

LAGRANGE L5 IN-SITU CONSORTIUM

MEPS Reliability Assessment Report

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**TABLE OF CONTENTS**

1 INTRODUCTION 6

1.1 Purpose 6

1.2 Scope 6

1.3 Project outline 6

1.4 Details of MEPS 9

2 GLOSARY AND DEFINITIONS 11

2.1 Acronyms and Abbreviations 11

3 APPLICABLE AND REFERENCE DOCUMENTS 12

3.1 Applicable Documents (heritage from Solar Orbiter) 12

3.2 Normative documents 12

3.3 Reference documents 13

4 RELIABILITY requirements 13

4.1 Applicable Reliability Requirements 13

4.2 ECSS guidelines 13

4.2.1 Parts Count Analysis 14

5 Data for the Parts Count Analysis 15

5.1 Unit part types 15

5.2 Microcircuit evaluation 15

5.3 Parts Count (draft from EPT-HET/Solar orbiter reliability table) 17

6 Summary 32

**LIST OF FIGURES**

Figure 1: MEPS single unit CAD-study with two sensor heads, each of which has two double-ended telescopes. One MEPS unit provides eight view cones in total, four for electrons and four for ions. 6

Figure 2: Working principle of an EPE double-ended telescope. The polyimide layer stops ions but lets electrons pass, whereas on the other side electrons are deflected by magnets and ions pass unaffected. The thin detector on the right side enables the separation of different ion species via the *d E/dx* vs. *E*-method (in the MeV*/*nuc energy range; for the separation at lower energies see text). 8

Figure 3: Electron Proton Telescope on Solar Orbiter (EPT) EM measurements with a Bi- 207 source. The conversion electron lines at 482 keV and 554 keV are seen on the PI-side (Det 1) but vanish on the magnet-side (Det 2). 9

Figure 4 MEPS as part of the Lagrange L5 In-situ Consortium 10

Figure 3 MEPS electronics boards 32

**LIST OF TABLES**

Table 1: Proposed MEPS instrument heritage of MEPS from EPT Solar Orbiter Technical Parameters 7

Table 1 Applicable documents 12

Table 2 Normative documents 12

Table 3 Reference documents 13

Table 4 Data sources for component families 14

Table 5 Failure rate computation following UTE C 80-810 15

Table 6 Summary of microcircuit failure rate data and computations 16

Table 7 Parts count worksheet for EPT-HET LVPS board 19

Table 8 Parts count worksheet for EPT-HET digital board 22

Table 9 Parts count worksheet for EPT-HET analog ADC shaper board 24

Table 10 Parts count worksheet for MEPS-A preamp board (draft from HET/Solar orbiter reliability table) 26

Table 11 Parts count worksheet for MEPS-B preamp board (draft from EPT/Solar orbiter reliability table) 28

Table 12 Parts count worksheet for MEPS miscellaneous items 30

1. INTRODUCTION
   1. Purpose

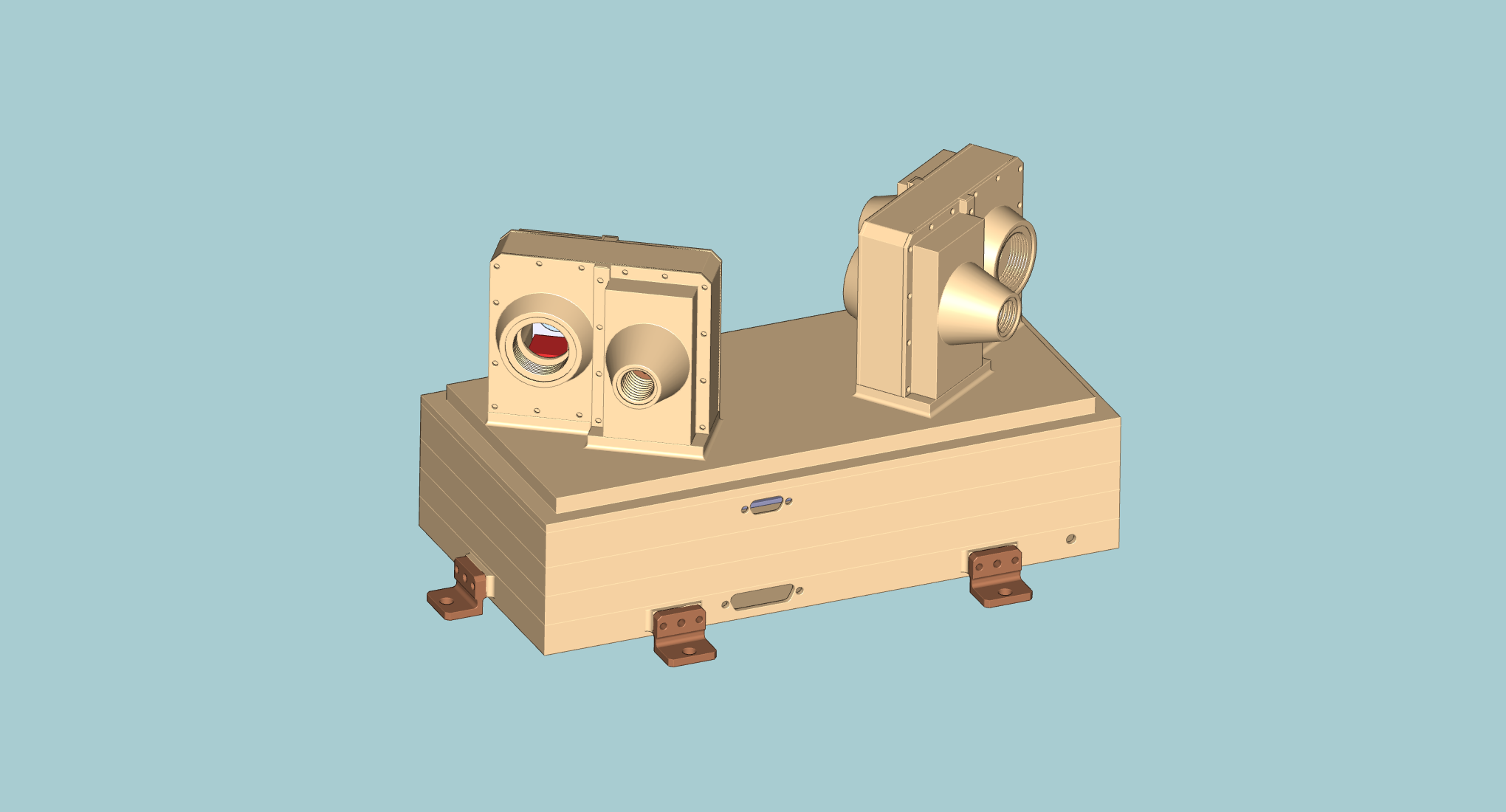
This document reports data and analysis for the assessment of the reliability of the MEPS sensors of the In-Situ Consortium for the Lagrange L5 Mission.

* 1. Scope

This document applies to the current design of the electronics for MEPS, and includes results for a component count analysis (RD-01).

* 1. Project outline

The MEPS instrument is a particle instrument measuring the energy spectra and angular distributions of energetic electrons (30-600 keV) and ions (30-6000 keV/nuc). The full experiment consists of one unit which provides one double-ended telescope pairs (sensor heads) with four view cones per pair, two dedicated for electrons and two for ions. Utilizing any spin of the spacecraft, MEPS observations cover the full sky with a total of eight electron and eight ion view cones. As the L5 S/C is not a spinner, MEPS still provides crucial pitch-angle information to determine whether the event is scatter free. This is an important indicator for interpreting the timing information of the space weather event. Figure 1 shows the MEPS unit, with eight view cones.

****

MEPS-B

Sensor

MEPS-A

Sensor

Electronics

Module

Figure 1: MEPS single unit CAD-study with two sensor heads, each of which has two double-ended telescopes. One MEPS unit provides eight view cones in total, four for electrons and four for ions.

|  |
| --- |
| **Units:** 1 |
| **Sensors:** 2 per unit |
| **FoVs:** 4 double FoVs per unit. The FOVs for each sensor are separated by 70°  C:\Users\Cesar Martin\AppData\Local\Microsoft\Windows\INetCache\Content.Outlook\K3ITX40U\tlg-meps-c2_sh_top_240mm-110deg.png |
| **Angular resolution:** 45° full angle |
| **Energy range:** |
| * 30keV/n-6MeV/n for the 20-300-300 um detector stack solution |
| **Volume:** 300x160x175 mm3 (including potential radiators and MLI) |
| **Power:** 5W for 1 unit |
| **Mass:** 2.4 kg for 1 unit |
| **Data Products:** Particle VDF |
| **Cadence:** 5(1) minutes |
| **TRL:** 6 (most parts 8-9) |

Table 1: Proposed MEPS instrument heritage of MEPS from EPT Solar Orbiter Technical Parameters

The two ends of a telescope observe electrons and ions, respectively. Each telescope consists of a stack of three solid-state detectors (Figure 2). On one end, the outer detector is covered with a thin polyimide layer or parylene foil (TBC), stopping ions below a few hundred keV/nuc but letting electrons pass almost unaffected. This uppermost detector (300 μm thick Si) on this side is operated in anticoincidence with the second (middle) detector and thus observes the energy spectrum of stopping electrons. The other end of the telescope has a broom magnet (instead of a PI layer) that defects electrons below a few hundred keV (see Figure 3 for electron deflection measured with the Solar Orbiter EPT EM). This side of the telescope employs a 20 μm thick Si detector in front of the 300 μm Si detector in the middle, which thus form an ion telescope observing at energies from 30-6000 keV/nuc. Ions passing the thin first detector can be identified at high energies (MeV/nuc range) using the d E/dx vs. E technique, operable at Ekin ≥ 1 MeV/nuc for protons and alphas and ≥ 2 MeV/nuc for heavier species. Lower ion energies can nevertheless be resolved using the middle detector as an anticoincidence: Anything above 1.2 MeV energy deposit in the thin detector is heavier than protons, which in return means that the thin detector may be used as a Z ≥ 2 channel SSDs for deposited energies > 1.2 MeV (or 300 keV/nuc for He). The same logic applies for penetrating He, enabling a Z ≥ 6 channel for energies > 4.8 MeV; or 420 keV/nuc for C, 360 keV/nuc for N and 310 keV/nuc for O.



Figure 2: Working principle of an EPE double-ended telescope. The polyimide layer stops ions but lets electrons pass, whereas on the other side electrons are deflected by magnets and ions pass unaffected. The thin detector on the right side enables the separation of different ion species via the *d E/dx* vs. *E*-method (in the MeV*/*nuc energy range; for the separation at lower energies see text).

The permanent magnets of one sensor head (double-ended telescope pair) form a quadrupole, significantly reducing the far field. The far field is reduced even further by the other sensor head on the same unit, since its quadrupole forms an angle of 70° with respect to the first sensor head. The MEPS unit integrates the sensors and electronics in a single package. Right below the sensors in the electronic box are the preamp boards, followed by an analogue board and the back-end electronics (digital and LVPS-board[s]). Pre-flight ground energy calibration (1 % level) of all detector elements, on-axis active area calibration, selected off-axis directions active area calibration and dead-time calibration will be performed. Calibration quality will be monitored in-flight using measured data and cross-calibration with suprathermal electron/ion instruments.



Figure 3: Electron Proton Telescope on Solar Orbiter (EPT) EM measurements with a Bi- 207 source. The conversion electron lines at 482 keV and 554 keV are seen on the PI-side (Det 1) but vanish on the magnet-side (Det 2).

* 1. Details of MEPS

Figure 4 shows the LGR In-situ suite star configuration.



Figure 4 MEPS as part of the Lagrange L5 In-situ Consortium

For the purposes of the analysis the MEPS unit is broken down into:

|  |  |
| --- | --- |
| **MEPS** | **Board** |
| MEPS-A | Preamp |
| MEPS-B | Preamp |
| Ebox | MEPS Analog ADC Shaper |
| Ebox | MEPS Digital |
| Ebox | MEPS Power (LVPS) |

There are also some parts not belonging specifically to any of the above boards, and these are included as a miscellaneous group.

1. GLOSARY AND DEFINITIONS
   1. Acronyms and Abbreviations

|  |  |
| --- | --- |
| CME | Coronal Mass Ejection |
| DOCS | Deep-space Optical Communication System |
| DPU | Data Processing Unit |
| EDAC | Error Detection and Correction |
| EEE | Electrical, Electronic and Electro-mechanical |
| EMC | Electro-Magnetic Cleanliness |
| EOL | End of Life |
| EPT | Electron Proton Telescope |
| HV | High Voltage |
| IMF | Interplanetary Magnetic Field |
| LCL | Latch Current Limiter |
| LET | Linear Energy Transfer |
| LGR | Lagrange |
| MAG | Magnetometer |
| MCP | Microchannel Plate |
| MEPS | Medium Energy Particle Spectrometer |
| MICD | Mechanical Interface Drawing |
| MRAM | Magneto-Resistive Memory |
| NGRM | Next Generation Radiation Monitor |
| PLA | Plasma Analyser |
| RADEM | Radiation Monitor |
| RAM | Random Access Memory |
| RAMS | Reliability, Availability, Maintainability, Safety |
| RM | Radiation Monitor |
| SEE | Single Event Effects |
| SEP | Solar Energetic Particles |
| SIR | Stream Interaction Region |
| SIXS | Solar Intensity X-ray and particle Spectrometer |
| SO | Solar Orbiter |
| SRAM | Static Random Access Memory |
| SSA | Space Situational Awareness |
| IS | Solar Wind Analyser |
| TC | Telecommand |
| TID | Total Ionizing Dose |
| TM | Telemetry |
| TOF | Time of Flight |
| XFM | X-ray Flux Monitor |

1. APPLICABLE AND REFERENCE DOCUMENTS
   1. Applicable Documents (heritage from Solar Orbiter)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID.** | **Title** | **Reference** | **Iss./Rev.** | **Date** |
| AD-01 | Product Assurance Requirements for instruments | SO-EPD-PA-0001 | 3 / 2 |  |
| AD-02 | EID-B | SO-EPD-PO-IF-0001 | 3 / 2 | 2012-07-10 |
| AD-03 | EPD DRD | SO-EPD-PO-TN-0002 | 1 / 1 | 2011-06-02 |
| AD-04 | EPT-HET & STEIN circuit diagrams | SO-EPD-KIE-CD-010 | 2 / 0 | 2013-10-08 |
| AD-05 | EPT-HET & STEIN EEE list | SO-EPD-KIE-LI-0050 | 2 / 0 | 2013-10-31 |

Table 2 Applicable documents

* 1. Normative documents

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID.** | **Title** | **Reference** | **Iss. / Rev.** | **Date** |
| ND-01 | Space product assurance: Dependability | ECSS-Q-ST-30C | C | 2009-03-06 |
| ND-02 | Space product assurance: Safety | ECSS-Q-ST-40C | C | 2009-03-06 |
| ND-03 | Space product assurance: Components Reliability Data Sources and their Uses | ECSS-Q-HB-30-08A | A | 2011-01-14 |
| ND-04 | Space product assurance: Electrical, electronic and electromechanical (EEE) components | ECSS-Q-ST-60C Rev.1 | C / 1 | 2009-03-06 |

Table 3 Normative documents

* 1. Reference documents

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID.** | **Title** | **Reference** | **Iss. / Rev.** | **Date** |
| RD-01 | Reliability prediction of electronic equipment | MIL-HDBK-217 Notice 1 Notice 2 | F | 1991-12-02 1992-07-10  1995-02-28 |
| RD-02 | Reliability data handbook - universal model for reliability prediction of electronics components, PCBs and equipment | UTE C 80-810 | 2 | 2005-08-01 |
| RD-03 | Reliability Methodology for Electronic Systems | FIDES guide 2009 | Edition A | 2010-09 |
| RD-04 | Presentation and specification of reliability data on electronic components | IEC 60319 |  |  |

Table 4 Reference documents

1. RELIABILITY requirements
   1. Applicable Reliability Requirements

The RAR is called for in AD-03, and the following shall be documented as a minimum:

Design baseline and description

Analysis assumptions, input data and results

Supporting information and analyses

Statement of compliance with applicable requirements

Recommendations for design, verification, test and operations (as relevant)

Conclusions

The outcomes of the analyses shall include identification of any reliability, availability or maintainability critical items.

* 1. ECSS guidelines

Reliability analyses are part of the ECSS dependability requirements (ND-01, §6.4). The analyses include reliability prediction, FMECA, HSIA and FTA. Reliability is part of the safety program (ND-02, §B.2), and reliability is of central importance in the evaluation and procurement of EEE components (ND-04).

To guide the reliability assessment process, the ECSS handbook ND-03 identifies potential data sources (Annex A) and methods (Annex B) that can be used in the analysis. Data sources are handbooks, manufacturer data and user data. ND-03 §4.2 describes the data selection process.

Among the references to methods, ND-03 cites the MIL-HDBK-217F handbook (RD-01), which although formally obsolete is most commonly used. Limitations on the application of RD-01 are tabulated in ND-03 Annex B for some part types. Where a part type is not covered in RD-01, or the limitations set out in ND-03 are exceeded, the methods of RD-01, §4.4 should be used to find an alternative source. Failing that option, the manufacturer's data should be collected and assessed as per HD-03 §4.6.

Parts Count Analysis

The parts count reliability prediction method is recommended in MIL-HDBK-217 (RD-01, Appendix A), for the early design stage. The information required is the generic part types (including complexity) and quantities, the part quality levels, and the unit or board level environment.

The part generic failure rate for a given environment is found in the tables in RD-01, and this times the quality factor and the quantity gives the part type failure rate. The sum over all unit part types is the unit failure rate.

The tables of ND-03 Annex B include quality factors for flight EEE part quality classes.

The environment is factored into the generic failure rate tables of RD-01, and there is one relevant use environment (RD-01 §3.4.3), "SF" for space flight, including Earth satellite orbits. The SF environment temperature is 50C junction temperature for active components, and 30C ambient temperature for passive components.

Table 5 Data sources for component families

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Component family** | **Category (ECSS Q HB 30-08)** | **Constraint on use of MIL 217F (ECSS Q HB 30-08)** | **MIL 217F §** | **IEC-TR-62380 §** | **UTE C 80-810 §** |
| Integrated Circuits | Logic devices | ≤ 60k gates  ≥ 0.8 µm | A-2 | 7 | 7.3 |
|  | Linear devices | ≤ 10k transistors | A-2 |  | 7.3 |
|  | Non-volatile memories | ≤ 1 Mbit  ≥ 0.8 µm | A-3 |  | 7.3 |
| Discrete semiconductor | Diodes |  | A-5 |  |  |
|  | Bipolar transistor |  | A-5 |  |  |
|  | Field effect transistors |  | A-5 |  |  |
| Resistors | Fixed & variable |  | A-7 | 11.1 | 130 |
|  | Thermistors |  | A-7 |  |  |
| Capacitors | Except Tantalum |  | A-8 |  |  |
|  | Tantalum |  | A-8 |  |  |
| Inductive devices | Fixed inductor or choke |  | A-9 |  |  |
| Connectors | General | ≤ 40A/ contact | A-9 |  |  |
|  | Sockets | ≤ 180 contacts | A-9 |  |  |
| Quartz crystals | Units | ≤ 105 MHz | A-10 |  |  |
| PCB & connections | PTH | ≤ 18 circuit planes | A-10 |  |  |
|  | SMT |  | A-10 |  |  |
|  | Solder connections |  | A-10 |  |  |

1. Data for the Parts Count Analysis
   1. Unit part types

Part types for MEPS are listed in AD-05.

* 1. Microcircuit evaluation

Manufacturer data for microcircuit failure rate were used where possible, and otherwise UTEC 80-810 §7.3 was used for computations. The following tables summarize the computation.

The first table lists the values for total failure rate = die + over stress + package.

Table 6 Failure rate computation following UTE C 80-810

| **IC** | **Generic part** | **Process** | **Tj [C]** | **Top max** | **N** | **λDie** | **λOS** | **λP** | **λ** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 3 | ADC128S102 ADC | CMOS | 44 | 105 | nn | 8.57 | 0 | 0 | 8.6 |
| 4 | 54LVDS055 Dual LVDS driver/receiver | CMOS | 48 | 125 | nn | 9.53 | 10 | 0 | 19.5 |
| 6 | UT8CR512K32 SRAM | CMOS | 41 | 125 | 8\*nn | 16.0 | 0 | 0 | 16 |
| 7 | 28LV010 EEPROM | MOS | 35 | 125 | 2\*nn | 23.5 | 0 | 0 | 23.5 |
| 8 | IS-1009 Shunt regulator diode | MOS | 36 | 125 | nn | 6.31 | 0 | 0.27 | 6.6 |
| 12 | CD4024 Ripple carry binary counter / divider | CMOS | 37 | 125 | 2\*nn | 2.67 | 0 | 0 | 2.7 |
| Notes on UTEC 80-810 table reference: | | | | | | | | | |
| IC3 | Linear circuit, ceramic SO-16 package (SO) | | | | | | | | |
| IC4 | Linear circuit, ceramic FP-18 package (SO), I/F to ICU | | | | | | | | |
| IC6 | SRAM, ceramic quad FP-68 (28x28 PQFP) | | | | | | | | |
| IC7 | EEPROM, ceramic radpak FP-32 (14x20 PQFP) | | | | | | | | |
| IC8 | Linear circuit, TO-206AB CAN (TO-92) | | | | | | | | |
| IC12 | Digital circuit, ceramic FP-14 (10x10 PQFP) | | | | | | | | |

The second table combines manufacturer data with calculations from UTE C 80-810 to provide a summary of failure rate in FIT for the microcircuits listed in the current version of AD-05.

Table 7 Summary of microcircuit failure rate data and computations

| **IC** | **Generic part** | **Qual level** | **Meth** | **§** | **CL [%]** | **T [C]** | **λ1** | **λ2** | **λ3** | **Failure rate [FIT]** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | MSK5058 Step-down switching regulator controller | S | V | a. | 60 | 55 |  |  |  | 0.08 |
| 2 | ISL78841ASRH Current mode PWM controller | B | V | b. | 60 | 55 |  |  |  | 19.28 |
| 3 | ADC128S102 ADC | S | UTE | 7.3 |  |  | 0.01 | 4.2 | 1.63 | 8.6 |
| 4 | 54LVDS055 Dual LVDS driver/receiver | S | UTE | 7.3 |  |  | 0.01 | 4.2 | 1.96 | 19.5 |
| 5 | RTAX2000SL-CQ256 FPGA | S | V | c. | 60 | 55 |  |  |  | 10.74 (7.04) |
| 6 | UT8CR512K32 SRAM | S | UTE | 7.3 |  |  | 1.7 10-7 | 8.8 | 23 | 16 |
| 7 | 28LV010 EEPROM | B1 | UTE | 7.3 |  |  | 6.5 10-7 | 16 | 10.2 | 23.5 |
| 8 | IS-1009 Shunt regulator diode | S | UTE | 7.3 |  |  | 0.01 | 4.2 | 1 | 6.6 |
| 9 | RH1498 Op Amp | B1 | V | d. | 60 | 55 |  |  |  | 0.6 |
| 10 | RH1056 Op Amp JFET input | B1 | V | e. | 60 | 55 |  |  |  | 0.6 |
| 11 | AD8005 Op Amp | Other | V | f. | 60 | 55 |  |  |  | 0.18 |
| 12 | CD4024 Ripple carry binary counter / divider | S | UTE | 7.3 |  |  | 3.4 10-6 | 1.7 | 4.1 | 2.7 |
| Notes | |  |  |  |  |  |  |  |  |  |
| 1. Method | |  | |  |  |  |  |  |  |  |
| a. V = Vendor | | | | | | | | | | |
| b. F=MIL-HDBK-217F | | | | | | | | | | |
| c. U=UTEC 80-810 | | | | | | | | | | |
| 2. Quality level from ECSS-Q-HB-30-08A, §B.4 | | | | | | | | | | |
| 3. Vendor reference | |  | | | | | | | | |
| a. Linear Technology: Reliability Data Report Product Family R530, Oct 09, 2009. | | | | | | | | | | |
| b. Intersil Technology: Report for P6 cumulative since Dec 24, 2011. | | | | | | | | | | |
| c. Microsemi: Reliability Report Rev 10, Nov 2012. | | | | | | | | | | |
| d. Linear Technology: Reliability Data RADHARD Devices 11/2/2010. | | | | | | | | | | |
| e. Linear Technology: Reliability Data RADHARD Devices 11/2/2010. | | | | | | | | | | |
| f. Analog Devices: Wafer Fabrication Data, March 28, 2012. | | | | | | | | | | |

* 1. Parts Count (draft from EPT-HET/Solar orbiter reliability table)

This preliminary parts count analysis is based on Demonstration Model circuit diagrams and projected flight parts lists. See AD-04 for circuit diagrams and AD-05 for component lists.

Component reliability data references as cited in the parts count worksheets are:

|  |  |  |  |
| --- | --- | --- | --- |
| (1) | ECSS-HB-30-08 | Components Reliability Data Sources and their Uses | ND-03 |
| (2) | MIL-HDBK-217 Notice 2 | Reliability prediction of electronic equipment | RD-01 |
| (3) | UTE C 80-810 | Reliability data handbook | RD-02 |
| (4) | FIDES 2009 | Reliability Methodology for Electronic Systems | RD-03 |
| (5) | Manufacturer |  |  |
| (6) | Heritage |  |  |

See ND-03, Table B-3 for designation of EEE part quality grades. The class S category is assumed in each of the following, unless noted otherwise.

The failure rate estimated here follows from RD-01, Appendix A, Equation 1, where possible. The equation is a sum over generic part category failure rates, where this failure rate (**λ**) is the product of Quantity, Quality factor (**πQ**) and generic failure rate (**λg** or **λo**). These values are listed in the indicated columns of Table 8 and following. Data for each board are collected to give a summary board failure rate. Part quality grades (S, B, B1, other) are from ND-03 §B.4. Values are failures/109 hours (FITS).

In the column headings **λg** refers to MIL-HDBK-217F generic failure rate, and the heading **λo** refers to either UTES or MIL-217F base failure rate. The column λ includes the Quantity.

For the complete board estimate the method of RD-02 §6 is followed in which PCB rate is combined with aggregate parts rate. The PCB rate includes terms depending on connection method, number of through holes, number of component connections, board size and predominant track width.

Of the influencing factors the major omission in the following is the lack of analysis of temperature cycling and duty cycle.

Table 8 Parts count worksheet for EPT-HET LVPS board

| **HEL** | **Generic part** | **Family** | **Quality level** | **N** | **πQ** | **λg** | **λo** | **λ** | **References** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | MSK5059 | 08 | S | 5 | .25 |  | 0.08 | 0.1 | (5) |
| 2 | ISL78841ASRH | 08 | S | 1 | .25 |  | 19.3 | 4.82 | (5) |
| 3 | IS-1009 | 08 | S | 1 | .25 |  | 6.6 | 1.65 | (3, §7.3) |
| 4 | RH1498 | 08 | S | 2 | .25 |  | 0.6 | 0.15 | (5) |
| 5 | RH1056 | 08 | S | 2 | .25 |  | 0.6 | 0.30 | (5) |
| 6 | CD4024 | 08 | S | 1 | .25 |  | 2.7 | 0.68 | (3, §7.3) |
| 7 | IRHLUB7970Z4 p-ch MOSFET | 12-06 | S | 3 | .25 | 15 |  | 11.25 | (2 §6.9) |
| 8 | IRHLUB770Z4, n-ch MOSFET | 12-05 | S | 3 | .25 | 15 |  | 11.25 | (2 §6.9) |
| 9 | IRHNJ57133SE, n-ch MOSFET | 12-06 | S | 1 | .25 | 24 |  | 6.00 | (2 §6.9) |
| 10 | 2N5401 | 12-06 | S | 1 | .25 | .37 |  | 0.09 | (2, §6.3) |
| 11 | 2N5551, Si NPN 150V 0.5A | 12-03 | S | 3 | .25 | .37 |  | 0.28 | (2, §6.3) |
| 12 | 1N5822 | 04-05 | S | 6 | .25 | 1.4 |  | 2.1 | (2, §6.1) |
| 13 | 1N5819 | 04-05 | S | 6 | .25 | 1.4 |  | 2.1 | (2, §6.1) |
| 14 | 1N5806 | 04-05 | S | 8 | .25 | 12. |  | 24 | (2, §6.1) |
| 15 | 1N6642 | 04-05 | S | 7 | .25 | 12 |  | 21 | (2, §6.1) |
| 16 | 1N3595 | 04 | S | 1 | .25 | 12 |  | 3 | (2, §6.1) |
| 17 | 1N4486 | 04-04 | S | 1 | .25 | 1.6 |  | 0.4 | (2, §6.1) |
| 18 | 1N4467 | 04-04 | S | 1 | .25 | 1.6 |  | 0.4 | (2, §6.1) |
| 19 | 1N6491 | 04-04 | S | 1 | .25 | 1.6 |  | 0.4 | (2, §6.1) |
| 20 | TES E 157 K 016, tant cap | 01-03 | S | 17 | 0.1 | 0.10 |  | 0.016 | (2, §10.1) |
| 21 | TES E 476 K 025 tant cap | 01-03 | S | 1 | 0.1 | 0.13 |  | 0.010 | (2, §10.1) |
| 22 | TES E 226 K 016, tant cap | 01-03 | S | 6 | 0.1 | 0.10 |  | 0.086 | (2, §10.1) |
| 23 | CNC34 47uF 10% 16V | 01-02 | S | 2 | 0.03 | 1.43 |  | 0.168 | (2, §10.1) |
| 24 | CNC32 4.7uF 10% 25V | 01-02 | S | 3 | 0.03 | 1.15 |  | 0.034 | (2, §10.1) |
| 25 | CNC32 10uF 10% 16V | 01-02 | S | 9 | 0.03 | 1.22 |  | 0.329 | (2, §10.1) |
| 26 | CNC54 8.2uF 10% 100V | 01-02 | S | 11 | 0.03 | 1.20 |  | 0.396 | (2, §10.1) |
| 27 | CNC54 3.9uF 10% 100V | 01-02 | S | 3 | 0.03 | 1.13 |  | 0.102 | (2, §10.1) |
| 28 | CNC56 6.8uF 10% 200V | 01-02 | S | 1 | 0.03 | 1.17 |  | 0.035 | (2, §10.1) |
| 29 | CNC12 10nF 10% 500V | 01-02 | S | 12 | 0.03 | 0.66 |  | 0.238 | (2, §10.1) |
| 30 | CNC4 470nF 10% 16V | 01-02 | S | 5 | 0.03 | 0.93 |  | 0.140 | (2, §10.1) |
| 31 | CNC2 100nF 10% 50V | 01-02 | S | 30 | 0.03 | 0.80 |  | 0.72 | (2, §10.1) |
| 32 | CEC2 1.5nF 1% 50V | 01-02 | S | 5 | 0.03 | 0.56 |  | 0.084 | (2, §10.1) |
| 33 | CNC14 10nF 5% 50V | 01-02 | S | 5 | 0.03 | 0.65 |  | 0.098 | (2, §10.1) |
| 34 | CEC14 1nF 1% 16V | 01-02 | S | 8 | 0.03 | 0.53 |  | 0.127 | (2, §10.1) |
| 35 | CEC14 221pF 1% 50V | 01-02 | S | 2 | 0.03 | 0.48 |  | 0.029 | (2, §10.1) |
| 36 | CEC 14 47pF 5% 50V | 01-02 | S | 2 | 0.03 | 0.41 |  | 0.025 | (2, §10.1) |
| 37 | CEC14 33pF 5% 50V | 01-02 | S | 1 | 0.03 | 0.40 |  | 0.012 | (2, §10.1) |
| 38 | CHPHR0603K10R0FB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, §9.1, Notice 2) |
| 39 | CHPHR0603K24R9FB | 10-09 | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, 9.1, Notice 2) |
| 40 | CHPHR0603K51R1FB | 10-09 | S | 7 | 0.03 | 1.8 |  | 0.378 | (2, 9.1, Notice 2) |
| 41 | CHPHR0603K1000FB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 42 | CHPHR0805K1820FB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 43 | CHPHR0603K2210FB | 10-09 | S | 5 | 0.03 | 1.8 |  | 0.270 | (2, 9.1, Notice 2) |
| 44 | CHPHR0603K1001FB | 10-09 | S | 4 | 0.03 | 1.8 |  | 0.216 | (2, 9.1, Notice 2) |
| 45 | CHPHR0603K1501FB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 46 | CHPHR0603K3321FB | 10-09 | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, 9.1, Notice 2) |
| 47 | CHPHR0603K1002FB | 10-09 | S | 13 | 0.03 | 1.8 |  | 0.702 | (2, 9.1, Notice 2) |
| 48 | CHPHR0603K1822FB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 49 | CHPHR0603K3322FB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 50 | CHPHR0603K1003FB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 51 | CHPHR0603K1213FB | 10-09 | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, 9.1, Notice 2) |
| 52 | CHPHR0603L1004GB | 10-09 | S | 1 | 0.03 | 1.85 |  | 0.054 | (2, 9.1, Notice 2) |
| 53 | PFRR0603E1001BB | 10- | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, 9.1, Notice 2) |
| 54 | PFRR0603E1331BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 55 | PFRR0603E1581BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 56 | PFRR0603E1621BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 57 | PFRR0603E2321BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 58 | PFRR0603E2801BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 59 | PFRR0603E3241BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 60 | PFRR0603E3651BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 61 | PFRR0603E4021BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 62 | PFRR0603E4221BB | 10- | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, 9.1, Notice 2) |
| 63 | PFRR0603E5111BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 64 | PFRR0603E1002BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 65 | PFRR0603E1022BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 66 | PFRR0603E1472BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 67 | PFRR0603E1073BB | 10- | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 68 | CHPHR1206K1000FB | 10-9 | S | 15 | 0.03 | 1.8 |  | 0.810 | (2, 9.1, Notice 2) |
| 69 | CHPHR1206K75R0FB | 10-9 | S | 12 | 0.03 | 1.8 |  | 0.648 | (2, 9.1, Notice 2) |
| 70 | CHPHR1206K4702JB | 10-9 | S | 3 | 0.03 | 1.8 |  | 0.162 | (2, 9.1, Notice 2) |
| 71 | SMP-PW 2010 0.56R 1% 50ppm | 10- | S | 5 | 0.03 | 1.8 |  | 0.270 | (2, 9.1, Notice 2) |
| 72 | CHPHR0805K1005GB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, 9.1, Notice 2) |
| 73 | WA86PS-4706G 2% 200ppm | 10- | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, 9.1, Notice 2) |
| 74 | S1206CHX109J | 10- | S | 1 | 0.03 | 5.1 |  | 0.153 | (2, 9.1, Notice 2) |
| 75 | HCESC 10 M47 IS common mode choke | 07-03 | S | 2 | 0.03 |  | 0.20 | 0.012 | (3, §12) |
| 76 | ESI 7 1K2 1S inductor | 07-02 | S | 3 | 0.03 |  | 0.20 | 0.018 | (3, §12) |
| 77 | ESI 7 8K4 1S inductor | 07-02 | S | 13 | 0.03 |  | 0.20 | 0.078 | (3, §12) |
| 78 | SESI 9.1 10K 2WR power inductor | 07-02 | S | 5 | 0.03 |  | 0.6 | 0.09 | (3, §12) |
| 79 | 322Y060M35H 60pins female connector | 02-07 | S | 1 | 1 |  | 3.87 | 3.87 | (3 §16.3) |
| 80 | QT188HCD10S-2.000MHz | 03-01 | S | 1 | 1 | 8 |  | 8 | (2 §19.1) |
| 81 | EPT-HET LVPS PCB 100mm x 120mm |  | S | 1 | 1 |  | 0.72 | 0.72 | (3, §6.1) |
| 82 | FLYBACK-XFORMER PCB |  | S | 1 | 1 |  | 0.50 | 0.50 | (3, §6.1) |
| 83 | G15K4D489 NTC thermistor | 11-03 | S | 1 | 1 |  | 3 | 3 | (3, §10.9) |
| SUM (failures/109 hours) | | | | | | | | 114 | HEL |

Table 9 Parts count worksheet for EPT-HET digital board

| **HED** | **Generic part** | **Family** | **Quality level** | **N** | **πQ** | **λg** | **λo** | **λ** | **References** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 54LVDS055 Dual LVDS driver/receiver | 08-55, 08-56 | S | 2 | 0.25 |  | 19.5 | 9.75 | (3, §7.3) |
| 2 | RTAX2000SL-CQ256 FPGA | 08-30 | S | 1 | 0.25 |  | 10.74 | 2.68 | (5) |
| 3 | UT8CR512K32 SRAM | 08-20 | S | 1 | 0.25 |  | 16 | 4 | (3, §7.3) |
| 4 | 28LV010 EEPROM |  | S | 1 | .25 |  | 23.5 | 5.88 | (3, §7.3) |
| 5 | IS-1009 Shunt regulator diode | 08-52 | S | 1 | 0.25 |  | 6.6 | 1.65 | (3, §7.3) |
| 6 | RH1498 Op Amp | 08-50 | S | 1 | 0.25 |  | 0.6 | 0.15 | (5) |
| 7 | IRHLUB7970Z4 P-ch MOSFET | 12-06 | S | 1 | 0.25 | 15 |  | 3.75 | (2, §6.9) |
| 8 | IRHLUB770Z4 N-ch MOSFET | 12-05 | S | 1 | 0.25 | 15 |  | 3.75 | (2, §6.9) |
| 9 | 1N6642 |  | S | 2 | 0.25 | 12 |  | 6 | (2, §6.1) |
| 10 | TES E 226 K 016 Tantalum cap | 01-03 | S | 16 | 0.1 | 0.10 |  | 0.16 | (2,§10.1) |
| 11 | CNC32 10uF 10% 16V | 01-02 | S | 2 | 0.03 | 1.22 |  | 0.073 | (2,§10.1) |
| 12 | CNC2 100nF 10% 50V | 01-02 | S | 73 | 0.03 | 0.80 |  | 1.75 | (2,§10.1) |
| 13 | CNC14 10nF 5% 50V | 01-02 | S | 9 | 0.03 | 0.65 |  | 0.18 | (2,§10.1) |
| 14 | CEC14 100pF 5% 50V | 01-02 | S | 1 | 0.03 | 0.43 |  | 0.013 | (2,§10.1) |
| 15 | CEC14 47pF 5% 50V | 01-02 | S | 2 | 0.03 | 0.41 |  | 0.025 | (2,§10.1) |
| 16 | CHPHR0603K24R9FB | 10-9 | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, §9.1) |
| 17 | CHPHR0603K1000FB | 10-9 | S | 8 | 0.03 | 1.8 |  | 0.432 | (2, §9.1) |
| 18 | CHPHR0603K2210FB | 10-9 | S | 3 | 0.03 | 1.8 |  | 0.162 | (2, §9.1) |
| 19 | CHPHR0603K3160FB | 10-9 | S | 4 | 0.03 | 1.8 |  | 0.216 | (2, §9.1) |
| 20 | CHPHR0603K4750FB | 10-9 | S | 4 | 0.03 | 1.8 |  | 0.216 | (2, §9.1) |
| 21 | CHPHR0603K3321FB | 10-9 | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, §9.1) |
| 22 | CHPHR0603K4751FB | 10-9 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, §9.1) |
| 23 | CHPHR0603K6811FB | 10-9 | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, §9.1) |
| 24 | CHPHR0603K1002FB | 10-9 | S | 9 | 0.03 | 1.8 |  | 0.486 | (2, §9.1) |
| 25 | CHPHR0603K1213FB | 10-9 | S | 2 | 0.03 | 1.8 |  | 0.108 | (2, §9.1) |
| 26 | CHPHR0603L1004GB | 10-9 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, §9.1) |
| 27 | HCESC 10 M47 IS |  | S | 2 | 0.03 |  | 0.2 | 0.012 | (3, §12) |
| 28 | HRB0603S102P.200FT |  | B1 | 4 | 1 |  | 0.2 | 0.2 | (3, §12) |
| 29 | 321Y060F58H Male 60pins connector | 02-07 | S | 1 | 1 |  | 3.87 | 3.87 | (3, §16.3) |
| 30 | 322Y060M35H Female 60pins connector | 02-07 | S | 1 | 1 |  | 3.87 | 3.87 | (3, §16.3) |
| 31 | QT188LD10S-48MHz Crystal oscillator | 03-01 | S | 1 | 1 | 0.72 |  | 0.72 | (2, §19.1) |
| 32 | HET-EPT-DIGITAL-PCB |  | S | 1 |  |  | 0.72 | 0.72 | (3, §6.1) |
| 33 | G15K4D489 NTC thermistor | 11-03 | S | 1 |  |  | 3 | 3 | (3, §10.9) |
| SUM (failures/109 hours) | | | | | | | | 62.1 | HED |

Table 10 Parts count worksheet for EPT-HET analog ADC shaper board

| **HEA** | **Generic part** | **Family** | **Quality level** | **Quantity** | **πQ** | **λg** | **λo** | **λ** | **References** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | ADC128S102 ADC | 08-61 | S | 32 | 0.25 |  | 8.6 | 68.8 | (3, §7.3) |
| 2 | RTAX2000SL-CQ256 FPGA | 08-30 | S | 1 | 0.25 |  | 10.7 | 2.68 | (5) |
| 3 | AD8005 Op-amp | 08-50 | Other | 30 | 10 |  | 0.18 | 54 | (5) |
| 4 | TES B 226 K 016 Tantalum cap | 01-03 | S | 25 | 0.1 | 0.10 |  | 0.25 | (2, §10.1) |
| 5 | CNC12 10nF 10% 500V Ceramic cap | 01-02 | S | 3 | 0.03 | 0.66 |  | 0.059 | (2, §10.1) |
| 6 | CNC2 220nF 10% 16V | 01-02 | S | 20 | 0.03 | 0.87 |  | 0.522 | (2, §10.1) |
| 7 | CNC2 100nF 10% 50V | 01-02 | S | 202 | 0.03 | 0.80 |  | 4.848 | (2, §10.1) |
| 8 | CEC2 2.67nF 1% 16V | 01-02 | S | 10 | 0.03 | 0.58 |  | 0.174 | (2, §10.1) |
| 9 | CEC2 1.5nF 1% 50V | 01-02 | S | 10 | 0.03 | 0.56 |  | 0.168 | (2, §10.1) |
| 10 | CNC14 10nF 5% 50V | 01-02 | S | 10 | 0.03 | 0.65 |  | 0.195 | (2, §10.1) |
| 11 | CNC14 6.8nF 10% 50V | 01-02 | S | 30 | 0.03 | 0.63 |  | 0.567 | (2, §10.1) |
| 12 | CEC14 475pF 1% 50V | 01-02 | S | 18 | 0.03 | 0.50 |  | 0.27 | (2, §10.1) |
| 13 | CEC14 432pF 1% 50V | 01-02 | S | 8 | 0.03 | 0.50 |  | 0.12 | (2, §10.1) |
| 14 | CEC14 392pF 1% 50V | 01-02 | S | 10 | 0.03 | 0.50 |  | 0.15 | (2, §10.1) |
| 15 | CEC14 365pF 1% 50V | 01-02 | S | 8 | 0.03 | 0.50 |  | 0.12 | (2, §10.1) |
| 16 | CEC14 332pF 1% 50V | 01-02 | S | 8 | 0.03 | 0.50 |  | 0.12 | (2, §10.1) |
| 17 | CHPHR0603K51R1FB | 10-9 | S | 30 | 0.03 | 1.80 |  | 1.62 | (2, §9.1) |
| 18 | CHPHR0603K75R0FB | 10-9 | S | 60 | 0.03 | 1.80 |  | 3.24 | (2, §9.1) |
| 19 | CHPHR0603K1000FB | 10-9 | S | 2 | 0.03 | 1.80 |  | 0.108 | (2, §9.1) |
| 20 | CHPHR0603K2210FB | 10-9 | S | 30 | 0.03 | 1.80 |  | 1.62 | (2, §9.1) |
| 21 | CHPHR0603K3160FB | 10-9 | S | 4 | 0.03 | 1.80 |  | 0.216 | (2, §9.1) |
| 22 | CHPHR0603K3321FB | 10-9 | S | 6 | 0.03 | 1.80 |  | 0.324 | (2, §9.1) |
| 23 | CHPHR0603K4751FB | 10-9 | S | 18 | 0.03 | 1.80 |  | 0.972 | (2, §9.1) |
| 24 | CHPHR0603K5111FB | 10-9 | S | 8 | 0.03 | 1.80 |  | 0.432 | (2, §9.1) |
| 25 | CHPHR0603K5621FB | 10-9 | S | 10 | 0.03 | 1.80 |  | 0.54 | (2, §9.1) |
| 26 | CHPHR0603K6191FB | 10-9 | S | 8 | 0.03 | 1.80 |  | 0.432 | (2, §9.1) |
| 27 | CHPHR0603K6651FB | 10-9 | S | 8 | 0.03 | 1.80 |  | 0.432 | (2, §9.1) |
| 28 | CHPHR0603K1002FB | 10-9 | S | 22 | 0.03 | 1.80 |  | 1.188 | (2, §9.1) |
| 29 | CHPHR0603K3322FB | 10-9 | S | 9 | 0.03 | 1.80 |  | 0.486 | (2, §9.1) |
| 30 | CHPHR0603K3652FB | 10-9 | S | 10 | 0.03 | 1.80 |  | 0.54 | (2, §9.1) |
| 31 | CHPHR0603K6812FB | 10-9 | S | 10 | 0.03 | 1.80 |  | 0.54 | (2, §9.1) |
| 32 | HRB0603S102P.200FT |  | B1 | 1 | 1 |  | 0.2 | 0.20 | (3, §12) |
| 33 | 321Y060F58H Male 60pins connector | 02-07 | S | 1 | 1 |  | 3.87 | 3.87 | (3, §16.3) |
| 34 | 322Y021M35H Female 21pins connector | 02-07 | S | 4 | 1 |  | 2.89 | 9.16 | (3, §16.3) |
| 35 | HET-EPT-ANALOG-PCB |  | S | 1 |  |  | 0.82 | 0.82 | (3, §6.1) |
| 36 | G15K4D489 NTC thermistor | 11-03 | S | 1 |  |  | 3 | 3 | (3, §10.9) |
| SUM (failures/109 hours) | | | | | | | | 163 | HEA |

Table 11 Parts count worksheet for MEPS-A preamp board (draft from HET/Solar Orbiter reliability table)

| **HP** | **Generic part** | **Family** | **Quality level** | **Quantity** | **πQ** | **λg** | **λo** | **λ** | **References** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | IS-1009 | 08-52 | S | 1 | 0.25 |  | 6.6 | 1.65 | (3, §7.3) |
| 2 | RH1498 | 08-50 | S | 2 | 0.25 |  | 0.6 | 0.3 | (5) |
| 3 | AD8005 | 08-50 | Other | 12 | 10 |  | 0.18 | 21.6 | (5) |
| 4 | IRHLUB7970Z4 | 12-06 | S | 2 | 0.25 | 15 |  | 7.5 | (2 §6.9) |
| 5 | IRHLUB770Z4 | 12-05 | S | 1 | 0.25 | 15 |  | 3.75 | (2 §6.9) |
| 6 | 2N2857 | 12-01 | S | 12 | 0.25 | 0.37 |  | 1.11 | (2 §6.3) |
| 7 | 2N4957 | 12-02 | S | 12 | 0.25 | 0.37 |  | 1.11 | (2 §6.3) |
| 8 | BF862 | 12-05 | Other | 12 | 10 |  | 0.24 | 28.8 | (3 §8.4) |
| 9 | 1N6642 |  | S | 3 | 0.25 | 12 |  | 9 | (2 §6.1) |
| 10 | TES B 226 K 016 | 01-03 | S | 8 | 0.1 | 0.10 |  | 0.08 | (2 §10.1) |
| 11 | CNC32 10uF 10% 16V | 01-02 | S | 3 | 0.03 | 1.22 |  | 0.11 | (2 §10.1) |
| 12 | CNC12 10nF 10% 500V | 01-02 | S | 40 | 0.03 | 0.66 |  | 0.79 | (2 §10.1) |
| 13 | CNC2 100nF 10% 50V | 01-02 | S | 91 | 0.03 | 0.80 |  | 2.18 | (2 §10.1) |
| 14 | CNC14 10nF 5% 50V | 01-02 | S | 12 | 0.03 | 0.65 |  | 0.234 | (2 §10.1) |
| 15 | CEC14 47pF 5% 50V | 01-02 | S | 3 | 0.03 | 0.41 |  | 0.037 | (2 §10.1) |
| 16 | CEC14 10pF 1% 50V | 01-02 | S | 8 | 0.03 | 0.35 |  | 0.084 | (2 §10.1) |
| 17 | CEC14 1pF +/-0,25pF 50V | 01-02 | S | 4 | 0.03 | 0.28 |  | 0.034 | (2 §10.1) |
| 18 | CHPHR0603K10R0FB | 10-9 | S | 3 | 0.03 | 1.8 |  | 0.162 | (2 §9.1) |
| 19 | CHPHR0603K24R9FB | 10-9 | S | 3 | 0.03 | 1.8 |  | 0.162 | (2 §9.1) |
| 20 | CHPHR0603K75R0FB | 10-9 | S | 36 | 0.03 | 1.8 |  | 1.94 | (2 §9.1) |
| 21 | CHPHR0603K2210FB | 10-9 | S | 13 | 0.03 | 1.8 |  | 0.702 | (2 §9.1) |
| 22 | CHPHR0603K4750FB | 10-9 | S | 24 | 0.03 | 1.8 |  | 1.30 | (2 §9.1) |
| 23 | CHPHR0603K8450FB | 10-9 | S | 2 | 0.03 | 1.8 |  | 0.108 | (2 §9.1) |
| 24 | CHPHR0603K1001FB | 10-9 | S | 12 | 0.03 | 1.8 |  | 0.648 | (2 §9.1) |
| 25 | CHPHR0603K1501FB | 10-9 | S | 2 | 0.03 | 1.8 |  | 1.188 | (2 §9.1) |
| 26 | CHPHR0603K2211FB | 10-9 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2 §9.1) |
| 27 | CHPHR0603K3321FB | 10-9 | S | 4 | 0.03 | 1.8 |  | 0.216 | (2 §9.1) |
| 28 | CHPHR0603K4751FB | 10-9 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2 §9.1) |
| 29 | CHPHR0603K6811FB | 10-9 | S | 4 | 0.03 | 1.8 |  | 0.216 | (2 §9.1) |
| 30 | CHPHR0603K1002FB | 10-9 | S | 4 | 0.03 | 1.8 |  | 0.216 | (2 §9.1) |
| 31 | CHPHR0603K3322FB | 10-9 | S | 12 | 0.03 | 1.8 |  | 0.648 | (2 §9.1) |
| 32 | CHPHR0603K6812FB | 10-9 | S | 12 | 0.03 | 1.8 |  | 0.648 | (2 §9.1) |
| 33 | CHPHR0603K1213FB | 10-9 | S | 15 | 0.03 | 1.8 |  | 0.810 | (2 §9.1) |
| 34 | CHPHR0805K1005GB | 10-9 | S | 36 | 0.03 | 1.8 |  | 1.944 | (2 §9.1) |
| 35 | WA86PS-1006J | 10-09 | S | 4 | 0.03 | 1.8 |  | 0.216 | (2 §9.1) |
| 36 | HCESC 10 M47 IS | 07-03 | S | 2 | 0.03 |  | 0.20 | 0.012 | (3 §12) |
| 37 | HRB0603S102P.200FT |  | B1 | 4 | 1 |  | 0.2 | 0.8 | (3 §12) |
| 38 | 321Y021F58H 21pin male connector | 02-07 | S | 2 | 1 |  | 2.29 | 4.58 | (3 §16.3) |
| 39 | HET-PREAMP-PCB |  | S | 1 | 1 |  | 0.69 | 0.69 | (3 §6.1) |
| 40 | G15K4D489 |  | S | 3 | 1 |  | 3.0 | 3.0 | (3, §10.9) |
| SUM (failures/109 hours) | | | | | | | | 105 | HP |

Table 12 Parts count worksheet for MEPS-B preamp board (draft from EPT/Solar Orbiter reliability table)

| **EP** | **Generic part** | **Family** | **Quality level** | **Quantity** | **πQ** | **λg** | **λo** | **λ** | **References** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | IS-1009 Shunt | 08-52 | S | 1 | 0.25 |  | 6.6 | 1.65 | (3, §7.3) |
| 2 | RH1498 | 08-50 | S | 2 | 0.25 |  | 0.6 | 0.3 | (5) |
| 3 | AD8005 | 08-50 | Other | 8 | 10 |  | 0.18 | 14.4 | (5) |
| 4 | IRHLUB7970Z4 | 12-06 | S | 2 | 0.25 | 15 |  | 7.5 | (2, §6.9) |
| 5 | IRHLUB770Z4 | 12-05 | S | 1 | 0.25 | 15 |  | 3.75 | (2, §6.9) |
| 6 | 2N2857 | 12-01 | S | 8 | 0.25 | 0.37 |  | 0.74 | (2, §6.3) |
| 7 | 2N4957 | 12-02 | S | 8 | 0.25 | 0.37 |  | 0.74 | (2, §6.3) |
| 8 | BF862, JFET | 12-05 | Other | 8 | 10 |  | 0.24 | 19.2 | (3, §8.4) |
| 9 | 1N6642 |  | S | 3 | 0.25 | 12 |  | 9 | (2, §6.1) |
| 10 | TES B 226 K 016 | 01-03 | S | 8 | 0.1 | 0.10 |  | 0.010 | (2, §10.1) |
| 11 | CNC32 10uF 10% 16V | 01-02 | S | 3 | 0.03 | 1.22 |  | 0.110 | (2, §10.1) |
| 12 | CNC12 10nF 10% 500V | 01-02 | S | 28 | 0.03 | 0.66 |  | 0.554 | (2, §10.1) |
| 13 | CNC2 100nF 10% 50V | 01-02 | S | 63 | 0.03 | 0.80 |  | 1.512 | (2, §10.1) |
| 14 | CNC14 10nF 5% 50V | 01-02 | S | 9 | 0.03 | 0.65 |  | 0.176 | (2, §10.1) |
| 15 | CEC14 47pF 5% 50V | 01-02 | S | 3 | 0.03 | 0.41 |  | 0.037 | (2, §10.1) |
| 16 | CEC14 1pF +/-0,25pF 50V | 01-02 | S | 8 | 0.03 | 0.28 |  | 0.067 | (2, §10.1) |
| 17 | CHPHR0603K10R0FB | 10-09 | S | 3 | 0.03 | 1.8 |  | 0.162 | (2, §9.1) |
| 18 | CHPHR0603K24R9FB | 10-09 | S | 3 | 0.03 | 1.8 |  | 0.162 | (2, §9.1) |
| 19 | CHPHR0603K75R0FB | 10-09 | S | 24 | 0.03 | 1.8 |  | 1.296 | (2, §9.1) |
| 20 | CHPHR0603K2210FB | 10-09 | S | 3 | 0.03 | 1.8 |  | 0.162 | (2, §9.1) |
| 21 | CHPHR0603K4750FB | 10-09 | S | 16 | 0.03 | 1.8 |  | 0.864 | (2, §9.1) |
| 22 | CHPHR0603K8450FB | 10-09 | S | 8 | 0.03 | 1.8 |  | 0.432 | (2, §9.1) |
| 23 | CHPHR0603K1001FB | 10-09 | S | 8 | 0.03 | 1.8 |  | 0.432 | (2, §9.1) |
| 24 | CHPHR0603K1501FB | 10-09 | S | 8 | 0.03 | 1.8 |  | 0.432 | (2, §9.1) |
| 25 | CHPHR0603K2211FB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, §9.1) |
| 26 | CHPHR0603K3321FB | 10-09 | S | 4 | 0.03 | 1.8 |  | 0.216 | (2, §9.1) |
| 27 | CHPHR0603K4751FB | 10-09 | S | 1 | 0.03 | 1.8 |  | 0.054 | (2, §9.1) |
| 28 | CHPHR0603K6811FB | 10-09 | S | 4 | 0.03 | 1.8 |  | 0.216 | (2, §9.1) |
| 29 | CHPHR0603K1002FB | 10-09 | S | 6 | 0.03 | 1.8 |  | 0.324 | (2, §9.1) |
| 30 | CHPHR0603K3322FB | 10-09 | S | 7 | 0.03 | 1.8 |  | 0.378 | (2, §9.1) |
| 31 | CHPHR0603K6812FB | 10-09 | S | 8 | 0.03 | 1.8 |  | 0.432 | (2, §9.1) |
| 32 | CHPHR0603K1213FB | 10-09 | S | 8 | 0.03 | 1.8 |  | 0.432 | (2, §9.1) |
| 33 | CHPHR0805K1005GB | 10-09 | S | 20 | 0.03 | 1.8 |  | 1.08 | (2, §9.1) |
| 34 | WA86PS-1006G | 10-09 | S | 8 | 0.03 | 1.8 |  | 0.432 | (2, §9.1) |
| 35 | HCESC 10 M47 IS Common mode choke | 07-03 | S | 2 | 0.03 |  | 0.2 | 0.012 | (2, §11.2) |
| 36 | HRB0603S102P.200FT |  | S | 4 | 1 |  | 0.2 | 0.8 | (3, §12) |
| 37 | 321Y021F58H Male 21pin connector | 02-07 | S | 2 | 1 |  | 2.29 | 4.58 | (3, §16.3) |
| 38 | MNSO-25-AA-N-ETH |  | S | 2 | 1 |  | 2.5 | 5 | (3, §16.3) |
| 39 | EPT-PREAMP-PCB | misc | S | 1 | 1 |  | 0.56 | 0.56 | (3, §6.1) |
| 40 | G15K4D489 NTC thermistor | 11-03 | S | 2 | 1 |  | 3 | 6 | (3, §10.9) |
| SUM (failures/109 hours) | | | | | | | | 84 | EP |

Table 13 Parts count worksheet for MEPS miscellaneous items

| **HE** | **Generic part** | **Family** | **Quality level** | **Quantity** | **πQ** | **λg** | **λo** | **λ** | **References** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | MDSA225SEW50B 25pin Socket prewired connector | 02-07 | S | 1 | 1 |  | 2.50 | 2.5 | (3, §16.3) |
| 2 | MDSA215SEW50B 15pin Socket prewired connector | 02-07 | S | 1 | 1 |  | 1.94 | 1.94 | (3, §16.3) |
| 3 | MNPO 25 FF N ETH Male flex connector | 02-07 | S | 2 | 1 |  | 2.5 | 5 | (3, §16.3) |
| 4 | G15K4D489 NTC thermistor | 11-03 | S | 6 | 1 |  | 3 | 18 | (3, §10.9) |
| SUM (failures/109 hours) | | | | | | | | 27 | HE |

1. Summary

The breakdown of the MEPS instrument for the purpose of the reliability analysis is sketched in Figure 5.

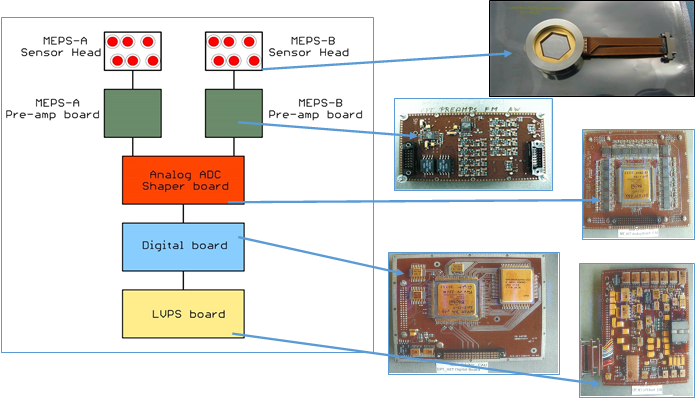


Figure 5 MEPS electronics boards

|  |  |  |  |
| --- | --- | --- | --- |
| Table | Board | FITS | Comment |
| HEL | LVPS | 114 |  |
| HED | Digital | 62 |  |
| HEA | Analog | 163 | AD8005 to be qualified |
| HP | HET Preamp | 105 | BF862 to be qualified |
| EP | EPT Preamp | 84 | BF862 to be qualified |
|  | HET Sensor head |  | Not yet analyzed |
|  | EPT Sensor head |  | Not yet analysed |
| HE | EPT-HET misc. | 27 |  |
|  | Total | 555 |  |

The intrinsic type failures treated by the methods of RD01 and RD02 are assumed to be random, independent failures, and the reliability based on these failure rates can be represented by the exponential function

R = exp(-λt),

where t is the time in hours and λ is the failure rate in failures per hour. Thus, the reliability for the above MEPS failure rate for a space flight operational time of seven years would be

RSPF = exp(555\*10^-9\*61362) = exp(-0.0340) = 0.966.