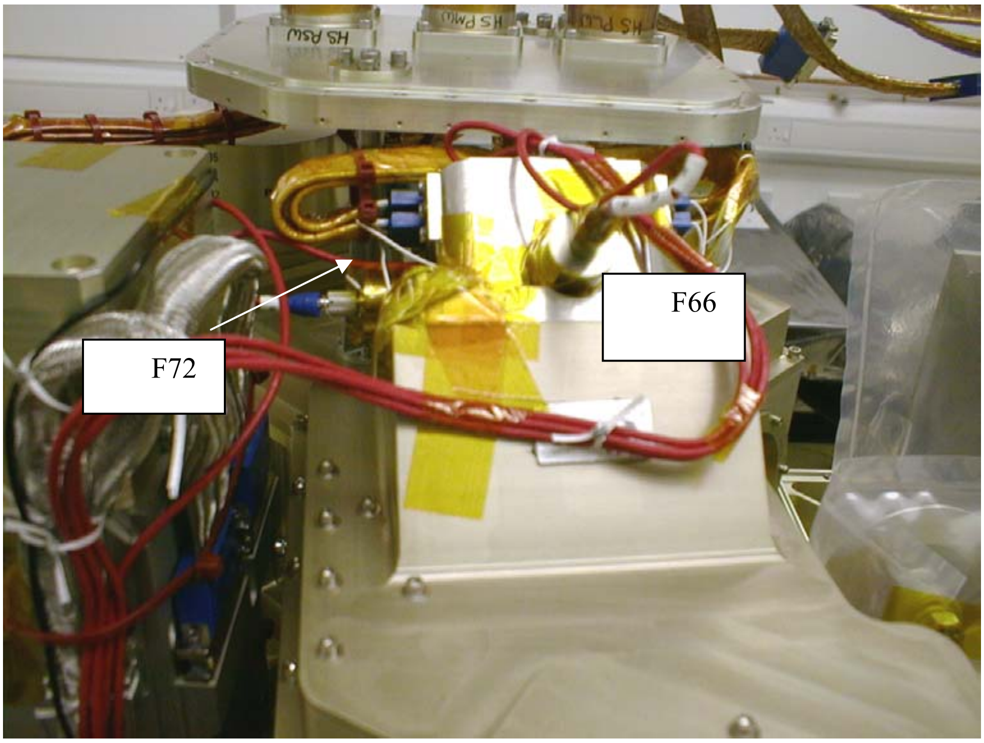
[1] are not cold-vibration accelerometers, they were calibrated during the tests
[2] have an acronym suggesting a different measurement axis, cables got swapped somewhere inside the facility. Name tag was consistently used throughout all tests.

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.

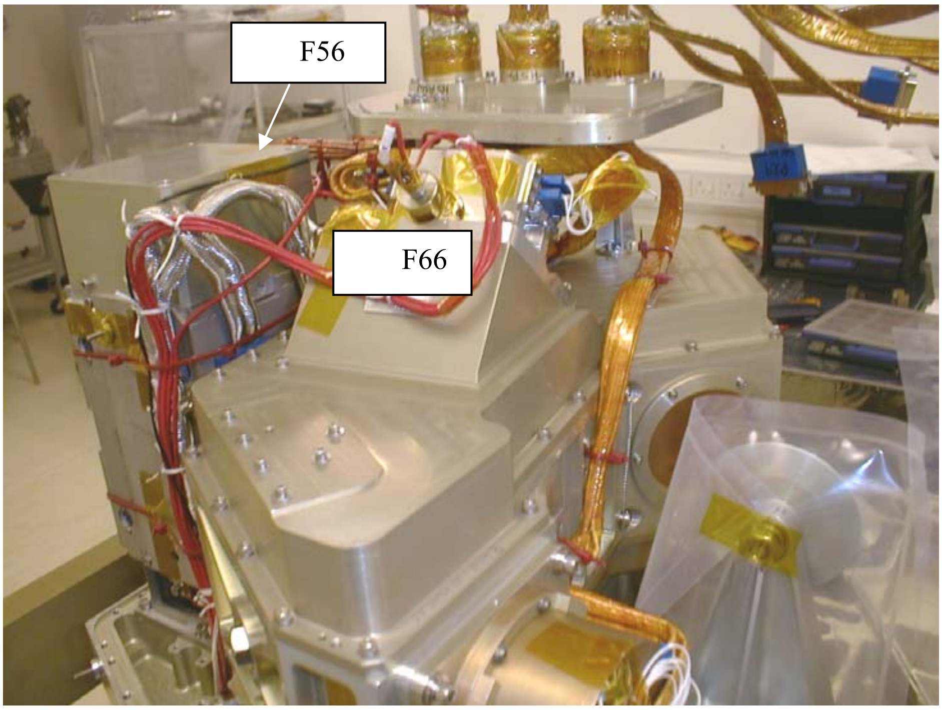
During the Y a Z axis vibration the SPECZ was not working properly (measuring in X) it was working properly during the X-axis vibration test.



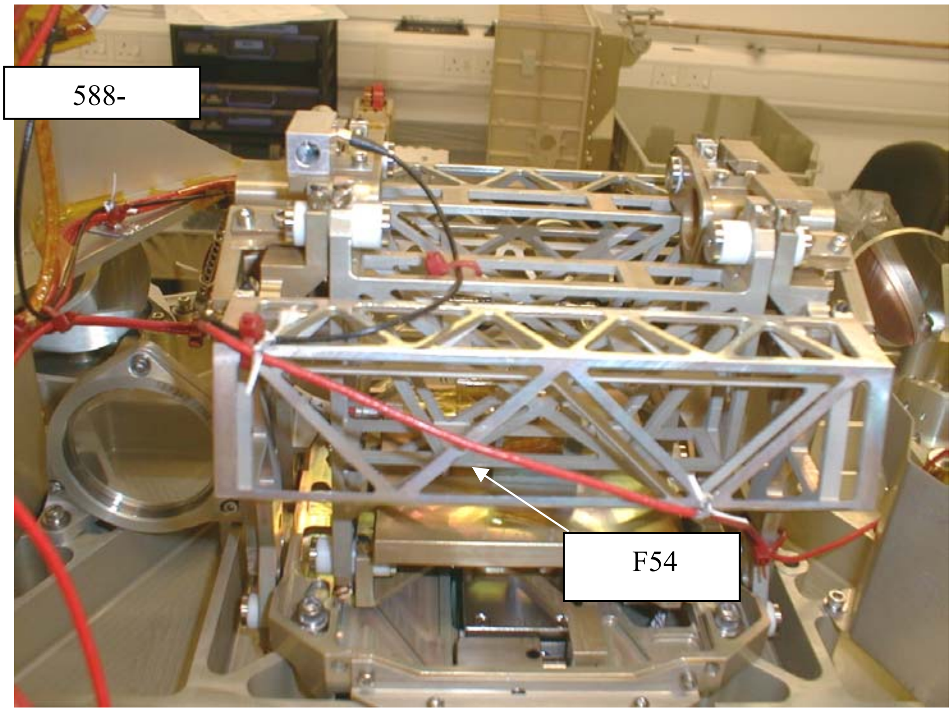
Spectrometer detector box



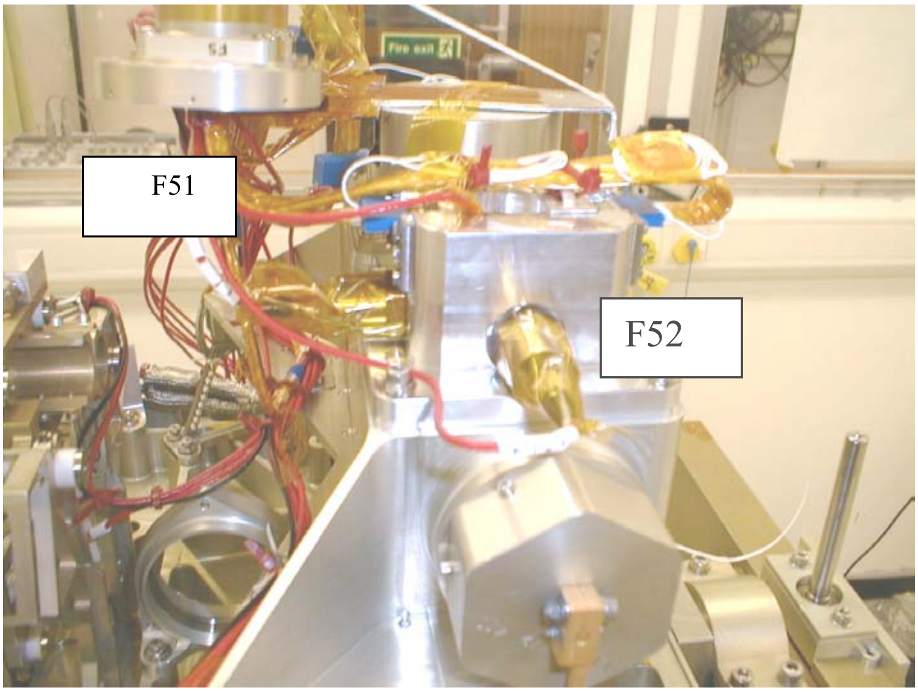
Photometer detector box



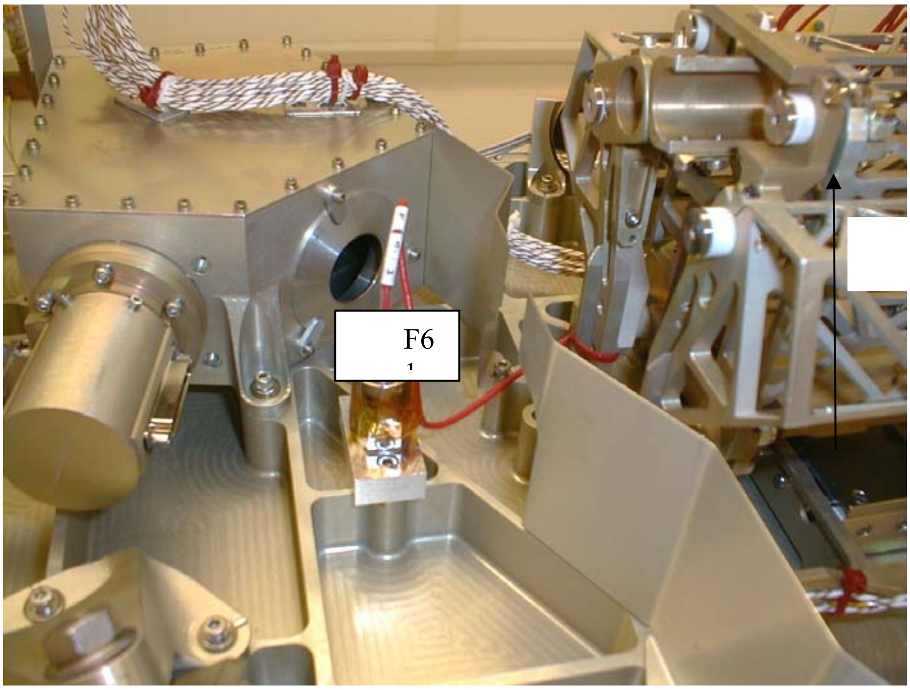
Photometer detector box and cooler



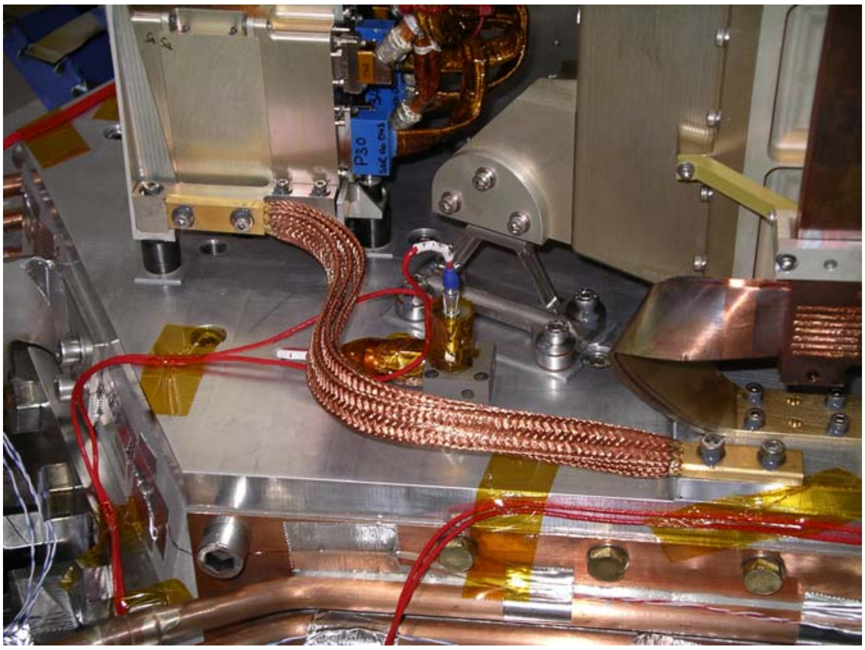
SMEC



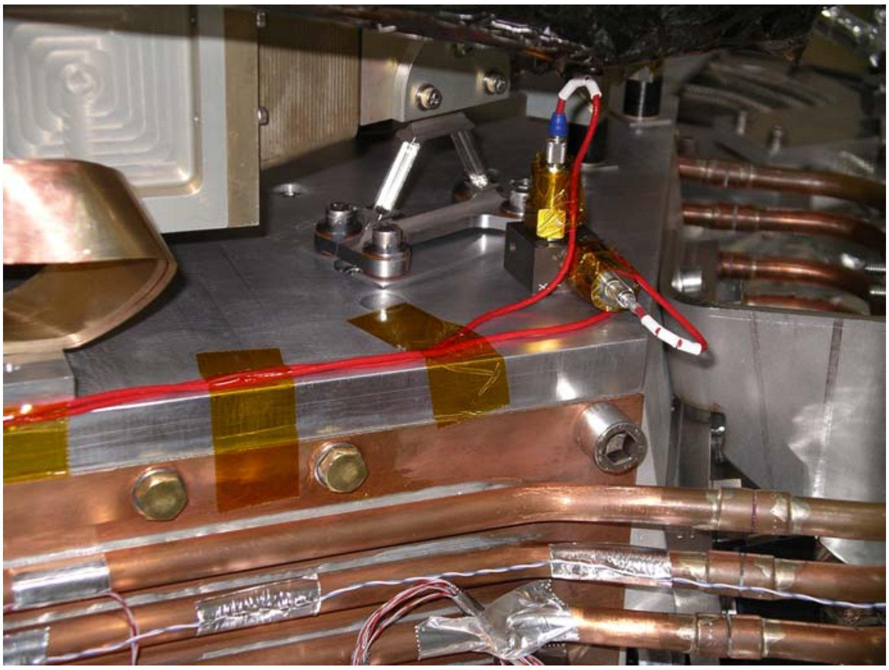
Spectrometer detector box



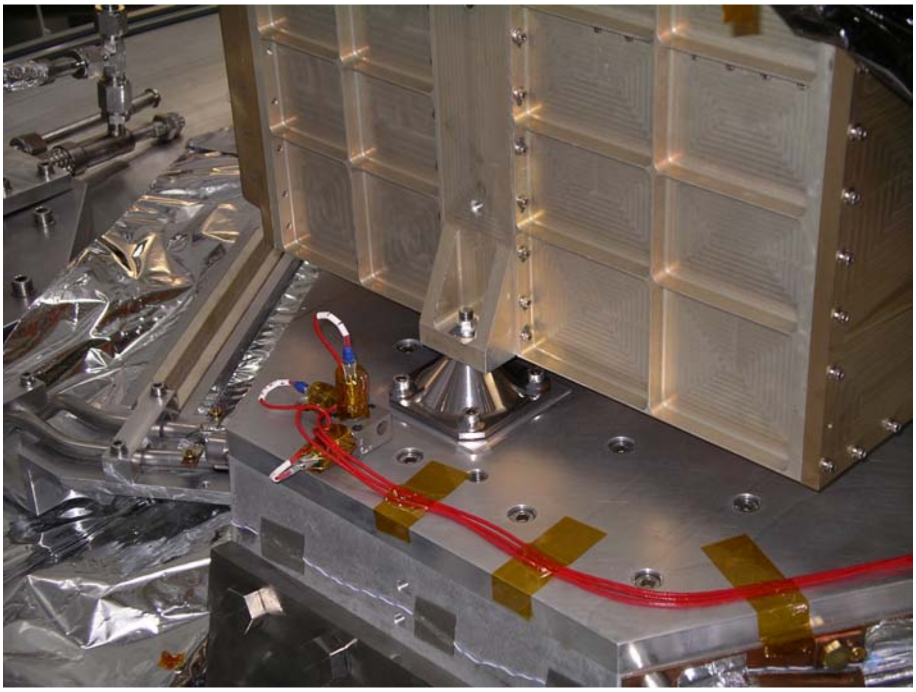
Optics bench near SMEC interface



FPU -Y foot



FPU + Y foot

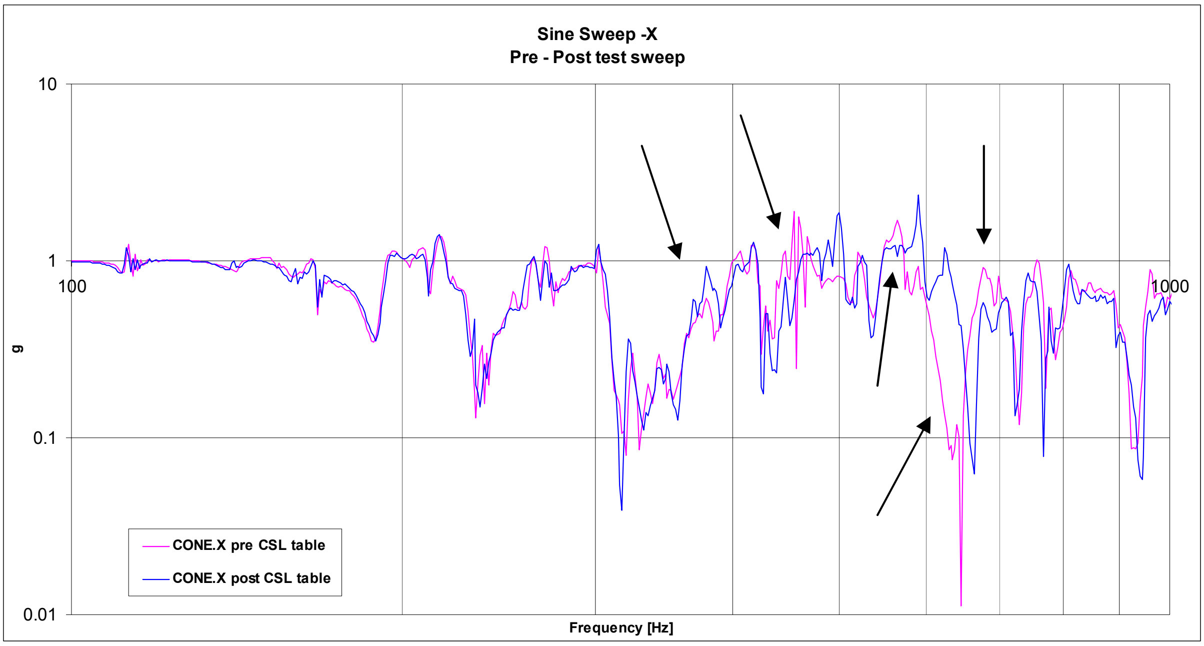


FPU Cone mount

Appendix B – Structural integrity

In this appendix various pre-post axis sine sweep accelerometer readings are shown. Proving the structural integrity after the high level sine and random tests. There is however an influence of the shaker and shaker control that makes verification between 350 and 700 Hz impossible. Since the shaker table behaves as it does and the control of the vibration is spread out over the average of 2 to 3 accelerometers the shaker input at these frequencies is never exactly the same when repeating tests. Making it therefore impossible to verify the traces at these frequencies.

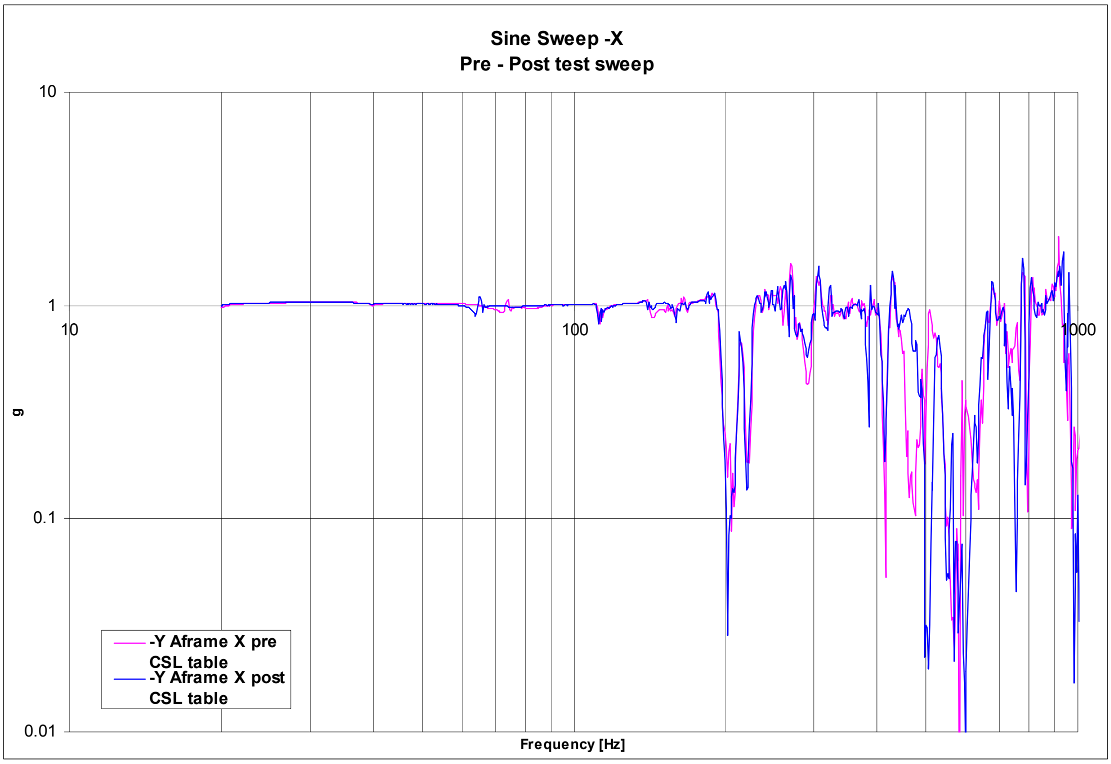
See as an example the following transfer function (pre-post test) between the drive and an accelerometer on the shaker table (not on the instrument)



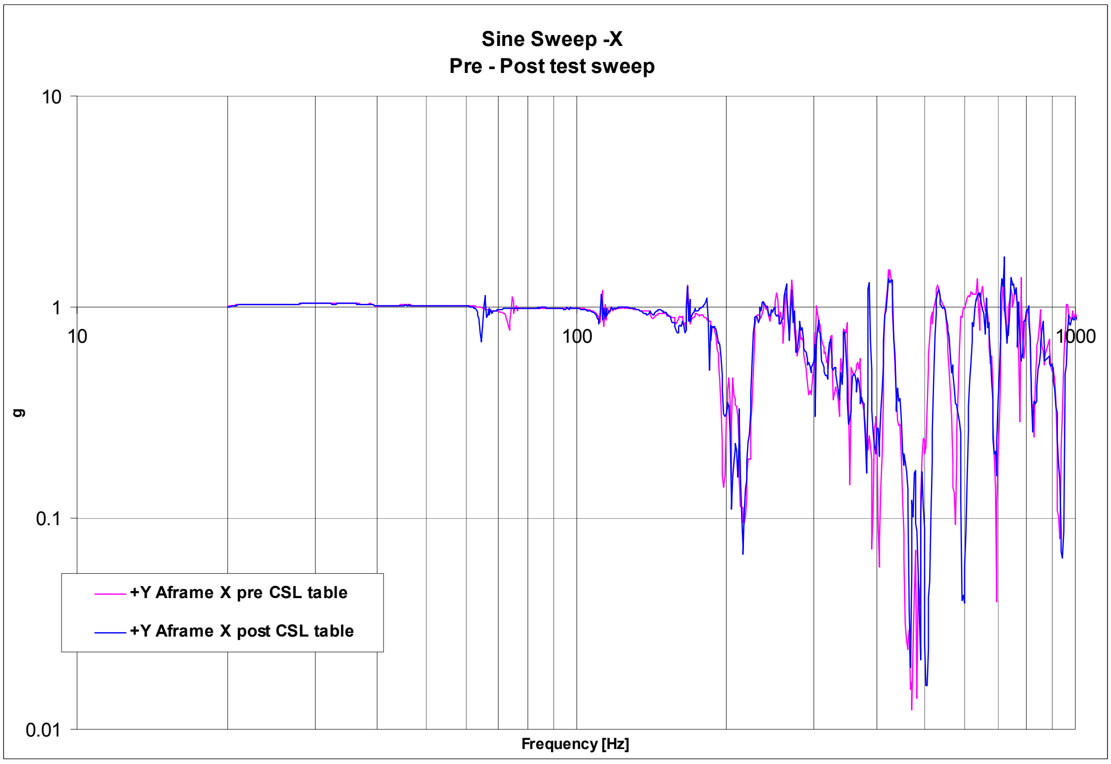
B-1: Example of a transfer function between the drive and an accelerometer on the shaker table (detail)

As can be seen checking the transfer function shown in C-1 the shaker table is rather flexible. The shaker control during this test was on the maximum of three accelerometers, mounted near the three interface points of the instrument.

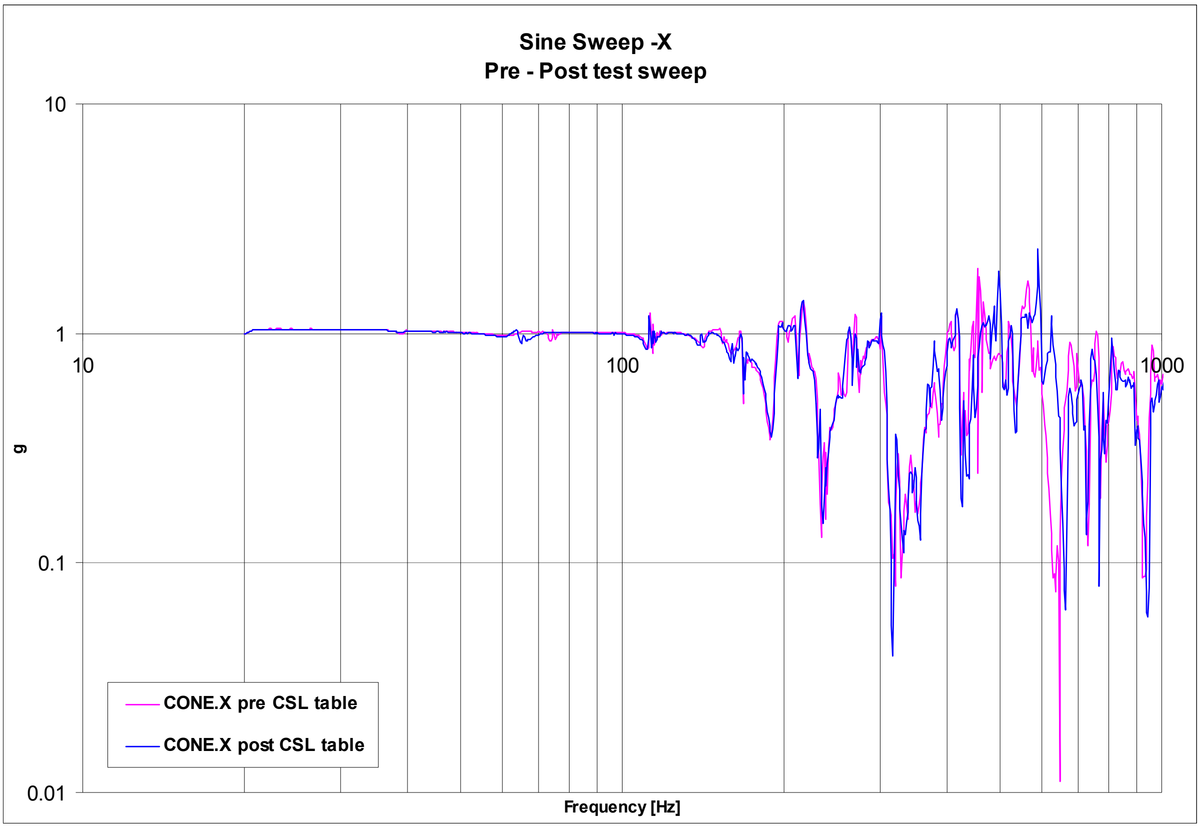
Hereafter the 3 different transfer functions (CSL shaker table, CSL drive) are shown between 20 Hz and 1 kHz



B-2: Differences in CSL table readings pre-post (at A-frame)



B-3: Differences in CSL table readings pre-post (at A-frame)



B-4: Differences in CSL table readings pre-post (at Cone)

Post test visual inspection upon return of the instrument at RAL showed now damage. The instrument supports are fine (after 2 qualification tests!) and the delicate SMec is also fine. The only change noticeable was that the dummy pivots in the SMec had shifted a little in axial direction during the various test runs. This explains the minor shifts visible in those accelerometer readings.

The following traces are some typical examples. Traces selected are on top of the instrument (FPU) in excitation direction and on one of the detector boxes. The comparison is limited to between 20 and 350 Hz

X-axis

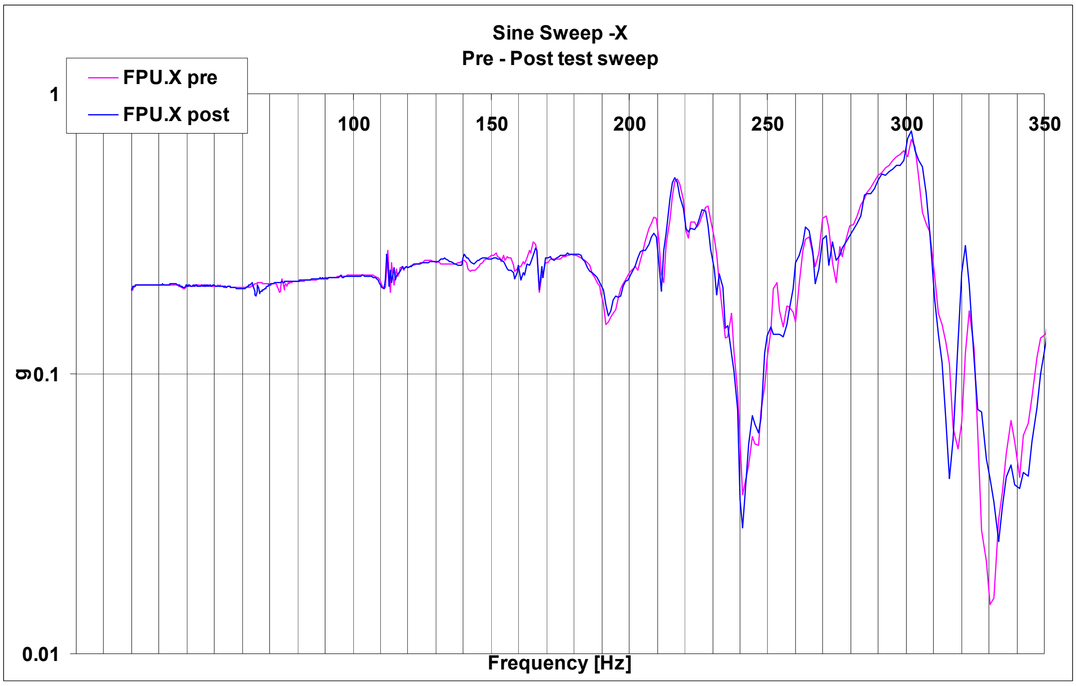


Figure B-5: Main structure in excitation direction (accelerometer at top SOB/instrument)

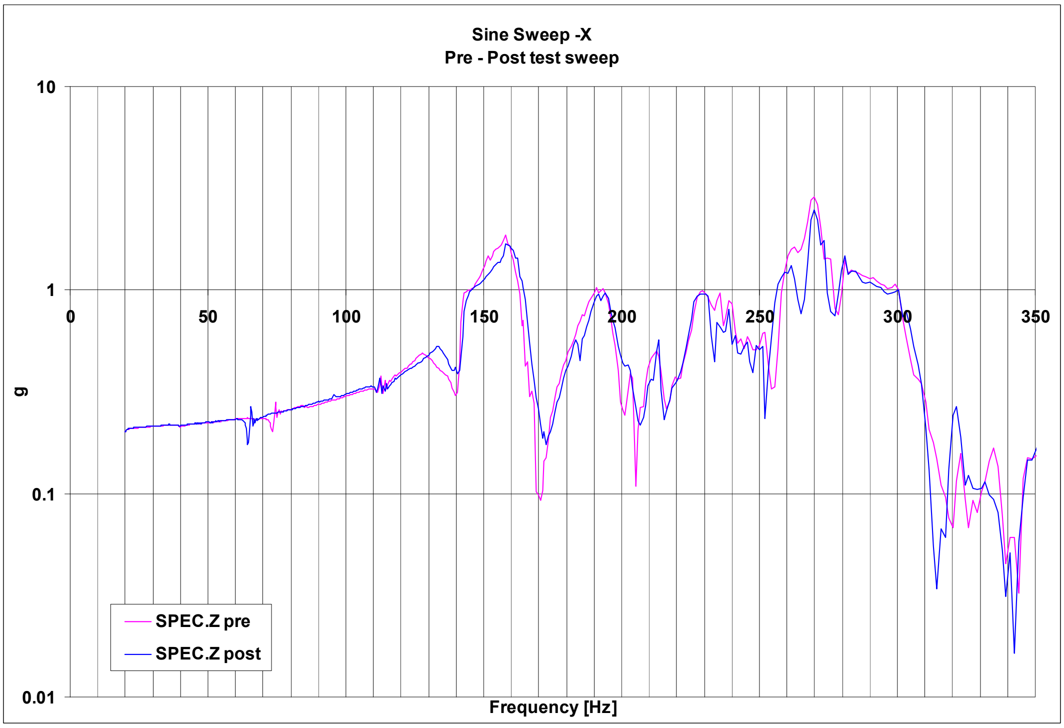


Figure B-6: Spec. det. box in excitation direction (accelerometer label Z is actually X)

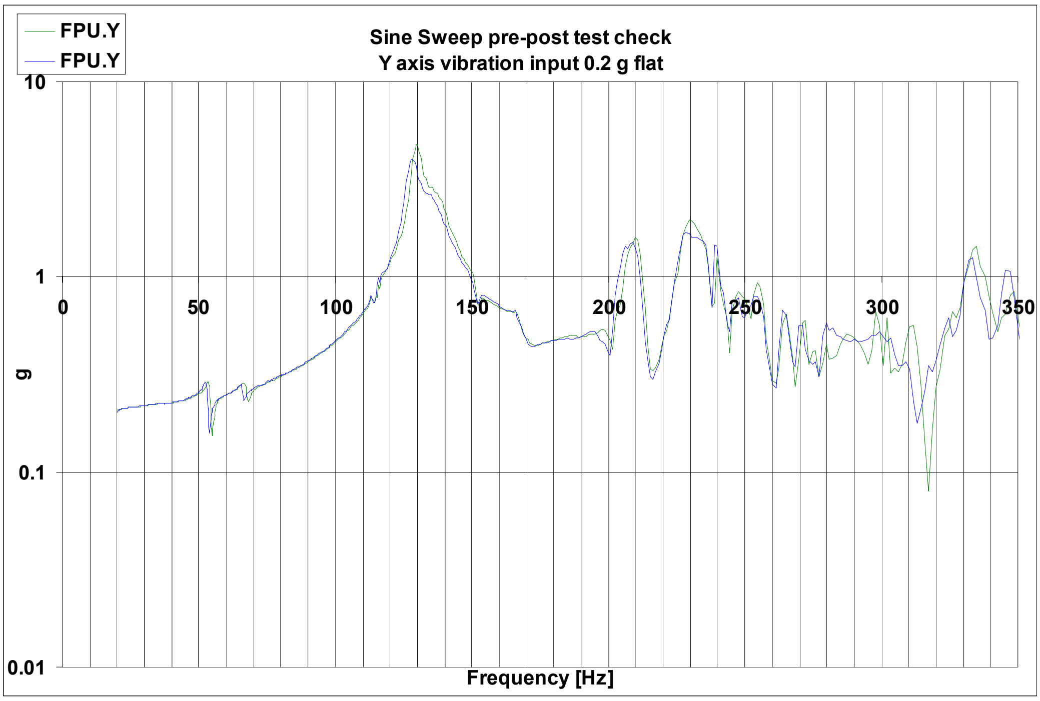


Figure B-7: Main structure in excitation direction (accelerometer at top SOB/instrument)

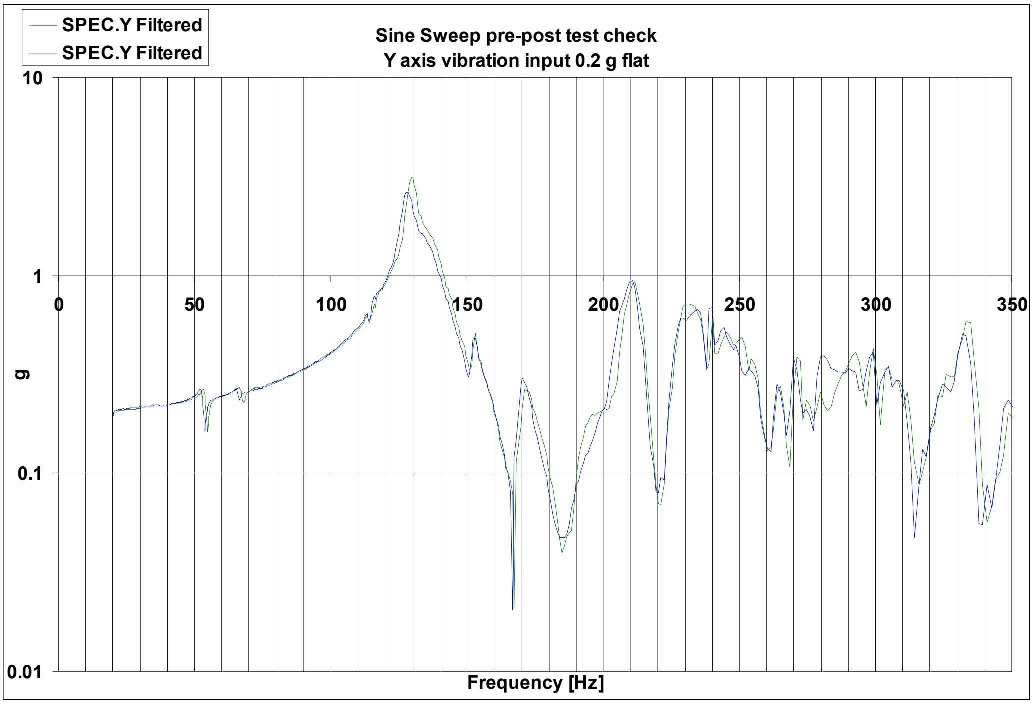


Figure B-8: Spec. det. box in excitation direction

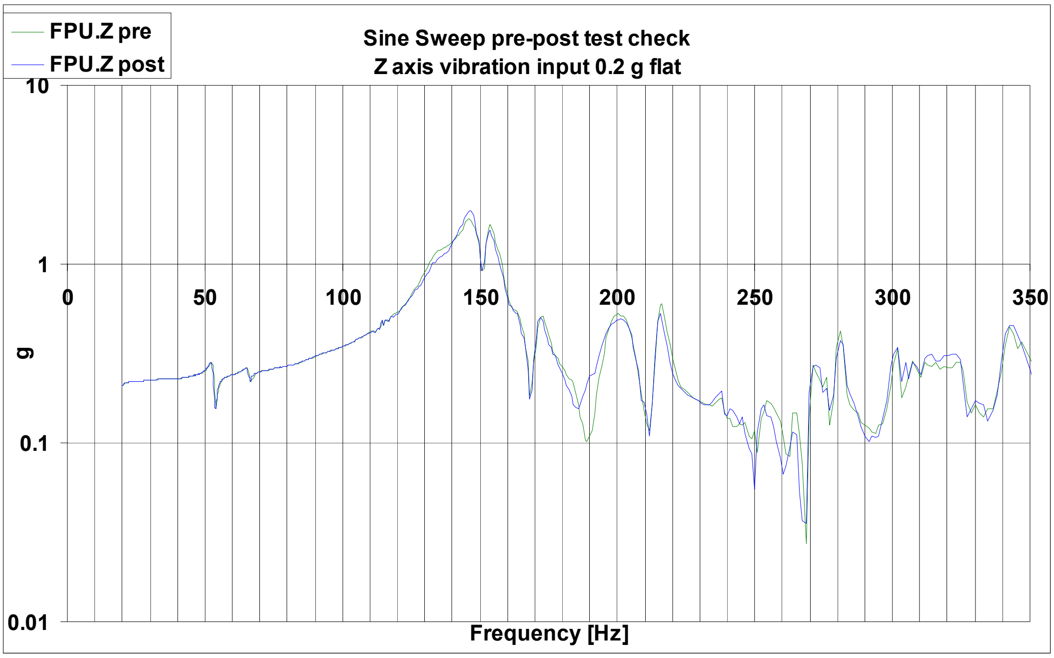


Figure B-9: Main structure in excitation direction (accelerometer at top SOB/instrument)

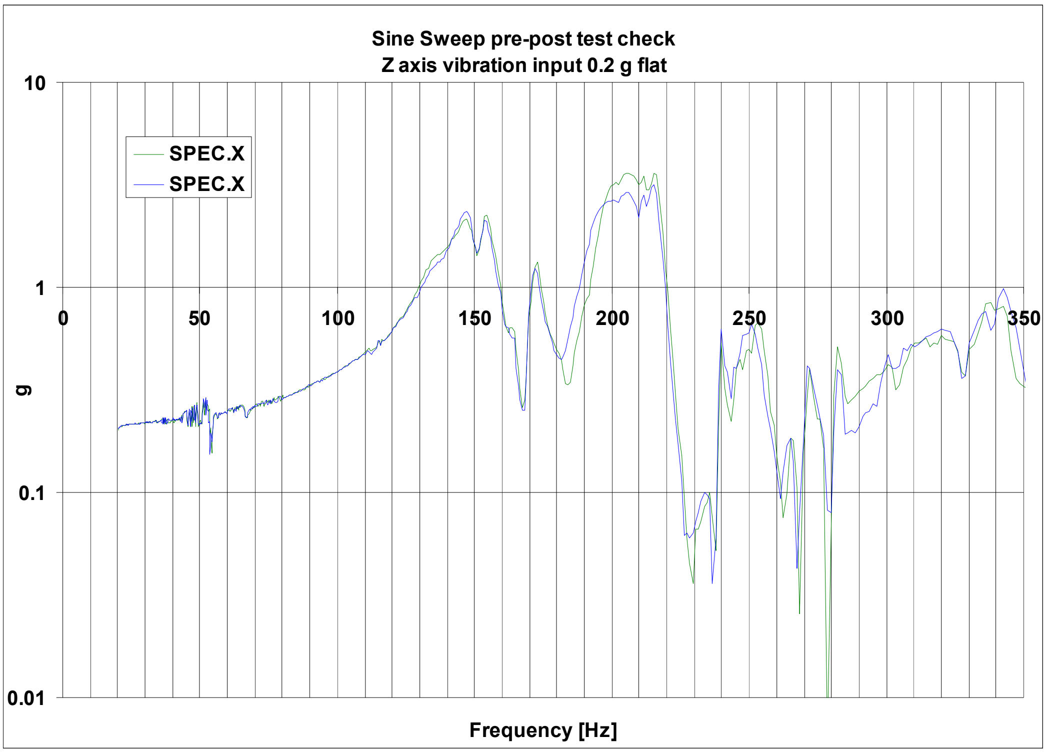


Figure B-10: Spec. det. box in excitation direction (accelerometer label Z is actually X)

Appendix C – Run list

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

Run	Date	Time	Axis	Description
BNS1Y	29/3/04	17:40	Y	Low level resonance search ambient pressure and temp
BNS2Y	5/4/04	11:04	Y	Low level resonance search stopped at 700Hz
BNS3Y	5/4/04	14:37	Y	Low level resonance search second try
NIS4Y	5/4/04	15:46	Y	Intermediate level sine test, to 200 Hz in error
BNS5Y	5/4/04	17:35	Y	Low level resonance search
HNS6Y	6/4/04	12:01	Y	Full level sine test
BNS7Y	6/4/04	12:15	Y	Low level resonance search
BNA8Y	6/4/04	12:35	Y	Flat random input 0.0001 g^2/Hz
BNA9Y	6/4/04	15:26	Y	-12dB Random run
BNA10Y	6/4/04	16:11	Y	-6dB Random run
NIA11Y	6/4/04	17:37	Y	-6dB Random run, second run
HNA12Y	6/4/04	18:16	Y	Full level random test
BNS13Y	6/4/04	18:26	Y	Low level resonance search

Run	Date	Time	Axis	Description
BNS1Z	7/4/04	14:27	Z	Low level resonance search, stopped at 850Hz
NIS2Z	7/4/04	15:45	Z	Intermediate level sine test 4g peak
HNS3Z	7/4/04	15:52	Z	High level sine test
BNS4Z	7/4/04	16:07	Z	Low level resonance search, stopped at 480Hz
BNA5Z	7/4/04	16:22	Z	Flat random input 0.0001 g^2/Hz
BNA6Z	7/4/04	17:22	Z	-12dB Random run
BNA7Z	7/4/04	18:11	Z	-6dB Random run
HNA8Z	7/4/04	18:22	Z	Full level random test
BNS9Z	7/4/04	18:30	Z	Low level resonance search, stopped at 730Hz

Run	Date	Time	Axis	Description
BNA4X	30/4/04	18:30	X	Flat random input 0.0001 g^2/Hz
BNS5X	1/5/04	08:55	X	Low level resonance search, stopped at 460Hz
NIS6X	1/5/04	10:00	X	Intermediate level sine test 9g peak
HNS7X	1/5/04	10:55	X	High level sine test
BNS8X	1/5/04	11:00	X	Low level resonance search,
BNA9X	1/5/04	11:20	X	-12dB Random run
NIA10X	1/5/04	14:40	X	-6dB Random run
NIA11X	1/5/04	15:40	X	-6dB Random run, repeat
HNA12X	1/5/04	15:50	X	Full level random test
BNS13X	1/5/04	16:00	X	Low level resonance search,

Appendix D – RMS ratios

During each tested axis one run was included with a flat 0.0001 g-rms input with the control on the average. The following tables show the measured g-rms values for the various accelerometers.

Shaker:			
Control channel [g²/Hz]			
0.425			
Shaker table (excitation direction)			
CONE.X (C) [g²/Hz]	-YAFRAME.X (C) [g²/Hz]	+YAFRAME.X (C) [g²/Hz]	
0.321	0.362	0.316	
Shaker table (cross-coupling)			
CONE.Z (M) [g²/Hz]	CONE.Y (M) [g²/Hz]	-YAFRAME.Y (M) [g²/Hz]	+YAFRAME.Z (M) [g²/Hz]
0.251	0.216	0.196	0.156
Top of the instrument (main structure)			
FPU.X (M) [g²/Hz]	FPU.Y (M) [g²/Hz]	FPU.Z (M) [g²/Hz]	
0.325	0.210	0.313	
Spire optical bench	Cooler-main structure (in fact Spire-optical-bench)		
OB.Y (M) [g²/Hz]	COOL.X (M) [g²/Hz]		
0.248	0.385		
Detector box (photometer)			
PHS.XY (M) [g²/Hz]	PHS.Z (M) [g²/Hz]	PHE.XY (M) [g²/Hz]	
0.363	0.618	0.300	
Detector box (spectrometer)			
SPEC.X (M) [g²/Hz]	SPEC.Z (M) [g²/Hz]	SPEC.Y (M) [g²/Hz]	
0.613	0.598	0.143	
Spectrometer mechanism			
SOB-mounted	Top (this is wc direction)		
SMECL.X (M) [g²/Hz]	SMECU.X (M) [g²/Hz]		
0.559	0.94		
Cooler cold tip (Kevlar suspended)			
CTIP.Y (M) [g²/Hz]			
0.578			

D1: Measured g-rms levels for the X-axis with flat 0.0001 g2/Hz input. (maximum control)

It can be seen looking at this table that the responses go up if one goes ‘higher up’ in the structure

Amplification between shaker table and the main structure (FPU) is typically 1 (no real amplification over the whole 10-2000 Hz frequency range). Components inside the structure show amplifications of about 2 (typically) for the detector boxes and other main components up to 3 for the spectrometer mechanism.

Shaker:			
Control channel [g²/Hz]			
0.52			
Shaker table (excitation direction)			
CONE.X (C) [g²/Hz]	-YAFRAME.X (C) [g²/Hz]	+YAFRAME.X (C) [g²/Hz]	
0.99	1.24	1.17	
Shaker table (cross-coupling)			
CONE.Z (M) [g²/Hz]	CONE.Y (M) [g²/Hz]	-YAFRAME.Y (M) [g²/Hz]	+YAFRAME.Z (M) [g²/Hz]
0.67	0.53	1.77	0.87
Top of the instrument (main structure)			
FPU.X (M) [g²/Hz]	FPU.Y (M) [g²/Hz]	FPU.Z (M) [g²/Hz]	
0.74	1.34	0.53	
Spire optical bench	Cooler-main structure (in fact Spire-optical-bench)		
OB.Y (M) [g²/Hz]	COOL.X (M) [g²/Hz]		
1.13	0.71		
Detector box (photometer)			
PHS.XY (M) [g²/Hz]	PHS.Z (M) [g²/Hz]	PHE.XY (M) [g²/Hz]	
0.59	0.60		
Detector box (spectrometer)			
SPEC.X (M) [g²/Hz]	SPEC.Z (M) [g²/Hz]	SPEC.Y (M) [g²/Hz]	
1.09	0.59	0.87	
Spectrometer mechanism			
SOB-mounted	Top (this is wc direction)		
SMECL.X (M) [g²/Hz]	SMECU.X (M) [g²/Hz]		
1.17	1.83		
Cooler cold tip (Kevlar suspended)			
CTIP.Y (M) [g²/Hz]			
1.50			

D2: Measured g-rms levels for the Y-axis with flat 0.0001 g2/Hz input (one channel control)

As for X, but now average control instead of maximum. Ratios are now (ignore A-frame reading, that one was faulty) 2.6 for the main structure between 1.2 and 2 for the detector boxes, 3 for the cooler cold tip and almost 4 for the SMec in cross coupling.

Shaker:			
Control channel [g²/Hz]			
0.46			
Shaker table (excitation direction)			
CONE.X (C) [g²/Hz]	-YAFRAME.X (C) [g²/Hz]	+YAFRAME.X (C) [g²/Hz]	
1.20	1.25	1.25	
Shaker table (cross-coupling)			
CONE.Z (M) [g²/Hz]	CONE.Y (M) [g²/Hz]	-YAFRAME.Y (M) [g²/Hz]	+YAFRAME.Z (M) [g²/Hz]
0.77	1.12	2.81	0.87
Top of the instrument (main structure)			
FPU.X (M) [g²/Hz]	FPU.Y (M) [g²/Hz]	FPU.Z (M) [g²/Hz]	
0.66	0.59	0.67	
Spire optical bench	Cooler-main structure (in fact Spire-optical-bench)		
OB.Y (M) [g²/Hz]	COOL.X (M) [g²/Hz]		
0.53	0.46		
Detector box (photometer)			
PHS.XY (M) [g²/Hz]	PHS.Z (M) [g²/Hz]	PHE.XY (M) [g²/Hz]	
0.64	0.96		
Detector box (spectrometer)			
SPEC.X (M) [g²/Hz]	SPEC.Z (M) [g²/Hz]	SPEC.Y (M) [g²/Hz]	
1.03	0.55	0.34	
Spectrometer mechanism			
SOB-mounted	Top (this is wc direction)		
SMECL.X (M) [g²/Hz]	SMECU.X (M) [g²/Hz]		
1.34	1.62		
Cooler cold tip (Kevlar suspended)			
CTIP.Y (M) [g²/Hz]			
0.55			

D3: Measured g-rms levels for the Z-axis with flat 0.0001 g2/Hz input (one channel control)

As for both previous axes we see amplifications between the base and the instrument of about 1, 1.5 for the detector boxes and 3 for the mechanism.

Appendix E - Summary of events

Date	Activity
28/3/04	Delivery of SPIRE to CSL
29/3/04	Unpack and set up
30/3/04	TRR
2/4/04	Cool down
5/4/04	Y axis tests
6/4/04	Y axis tests
7/4/04	Reconfigure to Z axis and carry out Z axis tests
13/4/04	Remove SPIRE
14/4/04	Reconfigure shaker to SPIRE X axis
15/4/04	Refit SPIRE
16/4/04	Start cool down
19/4/04	Cool down stopped due to faulty bellows
21/04/04	SPIRE removed
26/4/04	SPIRE refitted
28 /4/04	Start cool
1/5/04	X axis testing
2/5/04	Start warm up
5/5/04	SPIRE removed and packed in container
6/5/04	Collected from CSL
7/5/04	Returned to RAL

Appendix F - NCR

CCLRC Rutherford Appleton Laboratory	NON-CONFORMANCE REPORT (NCR)	PRODUCT ASSURANCE Space Science and Technology Department

NCR Number:	HR-SP-RAL-NCR-075

Spacecraft / Project	**Herschel / SPIRE**	**Originator's Name**	**Eric Sawyer**	
Experiment / Model	CQM	**Signature**		
Sub-System	Instrument	**Date**	12-May-04	
Assembly		**Level** (Highlight if applicable)	**Major**	Minor
Sub-Assembly				
Item		**NRB Reference**	Not required	
Serial Number				

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

NCR Title	**During Cold vibration test the sine test went to 200 Hz.**

NCR Description

During the cold vibration campaign, an intermediate level (2g) sine test was conducted up to 200Hz, when it was intended to stop at 100Hz.

Cause of NCR

Human error.

Disposition / Corrective Action

There was some discussion as to weather the detectors had seen levels above qualification. After detailed discussions and some simple analysis it was decided that was unlikely that the detectors has seen damaging levels.
It was decided to continue the test campaign.
Post test inspection has shown no visible damage to the detectors.
Final confirmation will be achieved during the post vibration cold verification test campaign.
Leave open until after the test.

Functional/Performance tests complete - No evidence of Damage to Detectors or to any other Sub-System. NCR can be closed

Document or Drawing Affected (Title, Number & Issue)

None

Estimated COST OF NCR (cost of : correction, Materials, Resource, and delay to Project etc.)

None

NCR CLOSED (Signatures & Date Required)	**PA Manager (Or Deputy)**	**Project Manager (Or Deputy)**
Customer / Industry	**ESA**	**Alcatel**