SOLAR ORBITER ENERGETIC PARTICLE DETECTOR

EPTHET-1 FM and EPTHET-2 PFM Random-Sine Vibration Test Plan and Procedure

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CHANGES RECORD

Issue	Revision	Date	Modified by	Section / Paragraph modified	Change implemented
1	0	28/02/2016		All	Initial release

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Purpose

The aim of this document is to define the vibration test plan and procedure.

1.2 Scope

This document applies to all activities related to EPTHET-1 FM and EPTHET-2 PFM vibration test campaigns performed by all institutions and personnel involved in the test.

Important notes:

- EPTHET PQM vibration tests during 18.05-20.05.2015 were unsuccessful and resulted to HW damage on electronic boards. The details of this are summarized in NCR-0016 [RD-5].
- By lessons learned from the electronic boards stiffeners used in STEP PQM before vibration tests, the electronic boars of EPTHET-2 PFM and EPTHET-1 FM are also stiffened with some stiffeners.
- Based on the new levels received from ESA, a notching plan for RV test on EPTHET-2 PFM and EPTHET-1 FM is planned and investigated which its details can be found in RFD-0017 [RD-6].
- During the “EPD-IQR co-location meeting” at ESTEC on 17.02.2016, due to the fact that EPTHET-1 &2 are identical, EPTHET-2 can comply with PFM approach which means qualification level and acceptance durations. And EPTHET-1 can comply with FM approach which is acceptance level and acceptance duration.

2 GLOSARY AND DEFINITIONS

2.1 Acronyms and Abbreviations

CAU Christian-Albrechts-Universität zu Kiel

CoG Center of Gravity

EIDA Experiment Interface Document-Part A

EPD Energetic Particles Detector

EPT Electron, Proton Telescope

EUT Equipment Under Test

FM Flight Model

HET High Energy Telescope

MI Mechanical Interface

MLI Multi-layer Insulator

MoI Moment of Inertia

PA Product Assurance

PFM Protoflight Model

PQM Proto-Qualification Model

TBC To Be Confirmed

TRR Test Readiness Review

ADS Airbus Defence & Space

3 APPLICABLE AND REFERENCE DOCUMENTS

3.1 Applicable Documents

ID.	Title	Reference	Iss./Rev.	Date
AD-1	Experiment Interface Document part A	SOL-EST-RCD-0050	5/0	16/03/2015
AD-2	EPT-HET and STEP Assembly, Integration and Test Plan	SO-EPD-KIE-PL-0010	2/1	30/10/2013
AD-3	EPTHET1 FM and EPTHET-2 PFM Functional test plan and procedure	SO-EPD-KIE-TP-0038	1/0	29/02/2016
AD-4	CIDL-ABCL for EPTHET-1 FM and EPTHET-2 PFM	SO-EPD-KIE-LI-0011	1/0	29/02/2016

3.2 Normative Documents

ID.	Title	Reference	Iss./Rev.	Date
ND-1	Testing	ECSS-E-ST-10-03C		01/06/2012

3.3 Reference Documents

ID.	Title	Reference	Iss./Rev.	Date
RD-1	EPT-HET Structural Analysis Report	SO-EPD-KIE-RP-0040	3/3	23/04/2014
RD-2	Request for Deviation (RFD) for mass properties measurement	SO-EPD-KIE-RD-0001	2/1	06/06/2014
RD-3	Drawing: EPTHET Mechanical Interface Control Drawing EPD_EPTHET_05022016_5-4_SO-EPD-KIE-DR-0001_fm_micd.pdf	SO-EPD-KIE-DR-0001_fm.idw	5/4	05/02/2016
RD-4	Drawing: so_epthet-step_ads-vibetest-adaptor_r01.pdf	ads-vibetest-adaptor	Rev. 01	26/03/2015
RD-5	Nonconformance Report (NCR) after failiour in EPTHET PQM qualification vibration tests	SO-EPD-KIE-NC-0016_rev1-postVibFTanomalies.pdf	-	20/05/2015
RD-6	Request for Deviation (RFD) for EPTHET vibration levels and notching	SO-EPD-KIE-RD-0016	1/0	25/02/2016
RD-7	EPT-HET PQM vibration test report	SO-EPD-KIE-TR-0015	1/0	16/09/2015

4 TEST OVERVIEW

4.1 Test objectives

The objective of the vibration test is to verify the structural design. That is to demonstrate EPTHET-2 PFM unit will tolerate the induced loads during different mission phases without degradation and EPTHET-1 FM is free of workmanship errors by passing the vibration at acceptance level.

4.2 Test facility

The vibration tests are conducted in Airbus Defence & Space Test Laboratories in Portsmouth, England.

4.3 Environmental conditions

- Cleanliness: ISO 8 clean-hood.

4.4 Test documentation

The approved test procedure will be used during the test to record observations and decisions. A completed test report will be presented after the test. It will include the final as-run test procedure approved by the PA (Product Assurance) responsible and will be accompanied by the accelerometers outputs and test report provided by ADS and CAU. Also, appropriate discussion will conclude the success/failure of the conducted test.

- The complete list of the test equipment and their calibration information will be included in in the final test report.
- Test anomalies will be reported in the final test report as part of the test documentation and in the form of NCR/RFD when applicable.
- Test deviations will be reported in the final test report as part of the test documentation and in the form of NCR/RFD when applicable.

4.5 Participants

The test participants and their responsibilities are defined in Table 4-1.

Table 4-1. Test participants (TBC before the test) and their responsibilities.

CAU		
#	Name	Responsibility
1	Ali Ravanbakhsh	AIVT, test responsible
2	Michael Richards	Quality assurance
3	Shri Kulkarni	Instrument lead
4	Lars Seimetz	Engineering lead
5	Mahesh Yedla	Electronic engineer
6	Sebastian Boden and Jan Tammen	Instrument scientists

ADS (test facility)		
#	Name	Responsibility
1	William Wright	Test facility responsible
2	Michael Stacey	Test facility engineer

4.6 Safety

ADS facility general safety requirements shall apply during all operations.

Handling, mounting and testing shall be performed by qualified personnel from CAU with support of ADS personnel in accordance with safety requirements of ADS.

4.7 Equipment under test

As seen in Fig. 4-7-1, the EPT and HET sensor heads share a common Ebox. For vibration test, EPT-HET PQM will not be covered by MLI. But, the MLI stand-offs are mounted on EPT-HET PQM for vibration tests.

Note: The MLI stand offs will not be glued on EPTHET-1 FM and EPTHET-2 PFM for vibration tests, nevertheless the structural integrity of MLI standoffs is already verified during EPTHET PQM vibration test.

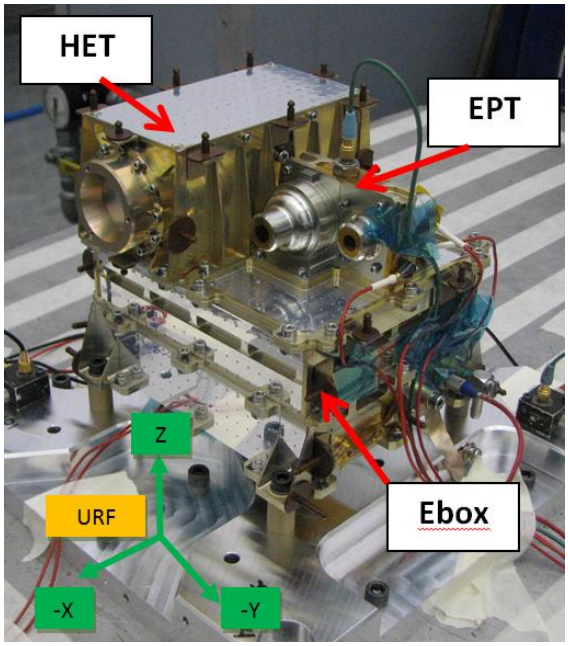


Figure. 4-1. EPTHET PQM during vibration test 18.05- 20.05.2015, EPTHET-1 FM and EPTHET-2 PFM are currently under assembly, and detail information about EPTHET-1 FM and EPTHET-2 PFM can be found in [AD-4].

After the complete assembly of the EPTHET-1 FM and EPTHET-2 PFM, its total mass is measured. The other mass properties like CoG and MoI are going to be verified analytically. The RFD, [RD-2], has been submitted for mass properties measurement.

Further information such as exact dimensions etc. can be found in [RD-3].

The EPTHET-1 FM and EPTHET-2 PFM will be mounted on the mechanical interface in all of the four instrument feet with the following bolts-nuts-washers:
-Hex socket screw: DIN EN ISO 4762-M5x45-12.9
-Washer: DIN EN ISO 7092-5, 3 Mat:12.9
-Hex nut: DIN EN ISO 4032-M5 Mat:12.9

The torque to be applied is 6.3 N.m ±0.1 in order to meet the required preload specification in the flight condition with LN29950 Bolts.

5 TEST SET UP

5.1 Mechanical interface

EIDA R-495: *The PI shall ensure that the adaptor shall have a first resonance frequency above 2 kHz in order not to influence the test.*

ADS is providing the MI (Mechanical Interface) for vibration test. This test adaptor is shown in Figure 5-1. A vibration test (jig test) will be performed on MI in order to verify its characteristics by test before the EUT integration to the MI. Two accelerometers are mounted on MI and an average value will be considered for analysis.

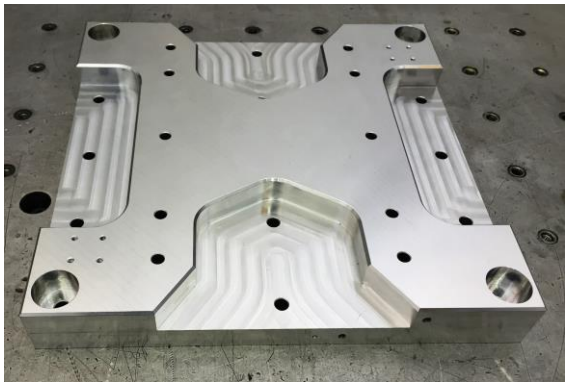


Figure 5-1. Mechanical interface for vibration test.

The mechanical interface is mounted on the shaker plate via ten "¼ UNF" screws with a 7 N.m applied torque. The details of the mechanical interface can be found in [RD-4].

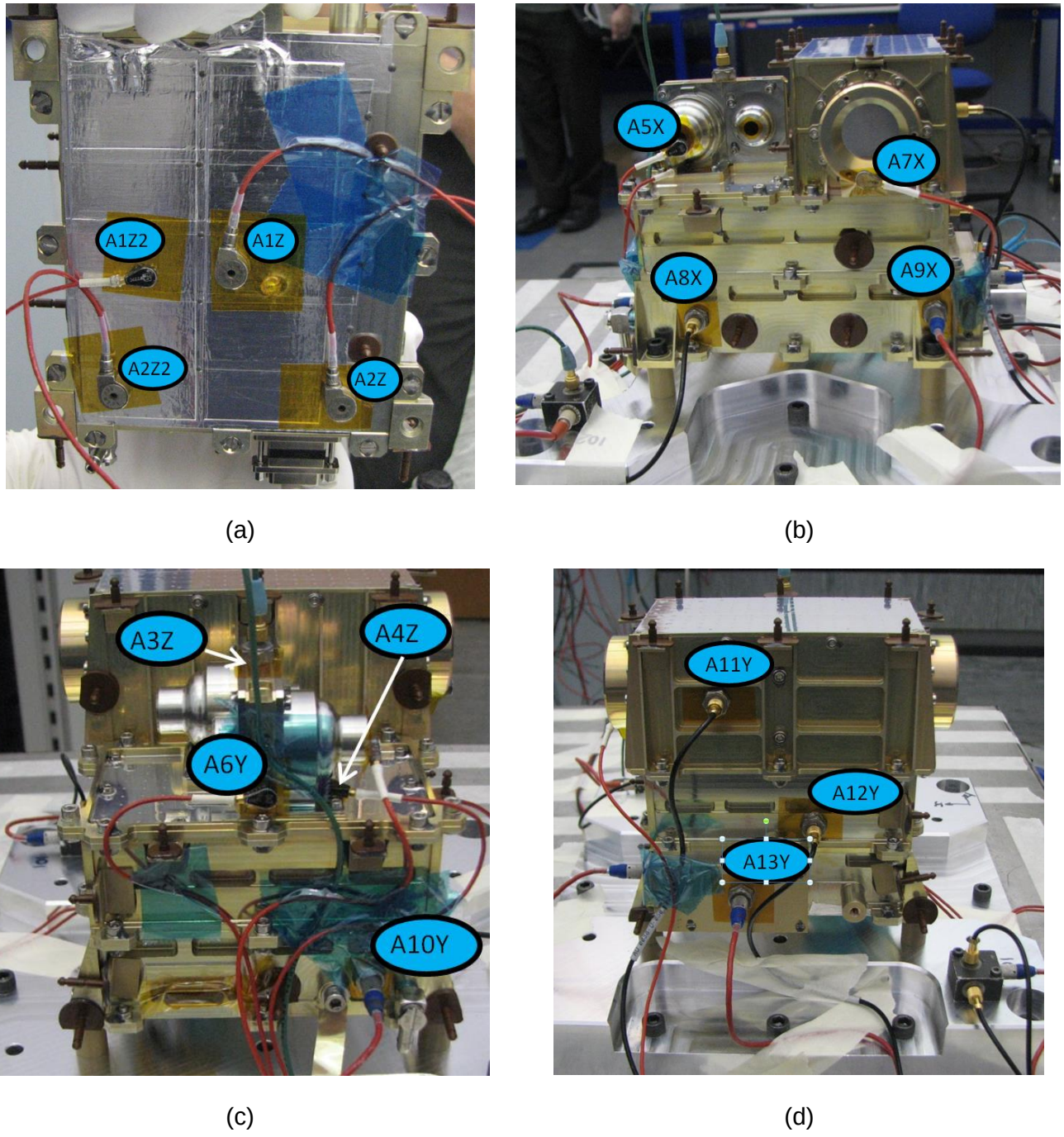
5.2 Accelerometers

ADS uses different types of calibrated 1-axis accelerometers indicated in Table 5-1 and their positioning is seen in Figure 5-2. Two control accelerometers are used on the MI to measure the frequency input to the EUT.

Note: The accelerometers locations, Fig. 5-2, will be exactly the same as the qualification vibration test performed on 18.05-20.05.2015, [RD-7] but ONLY the green-highlighted accelerometers in Table 5-1 will be used for EPTHET-1 FM and EPTHET-2 PFM vibration tests.

Table 5-1. Accelerometer positions used for EPTHET PQM vibration, the green-highlighted ones will be used for EPTHET-1 FM and EPTHET-2 PFM.

	Accelerometers		
EPTHET structural subassemblies	**X-direction**	**Y-direction**	**Z-direction**
Ebox bottom plate, **Fig. 5.2 (1)**	-	-	A1Z A1Z2 A2Z A2Z2
Ebox, **Fig. 5.2 (b) (c) (d)**	A8X, A9X	A10Y, A12Y, A13Y	To be added at the time of the test
EPT head, **Fig. 5.2 (b) (c)**	A5X	A6Y	A4Z, A3Z
HET head, **Fig. 5.2 (b) (d)**	A7X	A11Y	-



(a) (b)

(c) (d)

Figure 5-2. Accelerometer positions used for EPTHET PQM vibration, the green-highlighted ones in Table 5-1 will be used for both EPTHET-1 FM and EPTHET-2 PFM.

6 TEST PARAMETERS

6.1 Test requirements

Important notes:

- EPTHET PQM vibration tests during 18.05-20.05.2015 were unsuccessful and resulted to HW damage on electronic boars. The details of this are summarized in NCR-0016 [RD-5].
- By lessons learned from the electronic boards stiffeners used in STEP PQM before vibration tests, the electronic boars of EPTHET-2 PFM and EPTHET-1 FM are also stiffened with some stiffeners.
- Based on the new levels received from ESA, a notching plan for RV test on EPTHET-2 PFM and EPTHET-1 FM is planned and investigated which its details can be found in RFD-0017 [RD-6].
- During the "EPD-IQR co-location meeting" at ESTEC on 17.02.2016, due to the fact that EPTHET-1 &2 are identical, EPTHET-2 can comply with PFM approach which means qualification level and acceptance durations. And EPTHET-1 can comply with FM approach which is acceptance level and acceptance duration.

Resonance search sine sweep:

The resonance search sine sweep test was perfumed according to Table 6-1.

Table 6-1: Frequency range and level for Low Sine Sweep Tests.

Axis	Frequency (Hz)	Amplitude
All axis	5-2000	0.25 g --- 2 Oct/min

Acceptance Sine:

EIDA R-497**:** *The PI shall ensure that units mounted on the spacecraft panels are designed to withstand without degradation the sinusoidal environment as defined in table below at unit/structure interface.*

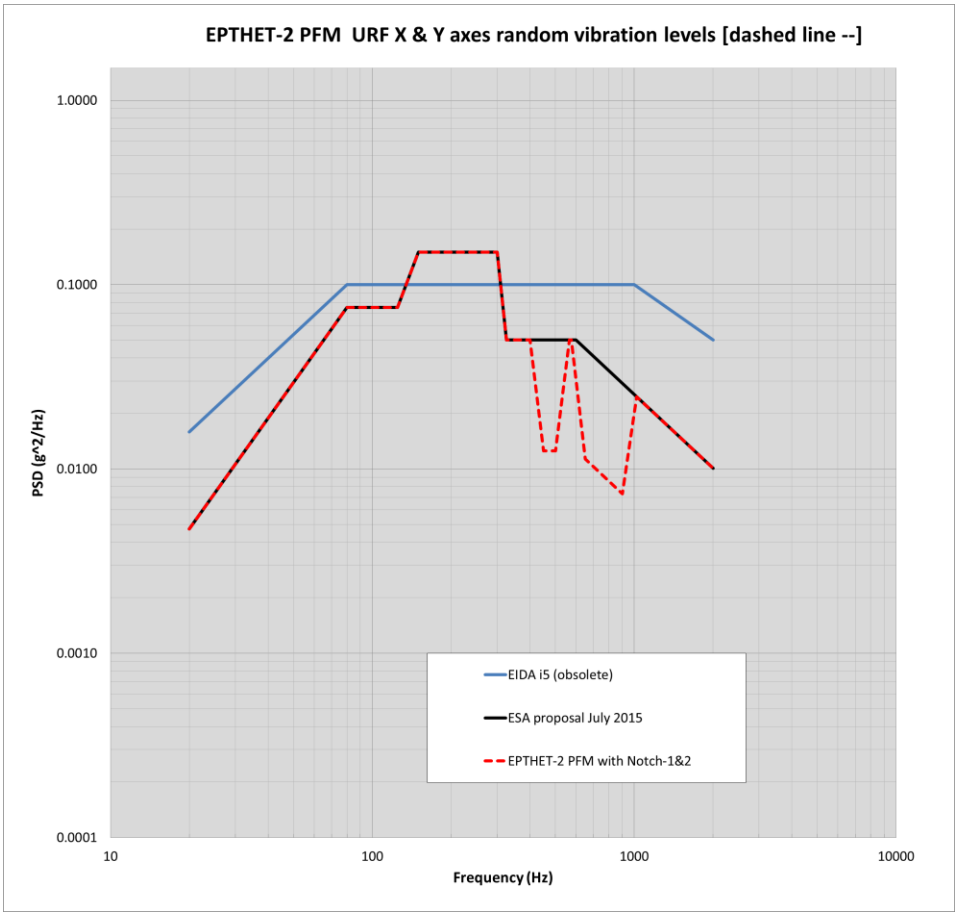
Table 6-2: Qualification Levels for Sine Vibration Tests [RD-06].

Axis	Frequency (Hz)	Qualification for EPTHET-2 PFM	Acceptance for EPTHET-1 FM (1)
In-plane and Out-of-plane	5-20	9.9 mm	6.6 mm
	20-100	16 g	10.7 g
		2 Oct/min	4 Oct/min

Acceptance Random:

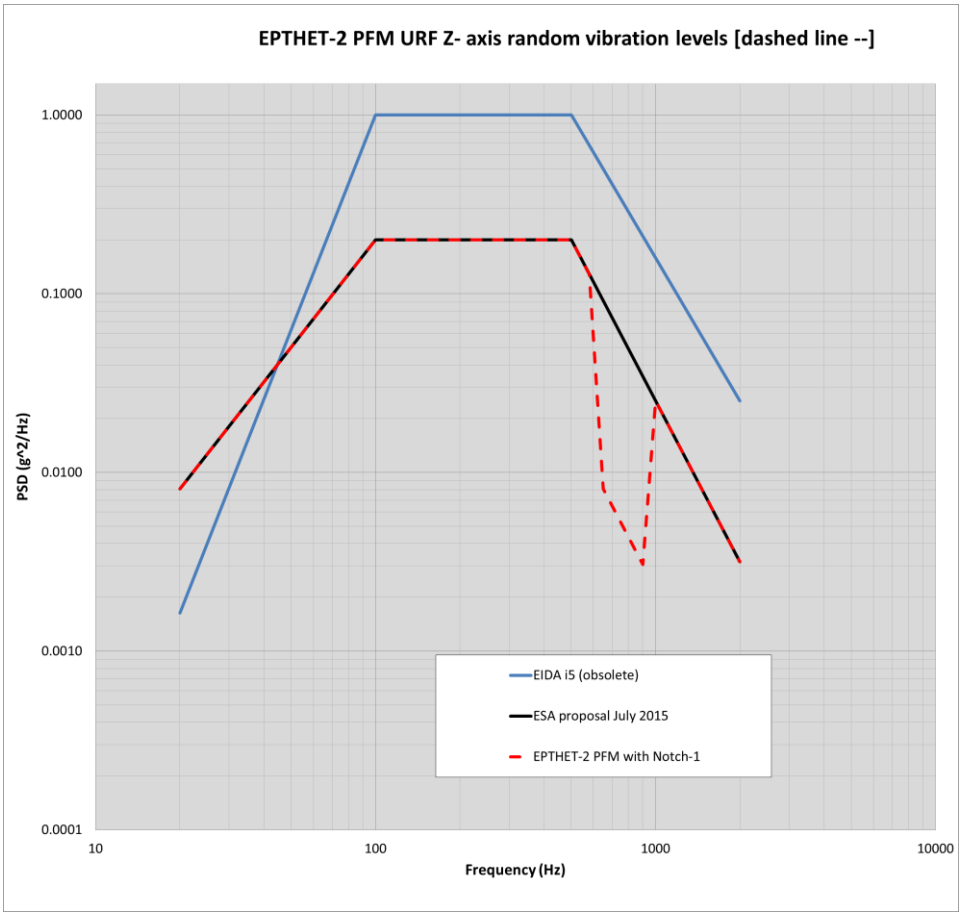
EIDA R-499**:** *The levels of this requirement from EIDAi5 [AD-1] are NO LONGER applicable to EPTHET, BUT the new levels according to [RD-6].*

6.2 EPTHET-2 PFM X and Y axes acceptance random vibration



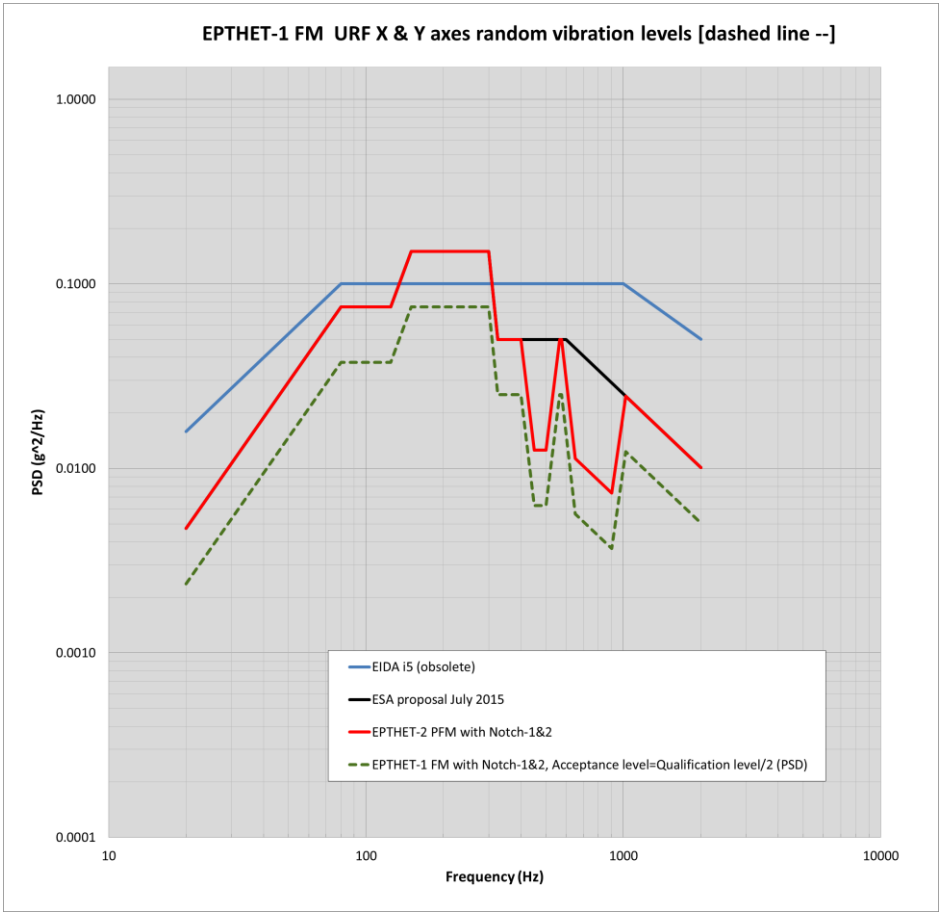
EPTHET-2 PFM X and Y axes RV profile details			
Acceptance duration = 1 minute			
	FREQ(Hz)	Qualification PSD(g^2/Hz)	dB/OCT
	20	0.0047	
	80	0.0750	6.00
	125	0.0750	0.00
	150	0.1500	11.44
	300	0.1500	0.00
	325	0.0500	-41.30
Notch-1	400	0.0500	0.00
	450	0.0126	-35.00
	500	0.0126	0.00
	565	0.0500	34.00
Notch-2	575	0.0500	0.00
	650	0.0113	-34.00
	900	0.0073	-4.00
	1022	0.0246	33.00
	2000	0.0101	-4.00
		G-rms	**7.85**

6.3 EPTHET-2 PFM Z-axis acceptance random vibration



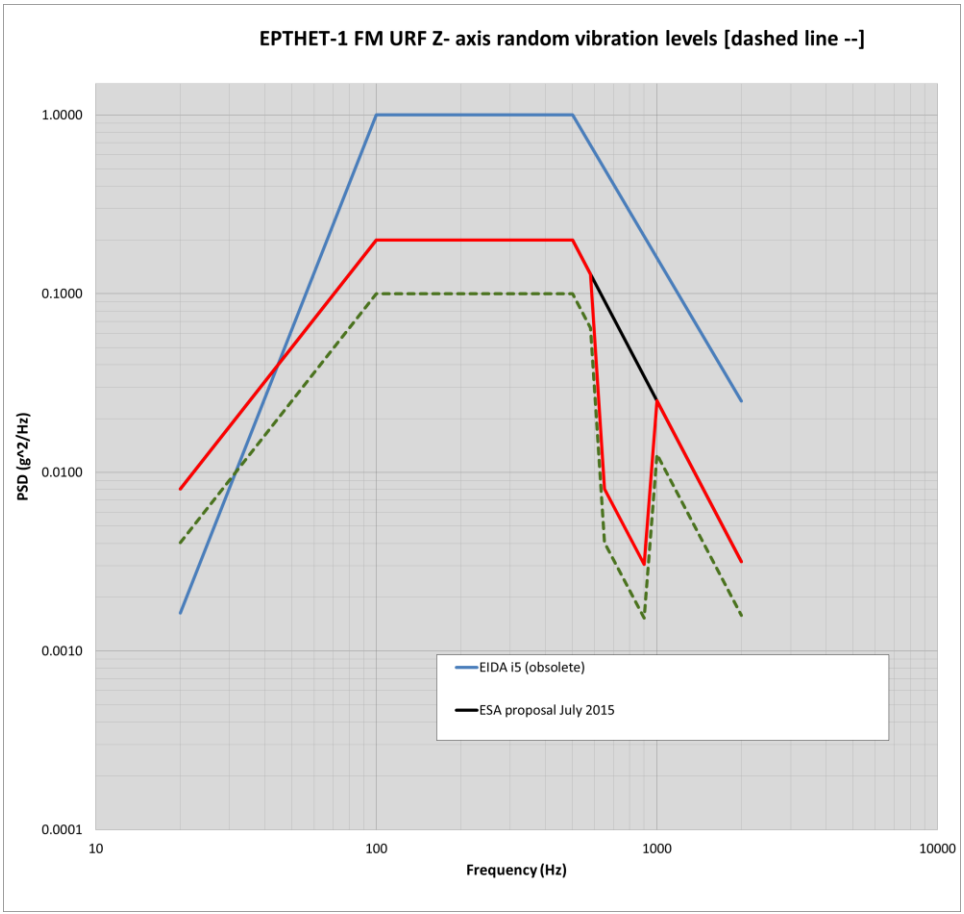
EPTHET-2 PFM Z-axis RV profile details			
Acceptance duration = 1 minute			
	FREQ(Hz)	Qualification PSD(g^2/Hz)	dB/OCT
	20	0.0081	
	100	0.2000	6.00
	500	0.2000	0.00
Notch-1	580	0.1283	-9.00
	650	0.0081	-73.00
	900	0.0031	-9.00
	1000	0.0252	60.24
	2000	0.0032	-9.00
		G-rms	**10.69**

6.4 EPTHET-1 FM X and Y axes acceptance random vibration



EPTHET-1 FM X and Y axes RV profile details			
Acceptance duration = 1 minute			
	FREQ(Hz)	Acceptance PSD(g^2/Hz) = Qualification/2 (PSD)	dB/OCT
	20	0.0024	
	80	0.0376	6.00
	125	0.0376	0.00
	150	0.0752	11.44
	300	0.0752	0.00
	325	0.0251	-41.30
Notch-1	400	0.0251	0.00
	450	0.0063	-35.00
	500	0.0063	0.00
	565	0.0251	34.00
Notch-2	575	0.0251	0.00
	650	0.0057	-34.00
	900	0.0037	-4.00
	1022	0.0123	33.00
	2000	0.0051	-4.00
		G-rms	**5.56**

6.5 EPTHET-1 FM Z-axis acceptance random vibration



EPTHET-1 FM Z-axis RV profile details			
Acceptance duration = 1 minute			
	FREQ(Hz)	Acceptance PSD(g2/Hz) = Qualification/2 (PSD)	dB/OCT
	20	0.0041	
	100	0.1002	6.00
	500	0.1002	0.00
Notch-1	580	0.0643	-9.00
	650	0.0041	-73.00
	900	0.0015	-9.00
	1000	0.0126	60.24
	2000	0.0016	-9.00
		G-rms	**7.57**

6.6 Test tolerances

EIDA R-440: *The PI shall respect the following test tolerances, unless otherwise specified.*

According to ***EIDA R-440*** the relevant test level tolerances are as below:

Sinusoidal vibration:

- Acceleration, amplitude ± 10%
- Frequency above 50 Hz ± 2%

Random vibration:

- Power spectrum density (50 Hz or narrower)

  20 to 500 Hz ± 1.5 dB

  500 to 2000 Hz ± 3.0 dB

- Overall g rms ± 1.5 dB

6.7 Test success criteria

(a) No visual damage.

(b) According to [ND-1], the amplitude and natural frequencies of the test specimen in its principal modes shall remain in the same range in all low sine sweeps prior and after each qualification level test.

1. Less than 5 % in frequency shift, for modes with an effective mass greater than 10 %.
2. Less than 20 % in amplitude shift, for modes with an effective mass greater than 10 %.

(c) The first natural frequency shall be well-above 140 Hz to ensure compliance with the stiffness requirement:

EIDA R-089: *The PI shall ensure that each instrument unit has all fundamental resonance frequencies above 140 Hz.*

(d) The achievement of the correct test level inputs.

(e) Successful functional test after the vibration tests.

7 STEP-BY-STEP TEST PROCEDURE

Note:

- During the test, at any circumstances which is suspicious to a total damage/loss of test specimen, ADS has the authority to interfere the mentioned test sequence.
- Before, after and during the test and in different sequences there is the possibility of functional test performance and lower level vibration tests on the EUT which will be included in the as run test report.

- Vibration test sequence in this procedure for EPTHET-1 FM and EPTHET-2 PFM is like the one performed on EPTHET PQM, i.e. starts with in-plane axes, X and Y and proceeds with Z-axis.

Step	Description	Expected result	Date/time	Sign	comment
00	MI (Mechanical Interface) jig test	1st natural frequency > 2 kHz			
05	Preparation of the test item				
10	Pre-vibration functional test				
15	Preparation of facility instrumentation				
20	Set up the test specimen into the test facility ✓ Use extension tool for the mechanical interfaces behind the Ebox radiator. ✓ Mount the accelerometers ✓ GND strap should be installed. ✓ Make photos of EUT				
25	Record the environmental conditions				
30	Test set up check				
35	Start test				
40	In plane (X-axis) low sine sweep up to 2000 Hz	1st natural frequency > 140 Hz			
45	In plane (X-axis) qualification level sine vibration				
50	In plane (X-axis) low sine sweep up to 2000 Hz -Decision on -12dB notching frequency band	1st natural frequency > 140 Hz			

Step	Description	Expected result	Date/time	Sign	comment
55	Compare sweep data	See test success criteria (b)			
60	In plane (X-axis) qualification level random vibration -Considering notch defined in Step 50				
65	In plane (X-axis) low sine sweep up to 2000 Hz	1st natural frequency > 140 Hz			
70	Compare sweep data	See test success criteria (b)			
75	In plane (Y-axis) low sine sweep up to 2000 Hz	1st natural frequency > 140 Hz			
80	In plane (Y-axis) qualification level sine vibration				
85	In plane (Y-axis) low sine sweep up to 2000 Hz -Decision on -12dB notching frequency band	1st natural frequency > 140 Hz			
90	Compare sweep data	See test success criteria (b)			
95	In plane (Y-axis) qualification level random vibration -Considering notch defined in Step 85				
100	In plane (Y-axis) low sine sweep up to 2000 Hz	1st natural frequency > 140 Hz			
105	Compare sweep data	See test success criteria (b)			
110	Out of plane (Z-axis) low sine sweep up to 2000 Hz	1st natural frequency > 140 Hz			
115	Out of plane (Z-axis) qualification level sine vibration				
120	Out of plane (Z-axis) low sine sweep up to 2000 Hz -Decision on -12dB notching frequency band	1st natural frequency > 140 Hz			
125	Compare sweep data	See test success criteria (b)			

Step	Description	Expected result	Date/time	Sign	comment
130	Out of plane (Z-axis) qualification level random vibration -Considering notch defined in Step 120				
135	Out of plane (Z-axis) low sine sweep up to 2000 Hz	1st natural frequency > 140 Hz			
140	Compare sweep data	See test success criteria (b)			
145	Post-vibration functional test				
150	Visual inspection and photo documentation				
155	Post-test review with ADS experts				
160	Dismount test set up				
165	Pack test item				