SOLAR ORBITER ENERGETIC PARTICLE DETECTOR

EPT-HET FMs Functional Test Plan and Procedure

Document ID: SO-EPD-KIE-TP-0038

Issue: 1

Revision: 0

Date: 29/02/2016

Signature not needed if electronically approved by route					
Written	**Checked**	**Approved Configuration Control**	**Approved QA**	**Approved Experiment Manager**	**Approved Principal Investigator**
S.R. Kulkarni Date and Signature	Michael Richards Date and Signature	Cesar Martin Date and Signature	NAME4 Date and Signature	NAME5 Date and Signature	NAME6 Date and Signature

DISTRIBUTION LIST

The following lists indicate the individuals and agencies in receipt of review copies of the present document:

Agency / Organization	Name & Title	Contact information
SRG-UAH	Javier Rodríguez-Pacheco EPD-Principal Investigator	javier.pacheco@uah.es
SRG-UAH	Manuel Prieto, EPD Project Manager	manuel.prieto@uah.es
SRG-UAH	Cecilia Gordillo EPD Configuration Control Responsible	cecilia.gordillo@uah.es
SRG-UAH	Andrés Russu Berlanga EPD AIVT Responsible	Andres.Russu@uah.es
SENER	Maria Teresa Gomez, EPD System Engineer	maite.gomez@sener.es
SENER	Santiago Jarabo Lopez, EPD Product Assurance Manager	santiago.jarabo@sener.es
CAU	EPD-Solar Orbiter Kiel Team	solo_kiel@physik.uni-kiel.de

CHANGES RECORD

Issue	Revision	Date	Modified by	Section / Paragraph modified	Change implemented
1	0	29/02/2016		All	Initial release

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Purpose

The aim of this document is to define the FM functional test procedure of the EPT-HET units related to testing and integration activities at unit, EPD suite and S/C level.

1.2 Scope

This document describes functional test of EPT-HET FM unit at unit and suite level activities and support to integration activity at EPD suite level as well S/C level.

1.3 Project Outline

The Energetic Particle Detector (EPD) suite consists of four sensors measuring electrons, protons, and ions from helium to iron, and operating at partly overlapping energy ranges from 2 keV up to 200 MeV/n. The EPD sensors are:

- Supra-Thermal Electrons & Protons (STEP),
- Supra-Thermal Ion Spectrograph (SIS),
- Electron Proton Telescope (EPT) and
- High Energy Telescope (HET).

The EPD sensors share the Instrument Control Unit (ICU) that is composed by the Common Data Processing Unit and the Low Voltage Power Supply (CDPU/LVPS), which is the sole power and data interface of EPD to the spacecraft.

STEP unit has two telescopes and one Electronics Box. The two telescopes look in the same direction. SIS consists of two sensor heads with roughly opposite (160°) view directions sharing a common Electronics Box. EPT-HET has multiple view cones sharing a common Electronics Box as well. There are two identical EPT-HET units.

The overall energy coverage achieved with the EPD sensors is 0.002 MeV to 20 MeV for electrons, 0.003 MeV to 100 MeV for protons, 0.008 MeV/n to 200 MeV/n for heavy ions (species-dependent). This energy and species coverage well satisfies and for a large part exceeds the requirements defined for EPD in the Solar Orbiter Payload Definition Document and in the report of the Joint Science and Technology Definition Team (JSTDT) for the Solar Orbiter/Sentinels mission.

1.4 Flight Model of EPT-HET

The Flight Model (FM) of EPT-HET is one of the deliverable models to ESA. The FM of the EPT-HET unit consists of a BGO crystal, photodiodes, detectors, magnet system, electronic boards, temperature sensors, and housing parts. All these parts are FM quality parts. A picture of the fully assembled FM unit is shown in Figure 1.

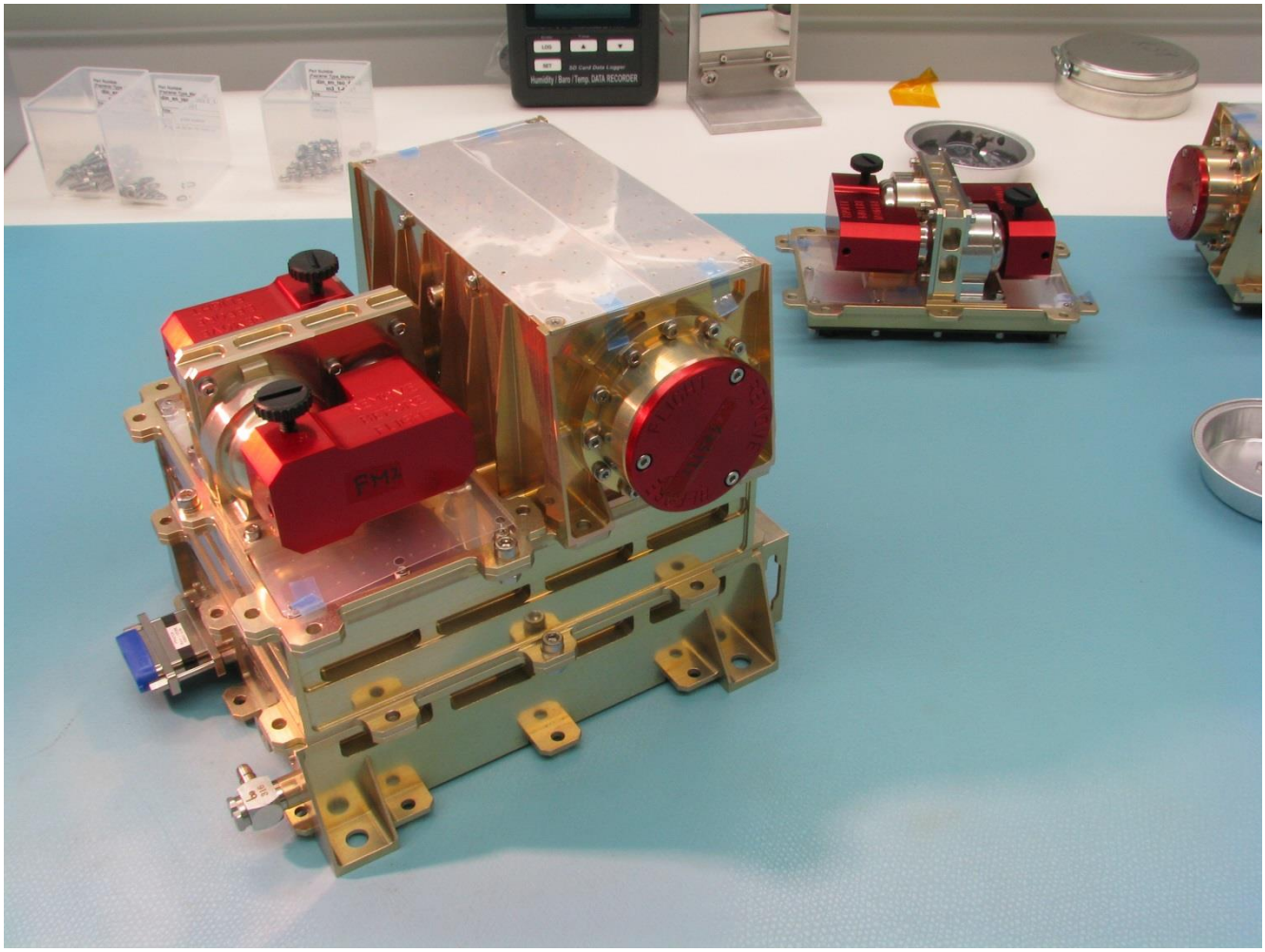


Figure 1: One of the FMs of EPT-HET unit (without bottom plate and MLI and also one can see another FM sensor heads) .

EPT-HET FM parts configurations are

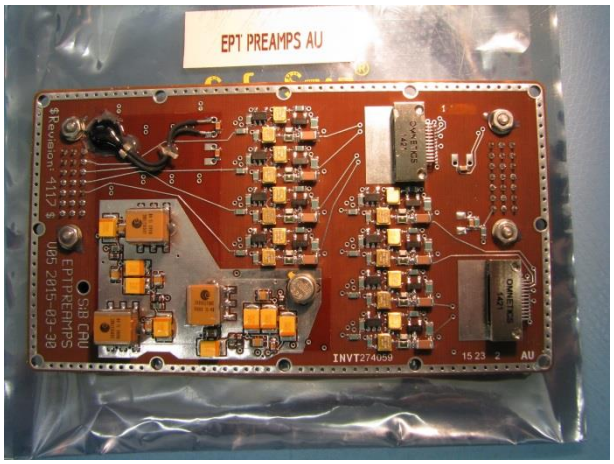
1. FM sensor heads (Detectors+ pre-amplifier boards)
2. FM analog board with Actel RTAX2000SL FPGA, firmware v05
3. FM digital board with Actel RTAX2000SL FPGA, firmware v09
4. FM power board

There are two FMs,

1. EPT-HET-1 and

2. EPT-HET-2

Picture of all sub-assemblies of FMs are shown below:



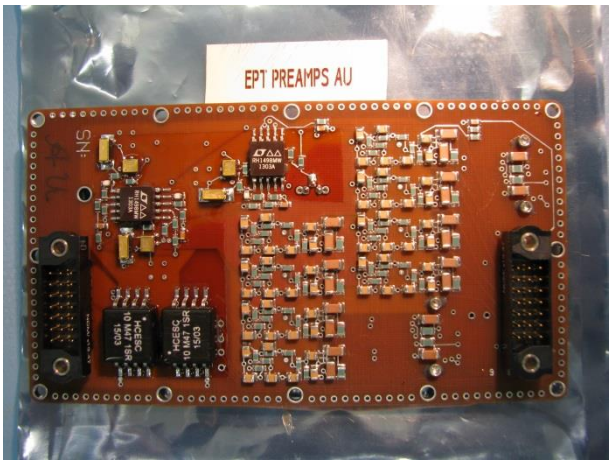
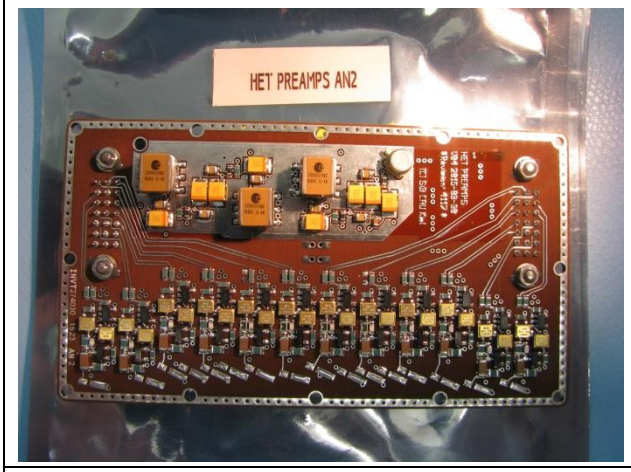


Figure 2a: FM EPT pre-amp board (both sides picture of one of the boards of FMs).



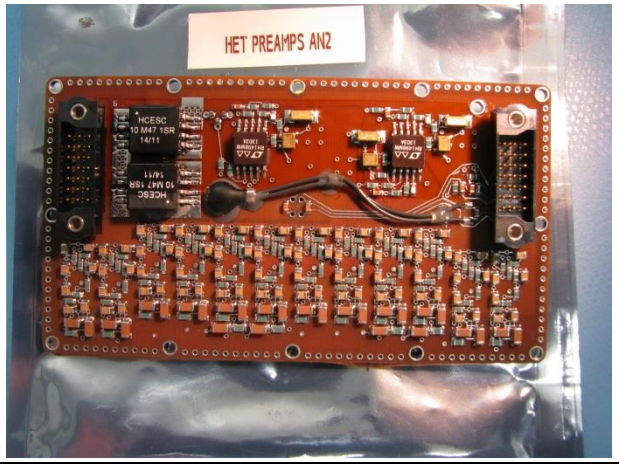


Figure 2b: FM HET pre-amp board (both sides picture of one of the boards of FMs).

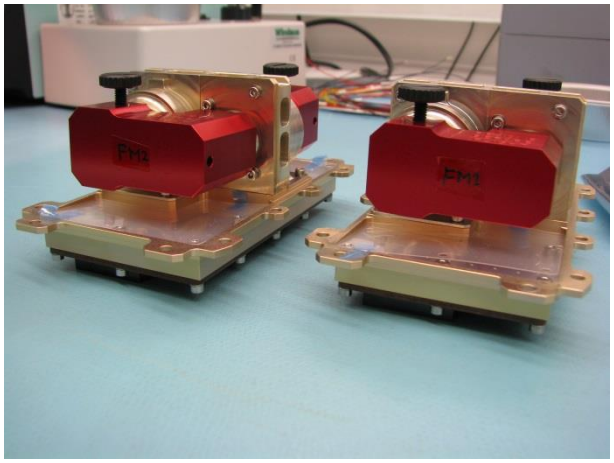


Figure 2c: The EPT FM sensor heads.

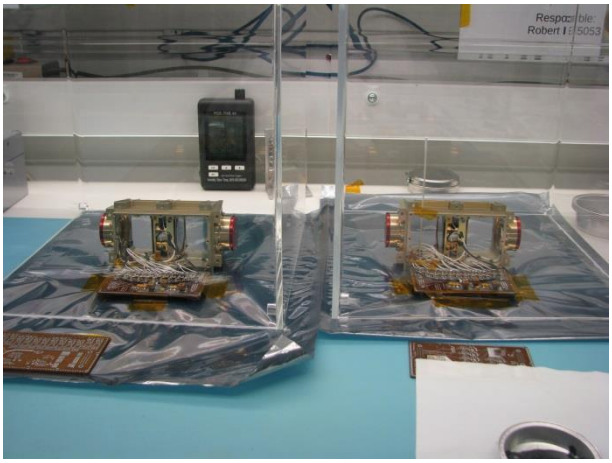


Figure 2d: The HET FM sensor heads.

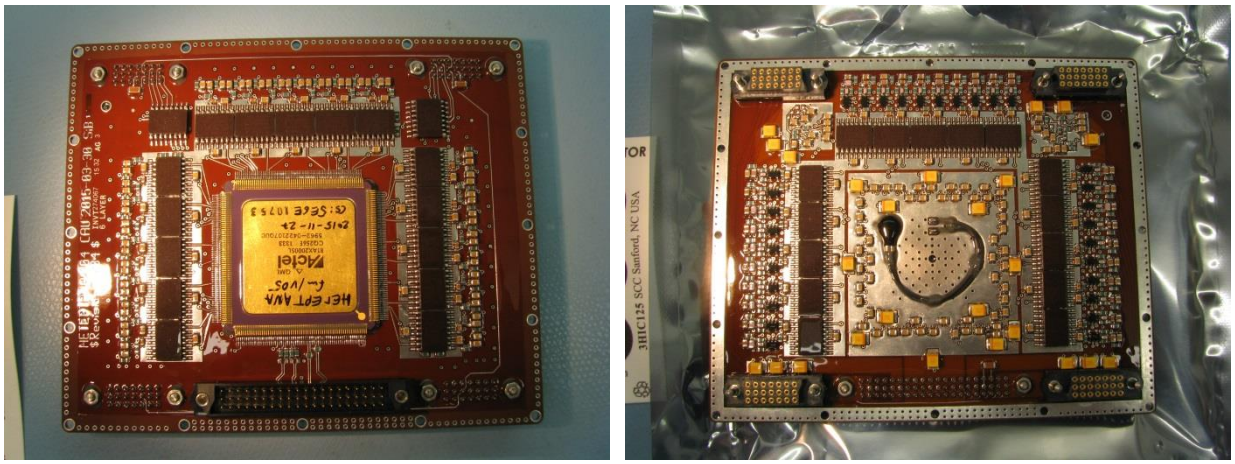


Figure 2e: One of the FMs Analog Board (both sides picture).

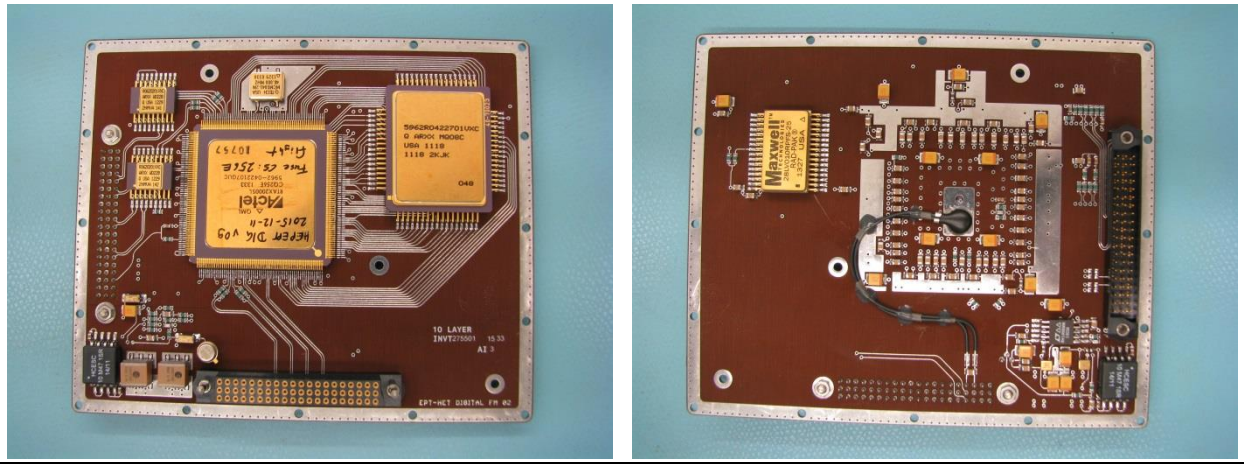
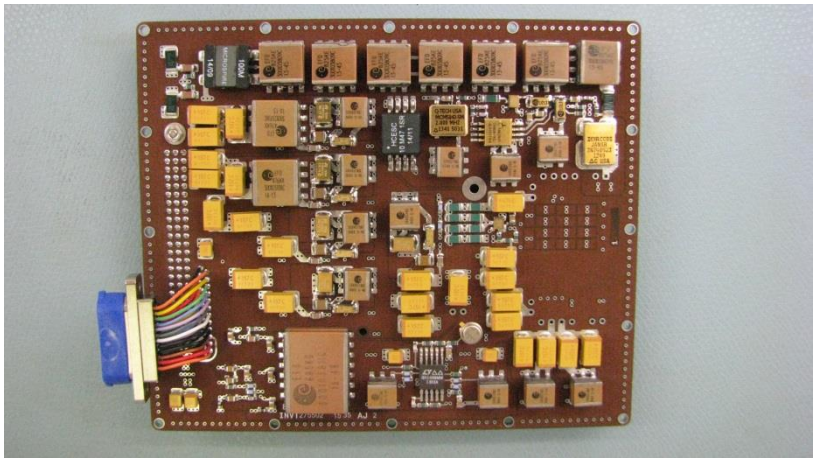


Figure 2f: One of the FMs Digital Board (both sides picture).



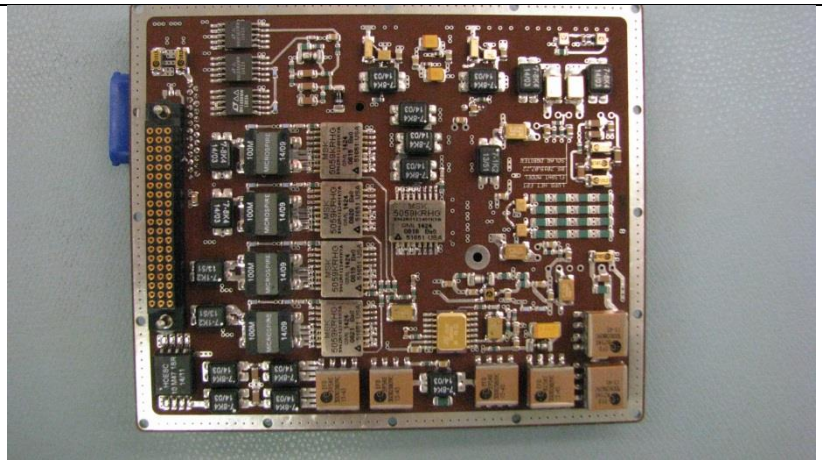


Figure 2g: One of the FMs power Board (both sides picture).

2 GLOSSARY AND DEFINITIONS

2.1 Acronyms and Abbreviations

EPT-HET-1	Electron Proton Telescope & High-Energy Telescope-1
EPT-HET-2	Electron Proton Telescope & High-Energy Telescope-2
EPD	Energetic Particles Detector
EM	Engineering Model
EMC	ElectroMagnetic Compatibility
EPT	Electron, Proton Telescope
FM	Flight Model
FT	Functional Test
HET	High Energy Telescope
H/W	Hardware
GSE	Ground Support Equipment
I/F	Interface
ICD	Interface Control Document
ICU	Instrument Control Unit
PA	Product Assurance
PO	Project Office
PQM	Proto-Qualification Model
QA	Quality Assurance
S/C	SpaceCraft
STEP	Supra-Thermal Electrons and Protons

3 APPLICABLE AND REFERENCE DOCUMENTS

3.1 Applicable Documents

ID.	Title	Reference	Iss./Rev.	Date
AD-01	Interface Control Document part-A	SOL.EST.RCD.0050	5/0	16/03/2015

Table 1: Applicable Documents

3.2 Reference Documents

ID.	Title	Reference	Iss./Rev.	Date
RD-01	EPT-HET FM MICD	SO-EPD-KIE-DR-0001	5/3	22-12-2015
RD-02	Integration Guidelines of EPT HET EM unit with ICU	SO-EPD-KIE-PR-0012	1/0	07-04-2014
RD-03	Safety instructions for IEAP CAU facilities	http://www.ieap.uni-kiel.de/sicherheit/		
RD-04	ESD Control Program for the SO/EPD-Project at CAU	SO-EPD-KIE-PL-0031	1/0	29-11-2015
RD-05	EPT-HET PQM Functional Test Procedure	SO-EPD-KIE-TP-0021	1/1	14-09-2015

Table 2: Reference Documents

4 TEST READINESS REVIEW AND PLAN

Test Readiness Review

Instrumentation and tools in use:

Instrument Name	Quantity	Serial Number/ Model Number
EPT-HET FM1 / FM2 Unit	1	
Lab power Supply (0-30 V and 0-1A)	1	Extech 382200
Multimeter (Fluke make 179 true RMS DMM)	1	Fluke 179
GSE Note Book and its charger	1	
SolO GSE	1	homemade
25 Pin MDM to SubD25 pin harness	1	homemade
GSE harness	1	homemade
GSE power cable	1	homemade
GSE USB cable	1	
25 Pin MDM pigtail connector	1	
15 Pin MDM pigtail connector	1	
ESD protective tools and clean room wares (apron, wrist-tape, hand gloves, etc)		
Tool: Hex key/screw driver (size:1.5 mm)	1	
Torque meter (range from 0.1 - 0.6 Nm)	1	
Particle counter	1	
Radiation source Bi^{207} (~1 µC strength)	1	
Radiation level measurement unit (see page 26)	1	LB124

Table 4: Instruments and tools detail.

5 ESD AND CLEANLINESS PRECAUTIONS

ESD Control: RD-04

Take care that:

- ESD Mat is in place/grounded metal desk is used

- ESD Straps (Hand-band) are used

- Handling will be done only with gloves

Cleanliness Control:

Wear Gloves while handling all cleaned items!

Required cleanliness level is 100,000 minimum or better.
Monitor the cleanliness inside the room with particle counter, and record all data with the facility Particle Counter. Maximum allowed particle concentration is given in the table below and maintain these particle concentrations under control:

Sl. No.	Particle size (µm)	Particle concentration (particles/m^3)
1	0.3 µm	10 200 000
2	0.5 µm	3 520 000
3	1 µm	832 000
4	5 µm	29 300

Table 5: Maximum allowed particle concentration for ISO class 8.

Monitor clean room environment and maintain the following parameter under control:

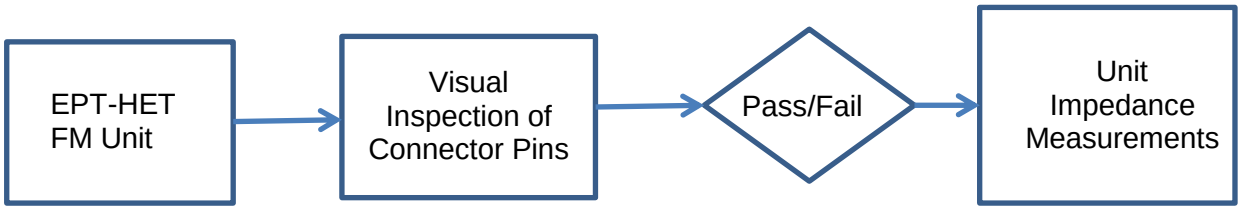
- ⇨ Temperature: 22 ^{0}C ± 3 ^{0}C
- ⇨ Relative humidity: 55 % ± 10 %

6 TEST PLAN

The plans of following tests are given below and procedures are explained in the next sections.

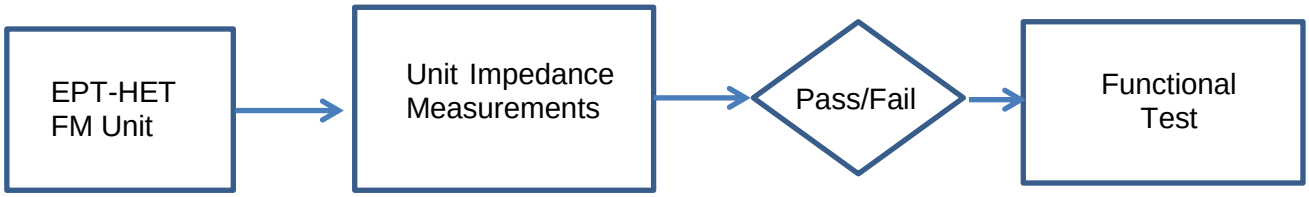
6.1 Safe-to-mate test flow of unit

(a) Safe-to-mate test by visual inspection of connectors:



Pass : No bending in pins and no obstructions in the connector(s).
Fail : Bending in pins(s) or obstructions in connector(s)

(b) Safe-to-mate test by unit impedance measurements



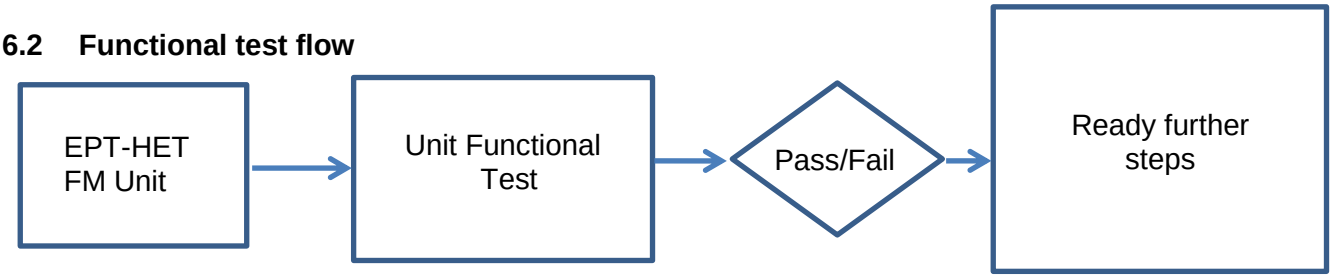
Pass : Measurement results satisfy the table 6 values.
Fail : Otherwise fail

(c) GSE and its harness safe-to-mate test

"Unit harness+ GSE harness+GSE+power supply" assemble (see section 7, c) and if satisfy following condition, then continue for next step.

Pass : Measurement results satisfy the table 7 values.
Fail : Otherwise fail

6.2 Functional test flow



Pass : HK and count rates should be expected values (see annexure B).
Fail : HK different from expected and count rates 4-5 orders more.

6.3 Participants and their responsibilities

Sl.No.	Name	Responsibilities
1	Robert Wimmer-Schweingruber (Principal Investigator)	Final Approval
2	Michael Richards (Product Assurance)	QA Approval
3	Cesar Martin (Project Manager)	Final release
4	S. R. Kulkarni (Instrument Scientist)	Test & Report
5	Stephan Boettcher (Senior Scientist)	Test & Report
6	Walter Boogaerts	QA
7	Other EPT-HET Team	Test

7 EPT-HET UNIT LEVEL SAFE TO MATE TEST PROCEDURE

EPT-HET Safe to Mate Procedure:

One has to perform following “safe to mate tests” before EPT-HET FM functional test.

a. Safe to mate test by visual inspection

1. EPT-HET connector(s) safe to mate test by visual inspection
2. Harness connector(s) / connector-saver and pigtail connector safe to mate test by visual inspection

b. The EPT-HET FM safe to mate test by sensor impedance measurements

The impedance measurements of EPT-HET FM unit is as follows:

STEP 1:
Visually inspect the connector of unit **[J29(EPT-HET-1)/J33(EPT-HET-2)]**, connectors of the harness / connector-saver and pigtail connector.

STEP 2:
Connect connector-saver to unit main connector (25 pin MDM connector) and fasten connector saver screws (hand tight). **NOTE:** Connector saver should not be removed until completion of unit level test, **but it should be removed during unit level vibration test**.

STEP 3:
Connect pigtail connector to other end of connector saver and fasten connector screws (hand tight).

STEP 4:
Using calibrated Fluke multimeter, measure the impedance of the unit by connecting appropriate pigtail connector wires to multimeter probes as mentioned in the table below.

Sensor Impedances measurements: connector serial number of EPT-HET1 is J29 and EPT-HET-2 is J33

Pin (+)	Signal	Pin (-)	Signal	Expected	Measurement
Nominal power and communication lines					
15	Chassis gnd	Chassis	Instrument chassis	**~1 ohm**	
1	Primary power	14	Power return	**>100K**	
1	Primary power	15	Chassis gnd	**>100K**	
14	Power return	15	Chassis gnd	**~100 K**	
4	LVDS l2S-	15	Chassis gnd	**>100 K**	
6	CLK+	15	Chassis gnd	**>100 K**	
8	LVDS S2I+	15	Chassis gnd	**>100K**	
16	LVDS l2S+	15	Chassis gnd	**>100 K**	
19	CLK-	15	Chassis gnd	**>100 K**	
21	LVDS S2I-	15	Chassis gnd	**>100K**	
6	CLK+	19	CLK-	**~100 ohm**	
8	LVDS S2I+	21	LVDS S2I-	**~50 ohms**	
16	LVDS l2S+	4	LVDS l2S-	**~100 ohm**	
Redundant power and communication lines					
13	Red. power	Chassis	Instrument chassis	**>100K**	
13	Red. power	25	Red. power return	**>100K**	
Chassis	Instrument chassis	25	Red. power return	**~100K**	
5	LVDS l2S-	24	Instrument chassis	**>100K**	
7	CLK+	24	Instrument chassis	**>100K**	
10	LVDS S2I-	24	Instrument chassis	**>100K**	
17	LVDS l2S+	24	Instrument chassis	**>100K**	
20	CLK-	24	Instrument chassis	**>100K**	
22	LVDS S2I-	24	Instrument chassis	**>100K**	
5	LVDS l2S-	17	LVDS l2S-	**100 ohm**	
7	CLK I2S+	20	CLK-	**100 ohm**	
10	LVDS S2I-	22	LVDS S2I+	**50 ohm**	

Table 6 : Sensor Impedances measurements.

STEP 5:
After finishing the measurements disconnect pigtail connector from the connector saver.

Now unit is ready for functional test.

c. GSE and its harness safe-to-mate test

The procedure for GSE safe-to-mate test is as follows:

STEP 1:
Switch-on power supply, set voltage to 28V and set current limit to 500mA. Switch-off power supply.

STEP 2:
Connect 25 pin MDM pigtail connector to 25 pin MDM connector of unit-GSE harness and fasten connector screws (hand tight).

STEP 3:
Connect subD25 connector of unit-GSE harness to D25 connector of Y-connector harness.

STEP 4:
Connect nominal connector of Y-connector harness to SolO-GSE (black).

STEP 6:
Connect GSE power connector and other end of cables (banana connectors) to power supply.

STEP 7:
Make sure all connector are connected properly, then switch-on power supply.

STEP 8:
Then measure voltages by connecting appropriate pigtail connector wires to multimeter probes as mentioned in the table below.

	Pin connection	Expected	Measurement
1.	Measure pin 1 (power) WRT 14 (power rtn)	~ 28V	
2.	Measure pin 13 (power) WRT 25 (power rtn)	~ 28 V	
3.	Measure any pin to 15	< 3.5 V	
4.	Measure pin 14 WRT pin 15	< 100 mV	
5.	Measure pin 25 WRT pin 15	< 100 mV	

Table 7 : unit harness+ GSE harness+GSE+power supply system voltage measurements.

STEP 9:
After test pass, switch-off power supply and remove pigtail connector.

STEP 10:
Now unit harness+ GSE harness+GSE+power supply are ready to mate with EPT-HET FM unit

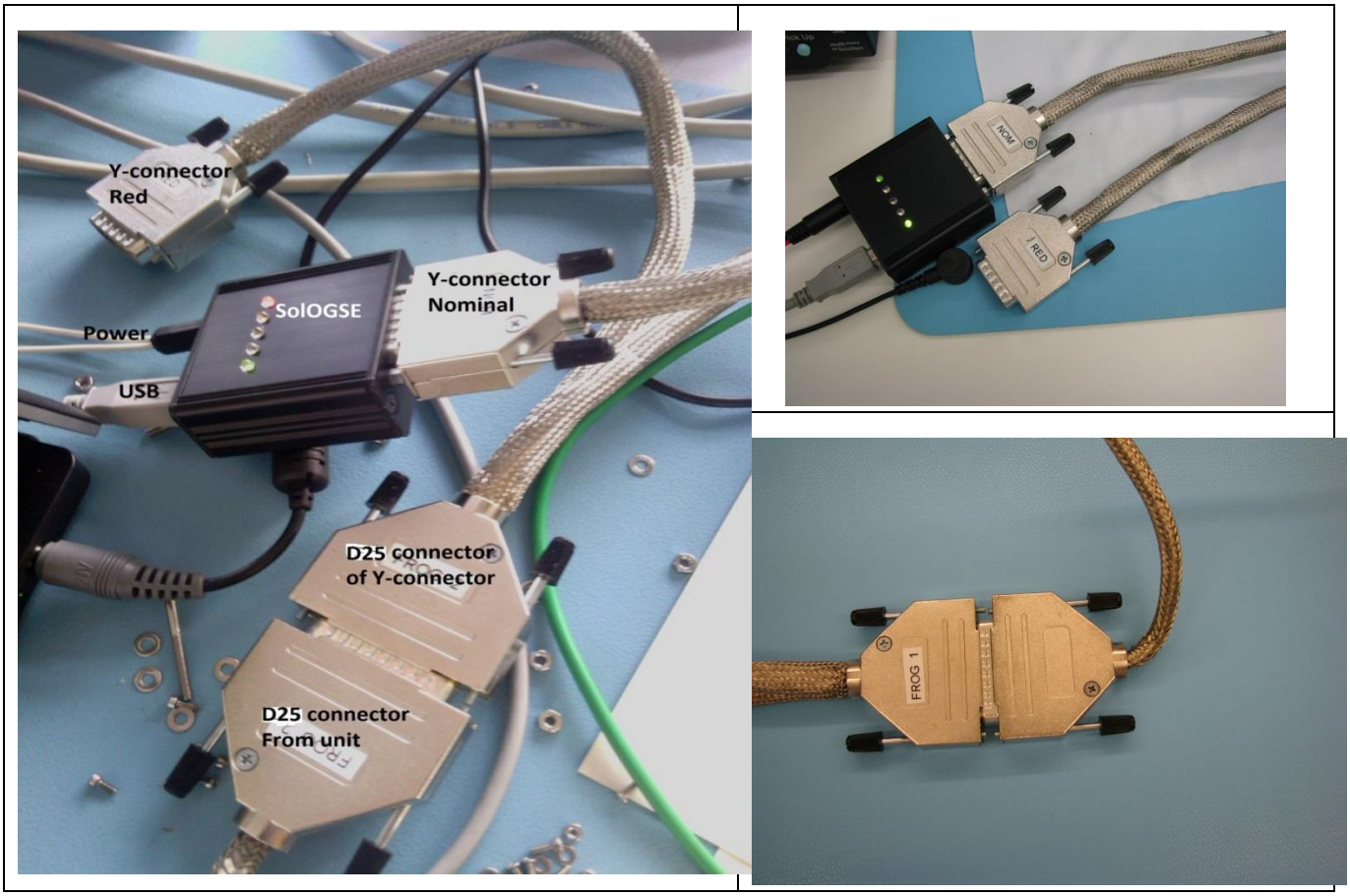


Figure 3: Solo GSE connection picture.

8 UNIT LEVEL FUNCTIONAL TEST PROCEDURE

The procedure for EPT-HET FM functional test is as follows:

8.1 Functional Test

In this setup EPT-HET FM unit connected to Kiel EGSE and will be acquired data of Cosmic Muon and/or of Bi^{207} spectrum (see annexure-A for Bi^{207} source safety precautions).

Configuration of the setup:
EPT-HET FM unit
Kiel GSE and its harness
0-30V, 0-1A lab power supply
GSE notebook

Experimental setup is shown in the following figure.

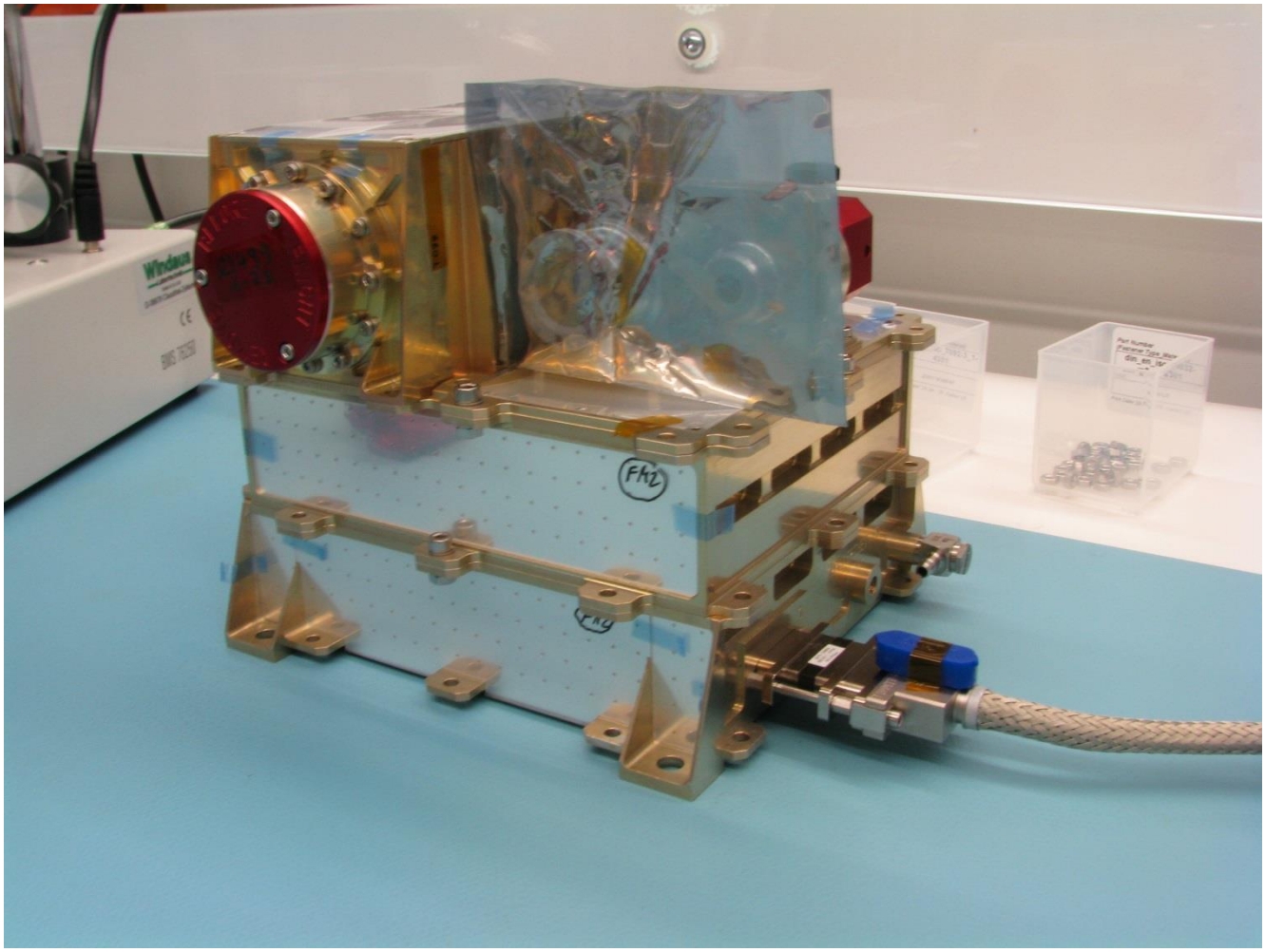


Figure 4: Bi^{207} electron data acquisition by one of the EPT-HET FM units with unit EGSE.

Commands used to acquire data are mentioned in the section 8.2.

STEP 1:
Connect unit harness+ GSE harness+GSE+power supply to unit other end of connector saver of 25 pin MDM connector.

STEP 2:
Open SolO-GSE notebook and switch-on power of notebook. Connect SolO-GSE notebook through USB connector.

STEP 3:
Orient the EPT-HET FM unit such a way that, 3 collimators (1 HET and 2 EPT) of unit should upward direction and other three should be downward direction (This arrangement to collect muon as well as mount Bi207 source. For the case of Bi207 source, source should be mounted on top of one of the collimators).

STEP 4:
Make sure all connectors are connected properly, then switch-on power supply. Check the current in power supply display, If the current in the display between 157±5 mA to 188±5 mA* then unit is alive (This is aliveness test). Now unit is ready for data acquisition. Follow commands mentioned in the next section to acquire and store data.

*Current of the unit initially 157 mA and will increase up to 188 mA as soon as data acquisition starts and ±5 mA also acceptable.

8.2 Commands for above test

After finish the assembly of the unit, perform unit level impedance test as well as safe to mate test GSE as described in the section 7. Follow the steps from 1 to 3 in section 8.1 to make set-up for “Functional Test setup” to check performance of the unit. It is suggested to acquire cosmic Muon and/or Bi207 spectrum for minimum 30-45 minutes (60 minutes better for cosmic muons case) for each test.

1. Follow the steps from 1 to 3 in section 8.1 to make set-up.
2. In the laptop type the following command to collect data
   Enter the directory and chose file

To START data acquisition
cd ~/eda/gse ./sologse.py reset() status() Start (“FileName.dat”) test=SFT( ) EMITEST( ) or STREAMTEST() senable( )

To STOP data acquisition	
Stop()	(<= enter)
disable()	(<= enter)
Ctrl-C for coming out of the prompt	

To Continue for next measurement	
Start (“FileName.dat”)	(<= enter)
senable()	(<= enter)
To come-out of prompt	
Ctrl-C to coming out of prompt	

After finishing data acquisition

3. Switch off the power-supply and disconnect all connectors carefully (except connector saver, removing of connector saver from the unit is depends on AIVT activities).

These are basic commands to control data (science and housekeeping) acquisition of EPT-HET FM unit..

Observed results like HK, trigger/count rates, … of each test will be record as-run-test-procedure and as a data file.

8.3 Power consumption of unit

Power consumption of unit will monitor during functional test of the unit. Once safe-to-mate test of GSE and unit made, then switch-on the power supply (after making proper connections, see section 8.1 & 8.2) and observe power consumption of unit and document as follows:

Voltage (operating) is 28 V			
Condition	Current (mA)	Power (W)	Remarks
Power-on			
Data acquiring mode (Normal Operation mode)			

9 SYSTEM LEVEL FUNCTIONAL TEST PROCEDURE

The system level functional test will be carried-out by ICU and PO experts at PO premises in presence of EPT-HET FM team. A detailed procedure for safe-to-mate test of ICU expected from ICU/PO team at the time of system level functional test.

ANNEXURE A: SAFETY INSTRUCTIONS FOR "BISMUTH207" RADIOACTIVE SOURCE – TO USE

Part of functional test requires a radioactive source. Hence, one has to follow the following radiation safety instructions:

1. Inform radiation safety officer before using source and follow his/her instructions.
2. Wear radiation-dosimeter.
3. Handle source very carefully.
4. Don't contaminate unit and any area with source.
5. After completion of measurements, check the workplace using a meter shown below, if radiation level is more than specified number, inform to radiation safety officer for further action:

6. Clean the working surface if radiation level is below the specified limit.
7. Return the source to its original place.

This safety instruction recommended at CAU facility. If unit functional test performed with radioactive sources at different premises, the radioactive safety instructions are depends on those facility instructions.

ANNEXURE B: PROTO-QUALIFICATION MODEL'S PRE-AIVT ACTIVITY UNIT FUNCTIONAL TEST RESULTS (EXPECTED SIMILAR KIND OF RESULTS FOR FM)

In this section results of functional test of PQM are shown. We are planning for similar kind of plots for FM1 and FM2.

Trigger rates of the test are shown in the following plot.

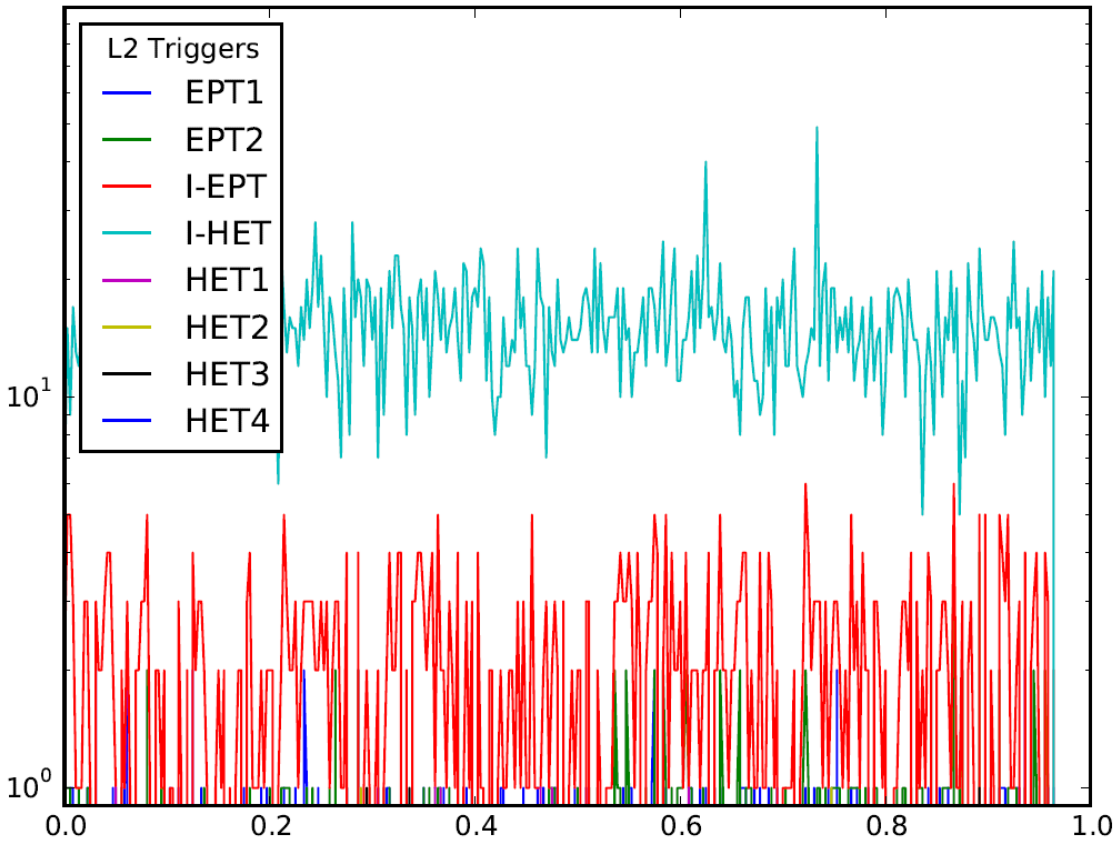


Figure B1: Unit trigger rate monitored during the PQM Functional Test .

Different HK, like voltages of different section of unit and temperature of different boards and sensor heads are shown below.

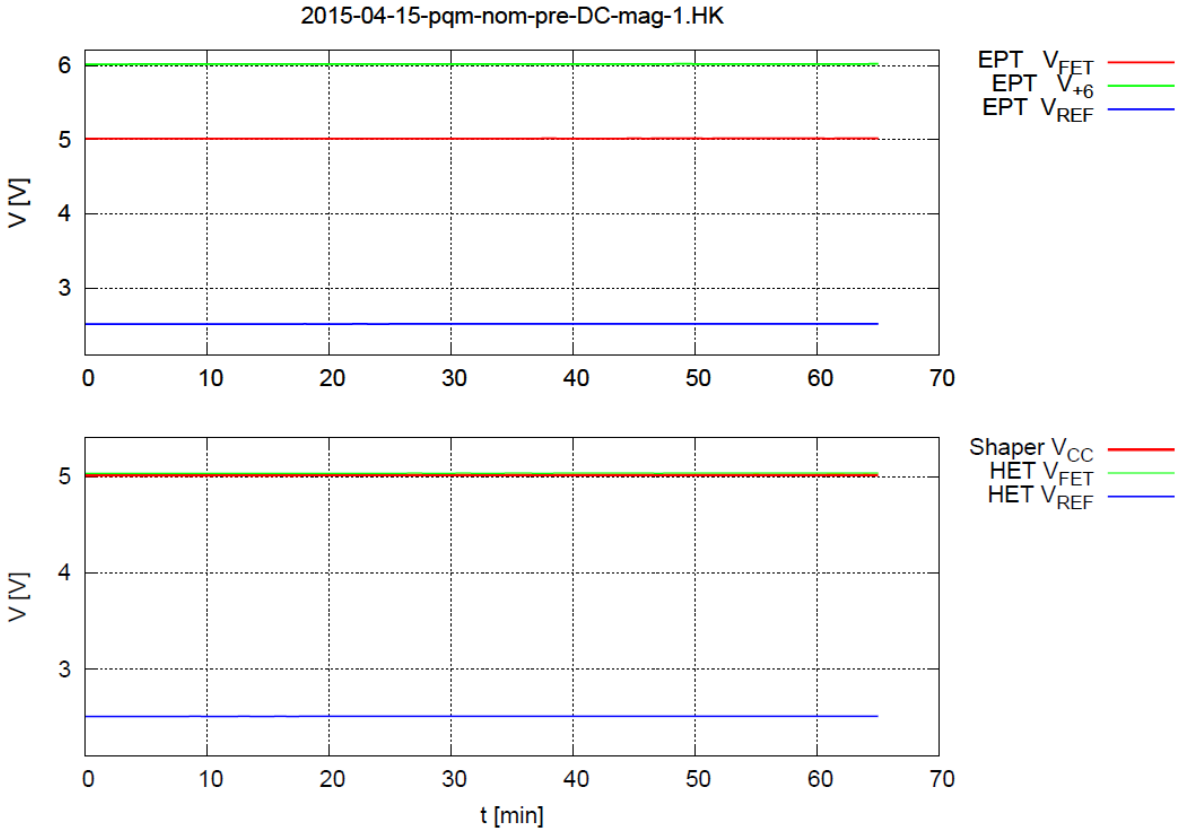


Figure B2: Unit voltages of different sections monitored during PQM Functional Test.

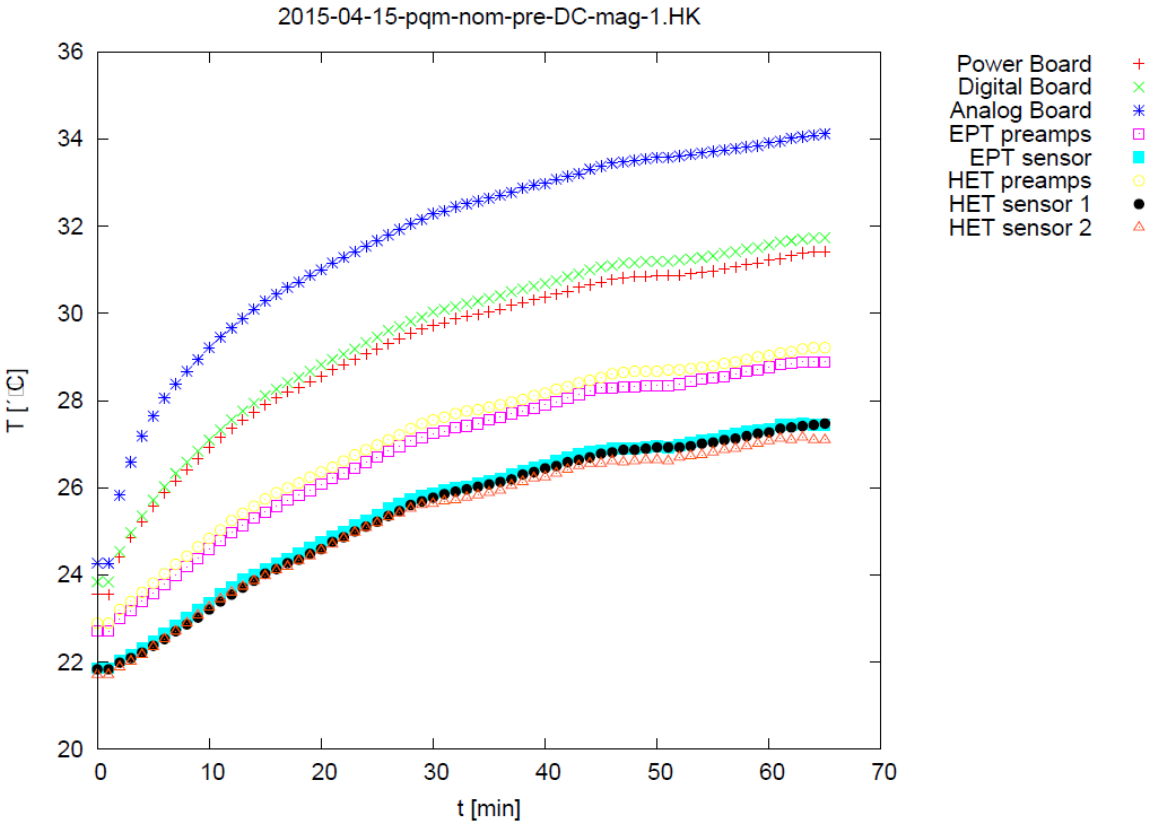


Figure B3: Temperature of all electronic boards and sensor heads were monitored during PQM Functional Test.

ANNEXURE C: AS RUN FUNCTIONAL TEST PROCEDURE FOR EPT-HET-1 AND EPT-HET-2

1.0 Functional test (FT) readiness

Date: Location:

Personnel:

Reason for performing FT: If test, then procedure:

Instrument Identification: EPT-HET-1 / EPT-HET-2

EGSE checklist review:

1.1 FT Constraints

Radiation source (Muon or Bi207):

Expected FT duration:	NOMINAL side	30 to 60 min
	REDUNDANT side	30 to 60 min

Instrument orientation (§8.2, step 3 or other)

Other constraints:

2.0 FT setup

Instrument setup:

Verify orientation and support frame.

Safe-to-mate:

Verify grounding of instrument

Connector saver of J29(EPT-HET1)/J33(EPT-HET2) and J40_S(EPT-HET1)/ J41_S(EPT-HET2) connecetors (used for nonop heaters): visual inspection

Pigtail connector: visual inspection

Resistance measurements as per Table 6,

Safe-to-mate: ok?

Remove flight representative cable if necessary:

Disconnect at connector saver

Configure EGSE for test starting with NOMINAL:

EGSE Y-cable for main & redundant power and signal (25pin Sub-D to 2 * 15pin Sub-D).

EGSE LVDS to USB (RS232) Box

EGSE Power supply (banana connectors to SoloGSE)

EGSE RS232 to USB cable

EGSE laptop (USB input)

Start EGSE laptop and verify script version:

3.0 Functional Test by direct streaming

Step	*Activity*	*Expected result*	*Actual result*	*Time or remark*
1	Power on at EGSE power supply (§7.c step 7) for NOMINAL side test	28V mV		
2	Verify housekeeping: Input 28V Capture and store full housekeeping data	 28 V mA		
3	Run preliminary scripts at EGSE laptop ./sologse.py reset() status() Start (“FileName.dat”) test=SFT() EMITEST() or STREAMTEST()			

4	Start data acquisition senable()			
5	Wait agreed duration for accumulation of data			
6	Stop acquisition: Stop()			
7	Verify housekeeping Input 28V Input current @28V Capture and store full housekeeping data			
8	Power OFF at EGSE power supply			
9	Demate NOMINAL 15pin sub-D			
10	Mate REDUNDANT 15pin sub-D			
11	Power ON at EGSE power supply (§7.c step 7) for REDUNDANT side test	28V mA		
12	Verify housekeeping: Input 28V Input current @28V Capture and store full housekeeping data	28V mA		
13	Run preliminary scripts at EGSE laptop ./sologse.py reset() status() Start (“FileName.dat”) test=SFT()			

	EMITEST()/STREAMTEST()			
14	Start data acquisition senable()			
15	Wait agreed duration for accumulation of data			
16	Stop acquisition: Stop() disable()			
17	Verify housekeeping Input 28V Input I @ 28V Capture and store full housekeeping data			
18	Power off at EGSE power supply			
19	Copy FileName.dat to data archive;			
20	Print results and plots to attach to this as-run procedure			

4.0 Post test review

Deviations

Anomalies

Signatures:

Test engineer	Instrument scientist	Quality assurance

ANNEXURE D: RESISTANCE MEASUREMENT OF SURVIVAL SECTION OF THE UNIT

Ssurvival heater and thermistors resistance measurement of the EPT-HET FM's unit is as follows:

STEP 1:
Visually inspect the connector of unit [**J40_S (EPT-HET-1) / J41_S (EPT-HET-2)**], connectors of the harness / connector-saver and pigtail connector.

STEP 2:
Connect connector-saver to unit survival compartment connector (15 pin MDM connector) and fasten connector saver screws (hand tight). **NOTE:** Connector saver should not be removed until completion of unit level test, **but it should be removed during unit level vibration test**.

STEP 3:
Connect pigtail connector to other end of connector saver and fasten connector screws (hand tight).

STEP 4:
Using calibrated Fluke multimeter, measure the resistance of the survival compartment of unit by connecting appropriate pigtail connector wires to multimeter probes as mentioned in the table below.

These measurement at temperature: ^{0}C.

Connector serial number: **For EPT-HET-1** : **J40_S and for EPT-HET-2: J41_S**

Sl.No.	Pin (+)	Pin(-)	Name of element	Resistance Expected	Resistance Observed
1	1	9	Thermistor 1		
2	2	10	Thermistor 2		
3	3	11	Thermistor 3		
4	7	14	Heater 1		
5	8	15	Heater 2		