SOLAR ORBITER ENERGETIC PARTICLE DETECTOR

STEP FM
Random-Sine Vibration Test Plan and Procedure

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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 STEP FM vibration test campaign performed by all institutions and personnel involved in the test.

Important notes:

- STEP PQM vibration tests during 30.09.2015 to 02.10.2015 were performed at Qualification levels which is reported in [RD-6].
- Manual notching was applied during STEP PQM vibration tests which the notching details are summarized in RFD-0017 [RD-7].
- During the “EPD-IQR co-location meeting” at ESTEC on 17.02.2016, it is decided that the new information need to be added to the notching RFD before STEP FM vibration tests which is currently planned for end-May 2016.

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
IQR	Instrument Qualification Review
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
STEP	SupraThermal Electrons and Protons
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	STEP FM Functional test plan and procedure	SO-EPD-KIE-TP-0043	1/0	01/02/2016
AD-4	CIDL-ABCL for STEP FM	SO-EPD-KIE-LI-0012	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	STEP Structural Analysis Report	SO-EPD-KIE-RP-0042	2/3	27/02/2015
RD-2	Request for Deviation (RFD) for mass properties measurement	SO-EPD-KIE-RD-0001	2/1	06/06/2014
RD-3	Drawing: STEP Mechanical Interface Control Drawing EPD_STEP_05022016_3-5_SO-EPD-KIE-DR-0003_c4_micd.pdf	SO-EPD-KIE-DR-0003_c4.idw	3/5	05/02/2016
RD-4	Drawing: so_epthet-step_ads-vibetest-adaptor_r01.pdf	ads-vibetest-adaptor	Rev. 01	26/03/2015
RD-5	Request for Deviation (RFD) for new random vibration tests for STEP after failiur in EPT-HET PQM	SO-EPD-KIE-RD-0011	1/1	24.09.2015
RD-6	STEP PQM Vibration Test Report	SO-EPD-KIE-TR-0020	1/0	03.12.2015
RD-7	Request for Deviation (RFD) for STEP vibration notching	SO-EPD-KIE-RD-0017	1/0	11.02.2016

4 TEST OVERVIEW

4.1 Test objectives

The objective of the vibration test at acceptance levels on STEP FM is to screen the workmanship and certify the flight unit.

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	Lauri Panitzsch	Instrument lead
4	Lars Seimetz	Engineering lead
5	Mahesh Yedla	Electronic engineer
6	Moritz Jüngling	Electronic engineer

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 can be seen in figure 4-1 STEP consist of two collimator telescopes, Proton Telescope (PT) and Integral Telescope (IT) facing in the same direction and one Ebox shared between the two telescopes.

Note: The MLI stand offs will not be glued on STEP FM for acceptance tests, nevertheless the structural integrity of MLI standoffs is already verified during STEP PQM vibration test.

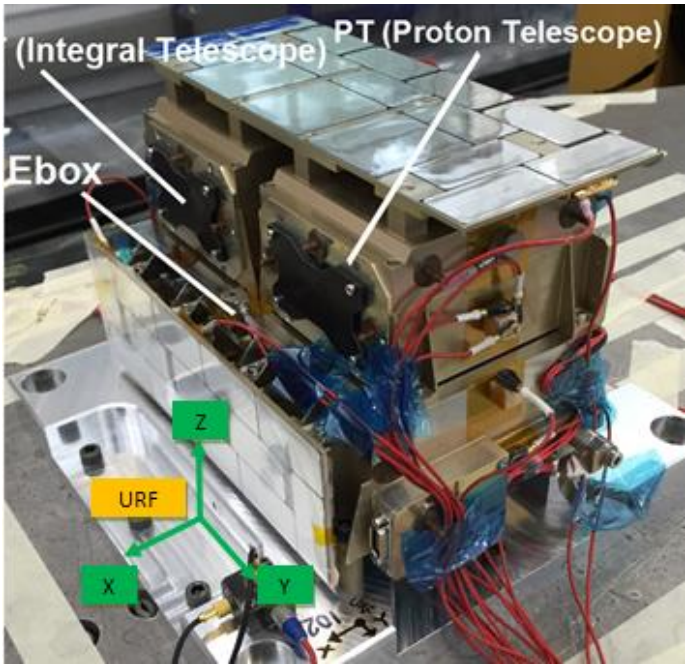


Figure. 4-1. STEP PQM with board stiffeners integrated during vibration test 30.09- 02.10.2015, STEP FM is currently under assembly, and detail information about STEP FM can be found in [AD-4].

After the complete assembly of the STEP FM, 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 STEP FM will be mounted on the mechanical interface in all of the six 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.

For fixing three out of six mechanical interfaces, those behind the Ebox radiator, an extension tool is needed. This extension tool is part of the GSE of the instrument is provided by CAU.

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.

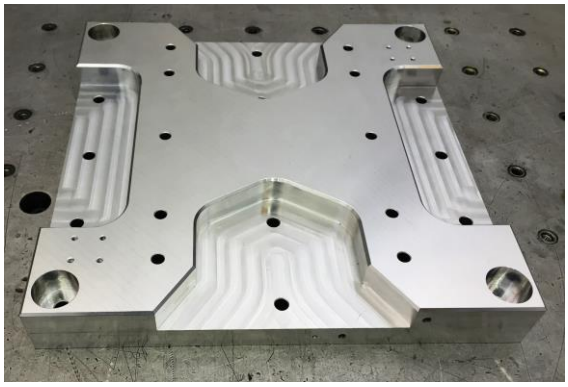


Figure 5-1. Mechanical interface for vibration test.

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].

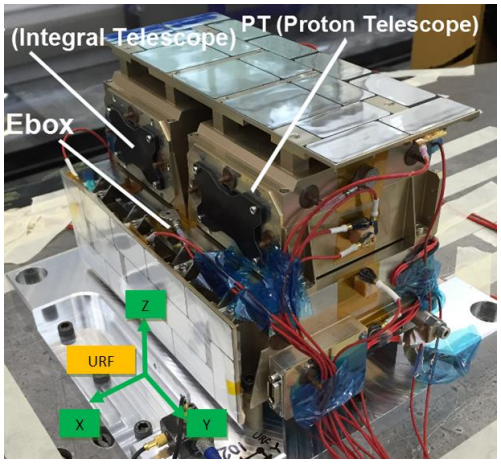
5.2 Accelerometers

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.

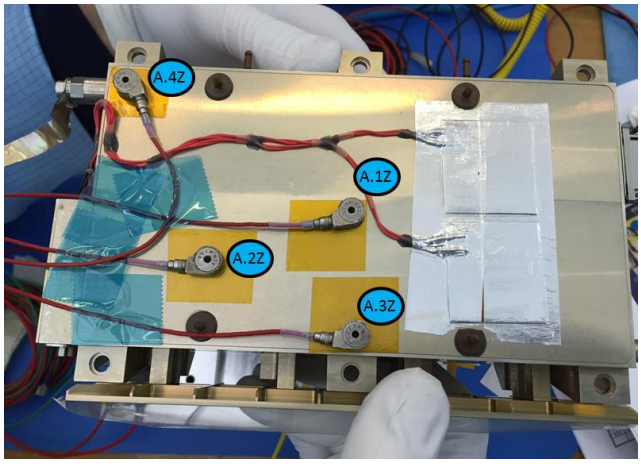
Note: The accelerometers locations, Fig. 5-2, will be exactly the same as the qualification vibration test performed on 30.09- 02.10.2015, [RD-08] but ONLY the green-highlighted accelerometers in Table 5-1 will be used for STEP FM acceptance vibration test.

Table 5-1. Accelerometer positions used for STEP PQM vibration, the green-highlighted ones will be used for STEP FM.

	Accelerometers		
STEP structural subassemblies	**X-direction**	**Y-direction**	**Z-direction**
Ebox bottom plate, Fig. 5.2 (b)			A1Z A2Z A3Z A4Z
Ebox radiator, Fig. 5.2 (c)	A9X A11X		
Telescopes radiator, Fig. 5.2 (c) (d)			A8Z A9Z A10Z
Ebox, Fig. 5.2 (c) (d) (e)	triA3X triA8X A4X	triA3Y triA8Y A.6Y	triA3Z triA8Z
Ebox Titanium cover, Fig. 5.2 (c) (d) (e)	A3X A7X		A5Z A6Z A7Z
Integral telescope, Fig. 5.2 (c) (d)	A5X A6X	A1Y A2Y	
Proton telescope, Fig. 5.2 (d) (e)	A.1X triA5X	A.4Y triA5Y	triA5Z



(a)



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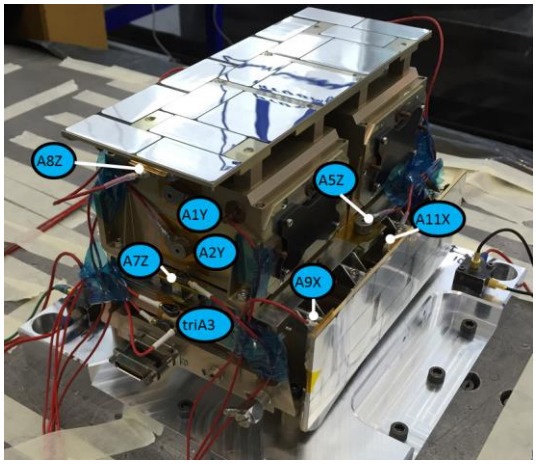
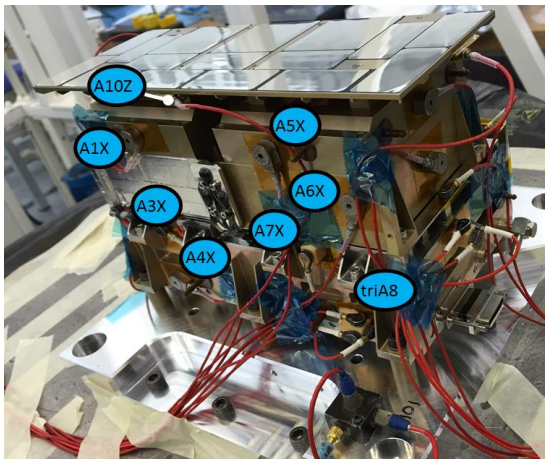


(c)



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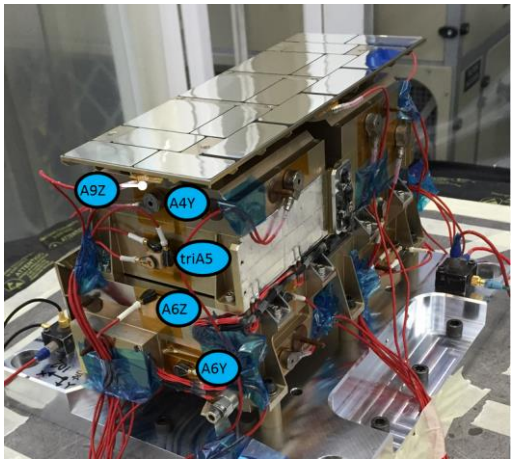


(e)

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

6 TEST PARAMETERS

6.1 Test requirements

Important notes:

- STEP PQM vibration tests during 30.09.2015 to 02.10.2015 were performed at Qualification levels which is reported in [RD-6].
- Manual notching was applied during STEP PQM vibration tests which the notching details are summarized in RFD-0017 [RD-7].
- During the "EPD-IQR co-location meeting" at ESTEC on 17.02.2016, it is decided that the new information need to be added to the notching RFD before STEP FM vibration tests which is currently planned for end-May 2016.

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.*

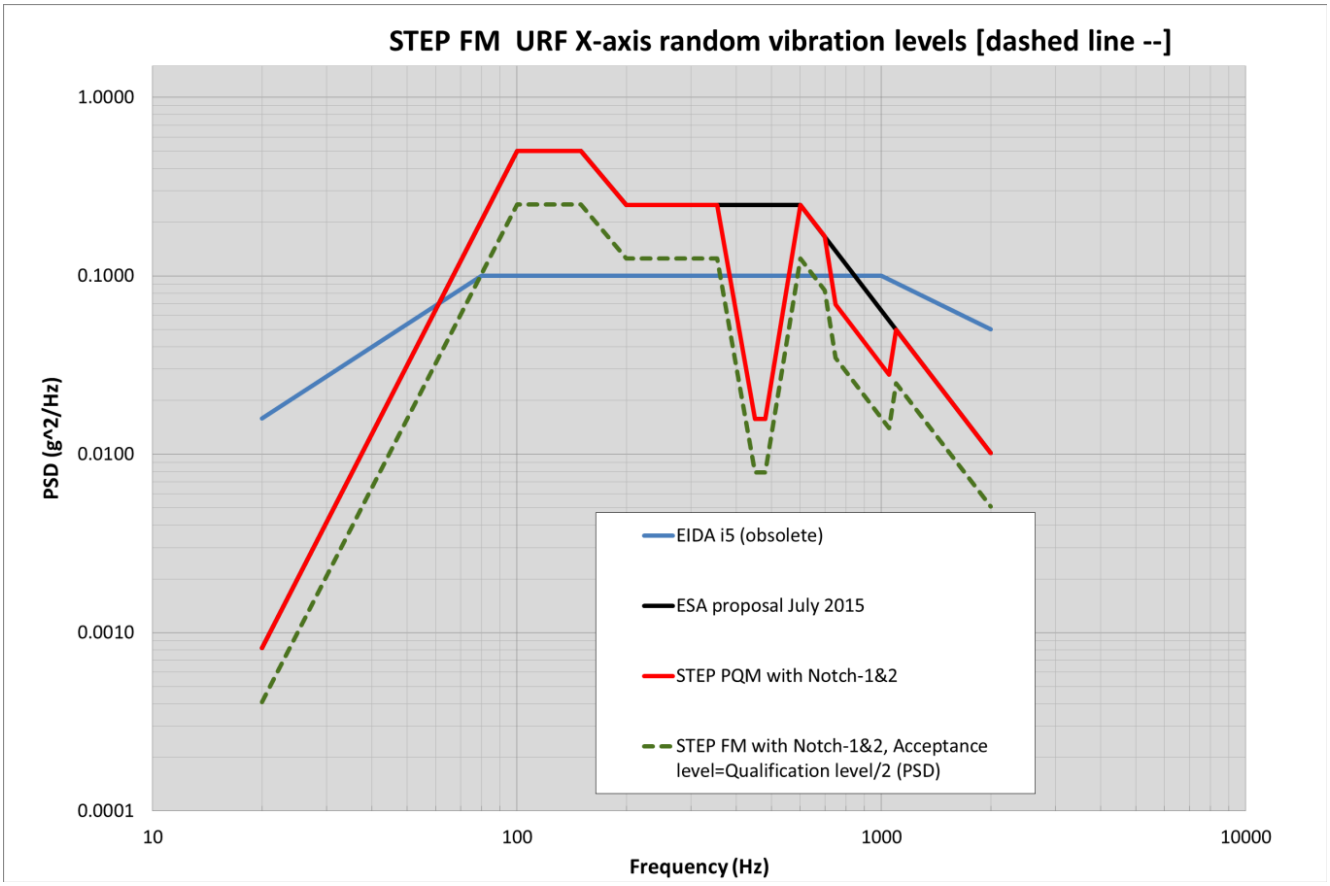
Table 6-2: Qualification Levels for Sine Vibration Tests [RD-06].

Axis	Frequency (Hz)	Qualification was performed on STEP PQM	Acceptance for STEP FM
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:

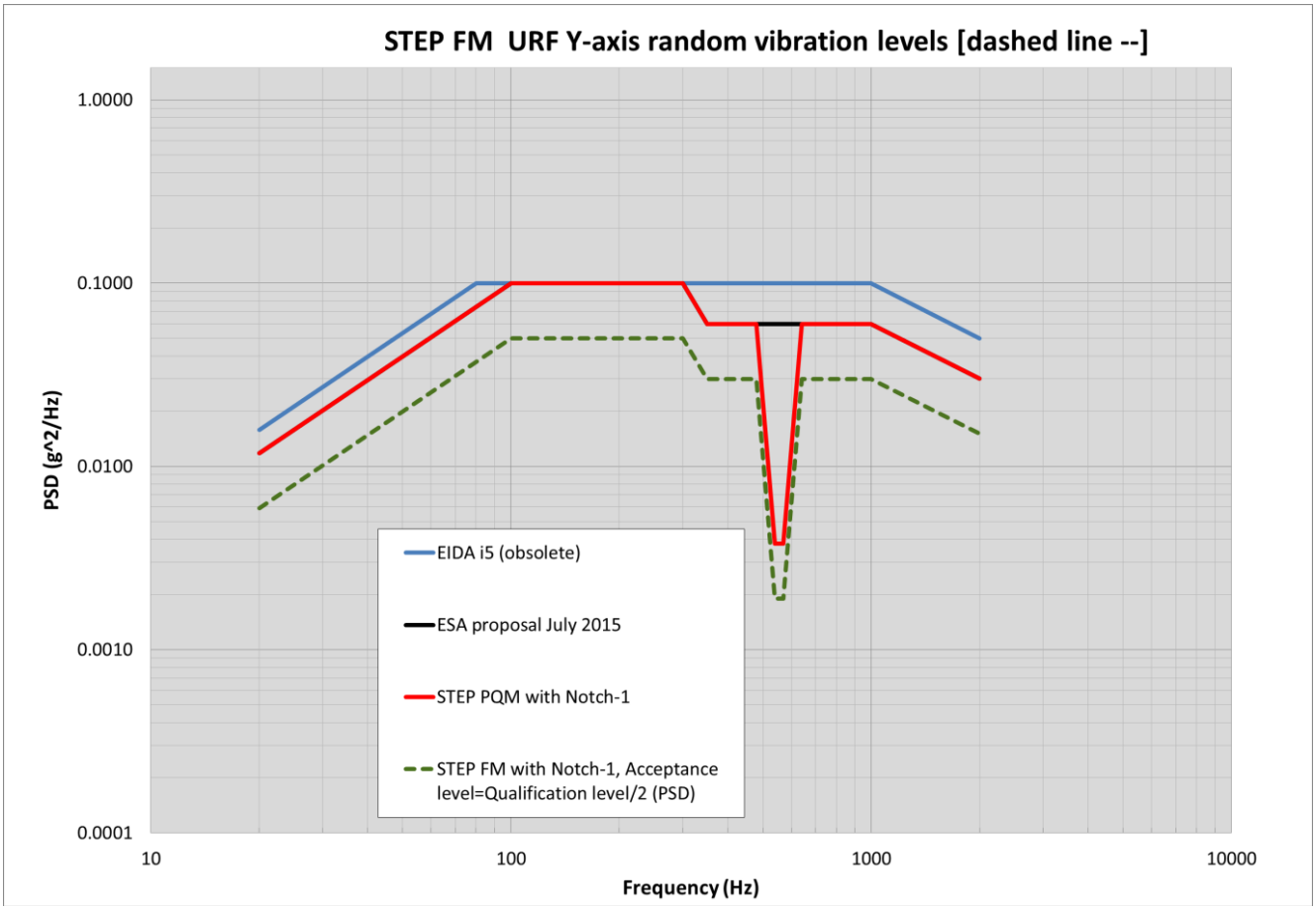
EIDA R-499**:** *The levels of this requirement from EIDAi5 [AD-1] are NO LONGER applicable to STEP, BUT the new levels according to [RD-6].*

6.2 X-axis acceptance random vibration



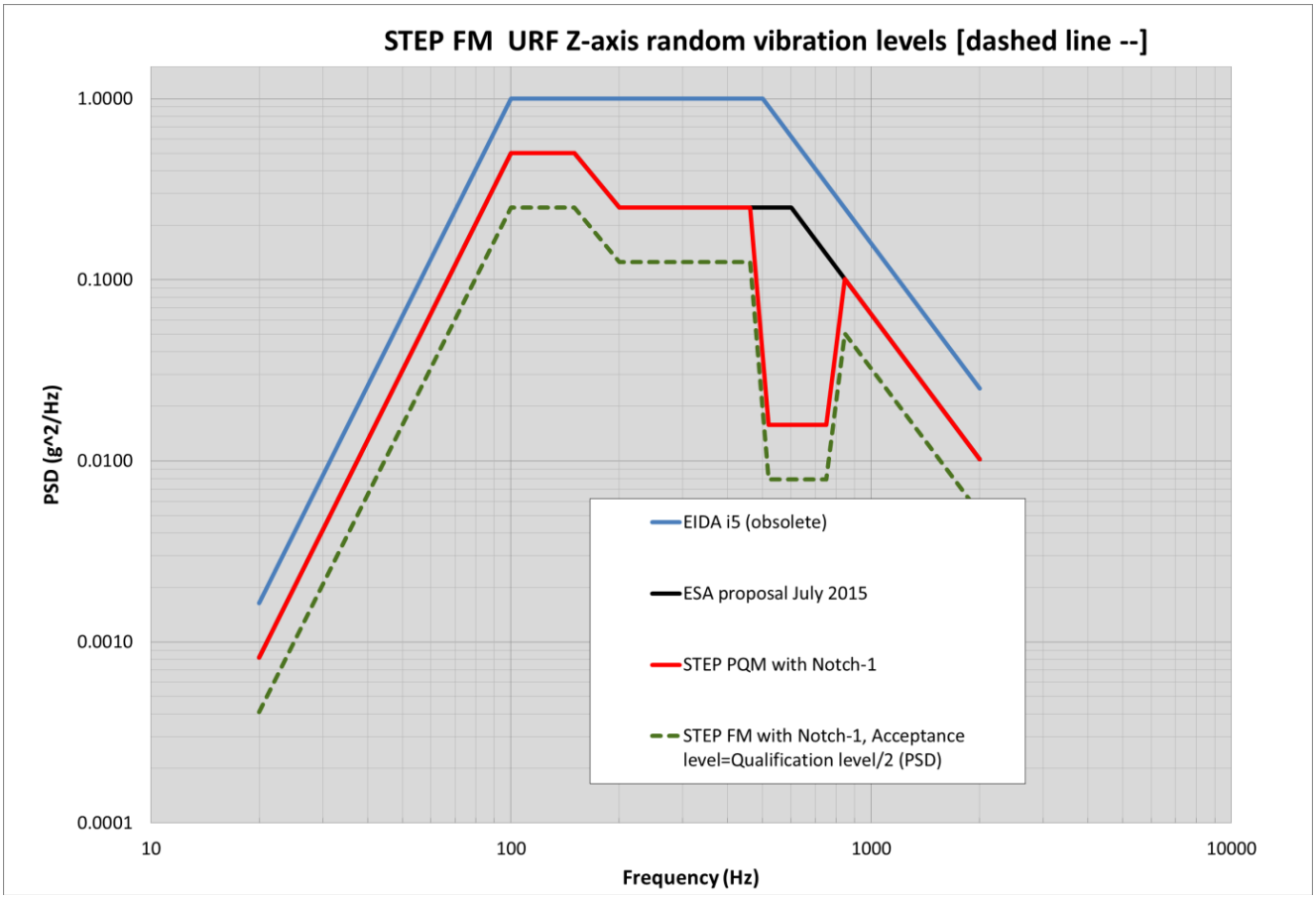
STEP FM X-axis RV profile details			
Acceptance duration = 1 minute			
	FREQ(Hz)	**Acceptance PSD(g2/Hz) = Qualification/2 (PSD)**	**dB/OCT**
	20	0.0004	
	100	0.2505	12.00
	150	0.2505	0.00
	200	0.1253	-7.25
	300	0.1253	0.00
Notch-1	355	0.1253	0.00
	450	0.0079	-35.06
	480	0.0079	0.00
	600	0.1253	37.25
Notch-2	700	0.0832	-8.00
	750	0.0346	-38.30
	1050	0.0140	-8.07
	1100	0.0251	37.52
	2000	0.0051	-8.00
		G-rms	**9.29**

6.3 Y-axis acceptance random vibration



STEP FM Y-axis RV profile details			
Acceptance duration = 1 minute			
	FREQ(Hz)	Acceptance PSD(g2/Hz) = Qualification/2 (PSD)	dB/OCT
	20	0.0059	
	100	0.0501	4.00
	300	0.0501	0.00
	350	0.0301	-9.98
Notch-1	480	0.0301	0.00
	540	0.0019	-70.52
	570	0.0019	0.00
	642	0.0301	69.83
	1000	0.0301	0.00
	2000	0.0151	-3.00
		G-rms	**7.14**

6.4 Z-axis acceptance random vibration



STEP FM Z-axis RV profile details			
Acceptance duration = 1 minute			
	FREQ(Hz)	Acceptance PSD(g2/Hz) = Qualification/2 (PSD)	dB/OCT
	20	0.0004	
	100	0.2505	12.00
	150	0.2505	0.00
	200	0.1253	-7.25
Notch-1	300	0.1253	0.00
	462	0.1253	0.00
	520	0.0079	-70.29
	750	0.0079	0.00
	845	0.0506	46.82
	2000	0.0051	-8.00
		G-rms	**9.24**

6.5 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

6.6 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 STEP FM is like the one performed on STEP 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				