SOLAR ORBITER

EXPERIMENT INTERFACE DOCUMENT - PART A

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FIGURES

1 GENERAL

D: This chapter provides a short historical introduction to the Solar Orbiter Mission, describes the 1096
scope of the Experiment Interface Documents (the EID-A and the EID-Bs) and outlines the structure
of the EID-A.

This descriptive chapter does not include any requirement. 1097

D: Throughout the present document, all requirements (functional, performance, design, interface, 1098
operation, verification, product assurance, management) are marked with an "**R**", followed by a
unique identifying number.

Text of descriptive nature is marked with a "**D**". 1099

1.1 *Introduction*

D: The Solar Orbiter mission has its origins in a proposal called “Messenger” that was submitted by 1102
Richter et al. in 1982 in response to an ESA call for mission ideas. At the meeting “Crossroads for
European Solar and Heliospheric Physics” held in Tenerife in March 1998, the Heliophysics
community recommended to: “launch an ESA Solar Orbiter as ESA's next flexible mission, with
possible international participation, for launch around 2007.” The kick-off meeting for a pre-
assessment study of the “ESA Solar Orbiter” concept was held at ESTEC on 25 March 1999.

D: Solar Orbiter was subsequently proposed in 2000 by E. Marsch et al. and was selected by the 1103
Science Programme Committee (SPC) in October 2000 as a Flexi-mission for launch after
BepiColombo, in the 2008- 2013 timeframe. A number of internal and industrial studies were then
carried out, including parallel system level Assessment Studies performed in industry between April
and December 2004. At its 107th meeting in June 2004 the SPC confirmed Solar Orbiter's place in
the Horizon 2000+ programme with the goal of a launch in October 2013 and no later than May 2015.

D: Work continued on the mission and payload definition throughout 2005 and 2006 and at its 1104
meeting in February 2007, SPC instructed the Executive to find ways to implement Solar Orbiter
within a financial envelope of 300 M€ (at 2006 EC), while keeping a realistic contingency margin. In
response to this request, a Joint Science and Technology Definition Team (JSTDT) comprising
scientists and engineers appointed by ESA and NASA, studied the benefits to be gained by
combining ESA's Solar Orbiter mission and NASA's Solar Sentinels into a joint programme.

D: This study led to the release of an ESA Announcement of Opportunity (AO) for the Solar Orbiter 1105
Payload on 18 September 2007 and of a NASA Small Explorer Focused Opportunity for Solar Orbiter
(SMEX/FOSO) AO on 22 October 2007. In total, 14 proposals were received by ESA in response to
the Payload AO.

D: The final report of the Payload Review Committee (PRC), giving a recommended payload for 1106
selection, was issued on 24 May 2008. Meanwhile, at its meeting in November 2007, SPC gave
approval to start an 18-month industrial Phase B1 study lead by Astrium Ltd. (UK) which was kicked
off in March 2008.

D: A major change in the progress of Solar Orbiter occurred in November 2008, when the SPC 1107
decided to integrate Solar Orbiter into the first planning cycle of Cosmic Vision 2015-25 as an M-
mission candidate for the first launch opportunity in 2017. In addition, in view of NASA's high
prioritization of Solar Probe Plus (SPP) in its Living With a Star programme, and the strong science
synergies between Solar Orbiter and SPP, ESA called for an independent review of the PRC's
recommended payload, now in the context of a joint Solar Orbiter-SPP scientific programme. The joint
ESA-NASA review panel confirmed the validity of the recommended payload in its report of March
2009. As a result, the instrument selections, as recommended by the PRC in 2008 were formally
announced on 20 March 2009. In parallel, NASA announced the results of the FOSO selection, and
selected 2 instruments and portions of 2 instruments to be included in the Solar Orbiter payload. A
Design Status Review, being the final review of the industrial Phase B1 study conducted by Astrium
Ltd. (UK) as Prime Contractor, was held in ESTEC in June 2009.

D: At its 128th meeting on 17th & 18th February 2010, ESA's Science Programme Committee made a 1108
further programmatic change by endorsing a “fast track” approach for Solar Orbiter outlined in
ESA/SPC(2010)3, rev. 1. This approach is based on the scientific viability of raising the minimum

perihelion to 0.28 AU and on making maximum re-use of BepiColombo technologies and units. It calls for the start of a full spacecraft implementation (Phases B2/C/D) in early 2011, with mission confirmation by the SPC in Q2 2011.

1.2 *Scope of the Experiment Interface Documents*

D: The main purpose of the set of Experiment Interface Documents (one EID-A, common to all ten instruments and ten EID-Bs, one for each instrument) is to ensure that: 1110

- The Principal Investigators (PIs) design, procure, build, qualify, test and calibrate their instruments in line with the technical and programmatic requirements and constraints defined in the EID-A. 1111
- The Solar Orbiter Prime Contractor designs, builds and verifies the spacecraft such that the instruments can be successfully integrated and tested into the system, in line with the instrument interface definitions and resources provided in the EID-Bs. 1112
- The spacecraft can be successfully launched and operated to achieve the scientific objectives of the Solar Orbiter mission in line with the instrument driven requirements detailed in the EID-A. 1113

D: The EID-A, together with its Normative Documents, defines the interface, the design, the operational, the verification, the management and the programmatic requirements applicable to each instrument. 1114

The EID-A also specifies the spacecraft performance requirements and the resources allocated to each instrument. 1115

Specific instrument driven requirements applicable to the spacecraft, namely EMC, cleanliness and pointing requirements are also specified in the EID-A.

D: Each EID-B, in response to the instrument technical requirements of the EID-A, specifies in detail the instrument interface information. 1116

D: Finally each EID-B defines the specific programmatic agreements between the ESA Solar Orbiter Project Office and each Solar Orbiter Principal Investigator. 1117

Once the EID-A and the EID-Bs have reached a satisfactory level of maturity, they will be placed under formal configuration and change control; the Prime Contractor will become the book-captain for them. 1118

D: The documentation tree for the top ESA requirements is shown in Figure 1.2-1 below. 1119

1120

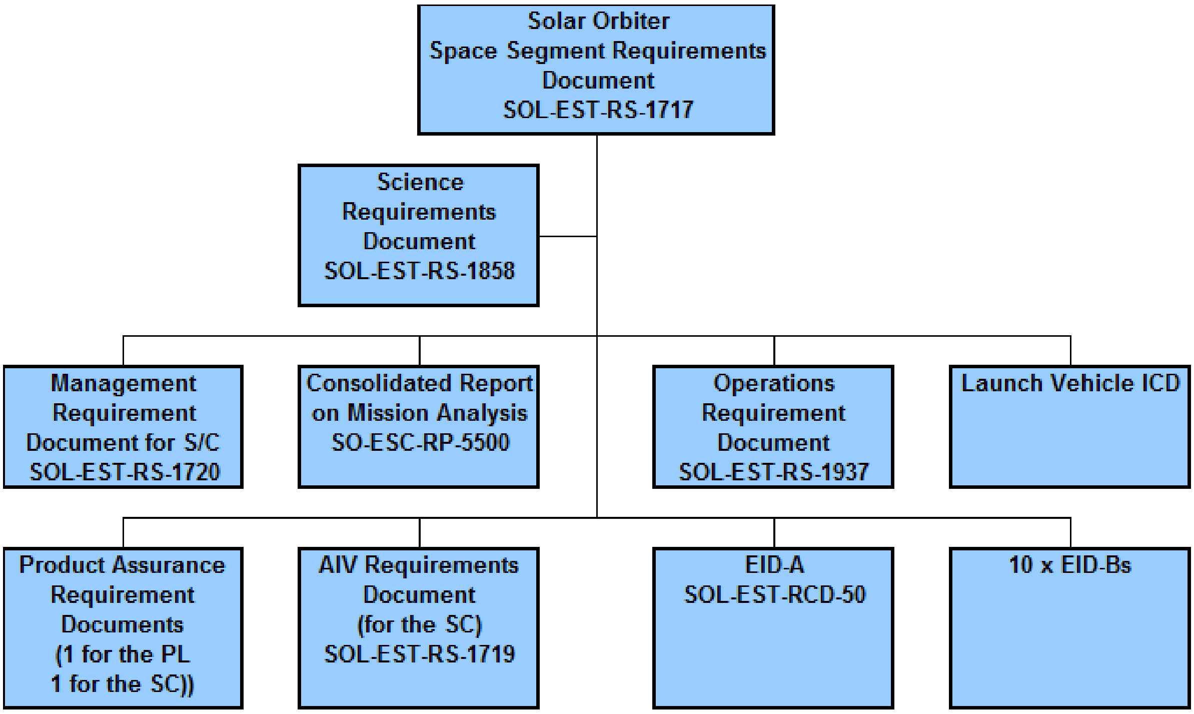

Figure 1.2-1: Top ESA Documents Tree 10395

1.3 Structure of Document

D: The EID-A is structured as follows: 1122

Chapter 1: General introduction. 1123

Chapter 2: Payload related key persons and points of contact. 1124

Chapter 3: Synthetic description of the mission, the spacecraft and the payload. 1125

Chapter 4: Interface and design requirements and resources. 1126

Chapter 5: Operations description and requirements. 1127

Chapter 6: Verification requirements. 1128

Chapter 7: Product Assurance requirements. 1129

Chapter 8: Management Requirements. 1130

Chapter 9: Instrument driven requirements; namely: EMC, pointing, cleanliness, applicable to the spacecraft and/or to the instruments. 1131

Chapter 10: Normative and informative documents. 1132

2 KEY PERSONNEL AND POINTS OF CONTACT

2.1 *ESA*

D: Address

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2.2 *Prime Contractor*

D: Address

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Key : 18531

EPD: Energetic Particle Detector 1226

EUI: Extreme Ultraviolet Instrument 1227

MAG: MAGnetometer instrument 1228

METIS: Multi Element Telescope for Imaging and Spectroscopy 1229

PHI: Polarimetric and Helioseismic Imager 1230

RPW: Radio and Plasma Wave experiment 1231

SOLOHI: SOLar Orbiter Heliospheric Imager 1232

SPICE: SPectral Imaging of the Coronal Environment 1233

STIX: Spectrometer / Telescope for Imaging X-rays 1234

SWA: Solar Wind Analyser 1235

3 SOLAR ORBITER MISSION DESCRIPTION

D: This chapter provides a synthetic overview of the Solar Orbiter mission, describes the mission 1237
objectives and some key characteristics of the spacecraft and of the payload.

This descriptive chapter does not include any requirement. 1238

3.1 *Mission Objectives*

D: Solar Orbiter's mission is to address the central question of Heliophysics: ***How does the Sun*** 1240
create and control the heliosphere? This, in turn, is a fundamental part of the second science question of ESA's Cosmic Vision programme: ***"How does the solar system work?".***

Solar Orbiter is specifically designed to identify the origins and causes of the solar wind, the 1241
heliospheric magnetic field, the solar energetic particles, the transient interplanetary disturbances, and the Sun's magnetic field itself.

D: Over the past two decades, an international effort to understand the Sun and heliosphere has been 1242
undertaken with an array of spacecraft carrying out both remote observations at visible, UV, and X-ray wavelengths, as well as in-situ observations of interplanetary plasmas, particles, and fields. Combined and coordinated observations from missions such as Ulysses, Yohkoh, SOHO, TRACE, RHESSI, Hinode and STEREO have resulted in an enormous advance in our understanding of the Sun and heliosphere and have proven that critical progress in understanding the physics requires both remote and in-situ observations working together.

D: Although our vantage point at 1 AU is close by astrophysical measures, it has been long known 1243
that much of the crucial physics in the formation and activity of the heliosphere takes place much closer to the Sun and that by the time magnetic structures, shocks, energetic particles and solar wind pass by Earth they have already evolved and in many cases mixed so as to blur the signatures of their origin. Given the success of the missions cited above, it is clear that ***flying a spacecraft with a combined remote-sensing and in-situ payload into the inner solar system will critically advance our knowledge***.

D: Solar Orbiter's scientific mission can be broken down into four top-level science objectives: 1244

· How and where do the solar wind plasma and magnetic field originate in the corona? 1245

· How do solar transients drive heliospheric variability? 1246

· How do solar eruptions produce energetic particle radiation that fills the heliosphere? 1247

· How does the solar dynamo work and drive connections between the Sun and the 1248
heliosphere?

D: Common to all of these questions is the requirement that Solar Orbiter make in-situ measurements 1249
of the solar wind plasma, fields, waves, and energetic particles close enough to the Sun that they are still relatively pristine and have not had their properties modified by dynamical evolution during their propagation. Solar Orbiter must also relate these in-situ measurements back to their source regions and structures on the Sun through simultaneous, high-resolution imaging and spectroscopic observations both in and out of the ecliptic plane.

D: The near-Sun part of the operational orbit will enable the spacecraft to approach the Sun as close 1250
as 0.28 AU during part of its orbit. The angular speed of a spacecraft at this distance approaches the rotation rate of the Sun, so that the remote sensing instruments will be able to observe a given point on the Sun's surface for many days.

D: During the out-of-ecliptic part of the orbit, the spacecraft will reach higher solar latitudes (up to 34° 1251
close to the end of the mission), making detailed studies of the Sun's polar regions possible.

D: The ESA document "Solar Orbiter Science Requirements Document" [IR-06], provides a more 1252
detailed discussion of the top scientific goals of the Solar Orbiter mission, their translation into specific scientific questions and derived basic scientific requirements. The document addresses also the scientific synergies between Solar Orbiter and NASA's Solar Probe Plus mission.

3.2 *Mission Overview*

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D: The mission will rely on a chemical propulsion system for manoeuvre performance and on reaction wheels for pointing performance. After Venus GAM 2 the spacecraft will be injected in a resonant orbit (the period of revolution of Solar Orbiter around the Sun is 3/4 the period of Venus), which will allow to increase the inclination of the orbit with respect to the ecliptic. The key orbit parameters and characteristics for the launch opportunities currently foreseen can be found in the Solar Orbiter Consolidated Report on Mission Analysis (CReMA), SOL-ESC-RP-05500 issue 3 Revision 1.

D: The duration of the nominal mission is approximately 3.5 years (1306 days), while the duration of 1581
the extended mission is approximately 3 years (1073 days).

D: Chapter 4 of the “Solar Orbiter Space Segment Requirements” document [NR-01] and the “Solar 1582
Orbiter Consolidated Report on Mission Analysis, CREMA” [IR-03] respectively provides a more detailed overview of the Solar Orbiter mission and of the trajectories analysis.

D: Further details about mission operations and related requirements on elements of the ground 1583
segment are provided in chapter 5.

3.3 *Spacecraft and Instruments Main Characteristics*

D: The Solar Orbiter Spacecraft is designed to be compatible with an Atlas V launch vehicle, 1585
launched from the Kennedy Space Centre (baseline) and, as back ups, with a Delta-4-type launch vehicle or with an Ariane 5 launch vehicle.

The design includes a heatshield extending on all sides of the front face as a means to protect the 1586
spacecraft from the intense solar flux at perihelion.

D: The payload complement, consisting of 10 instruments (6 remote-sensing instruments and 4 in-situ 1587
instruments, is listed in annex A1.

D: The remote sensing instruments requiring a sun view will have optical feedthroughs in the 1588
heatshield. The in-situ instruments, with the exception of RPW and SWA, will be most of the time in the shade of the sunshield.

D: The main spacecraft characteristics are as follows: 1589

- 3-axis stabilized spacecraft. 1590
- Sun pointing. 1591
- Reaction Control System based on reaction wheels and chemical propulsion thrusters. 1592
- Deployable solar arrays with single axis articulation. 1593
- RF subsystem, with one High Gain Antenna (HGA) for science telemetry downlink. 1594

D: The spacecraft will be equipped with an X-band transponder providing telemetry and telecommand 1595
communication links. The LEOP communications will be via the X-band LGAs. The HGA link will not be available during conjunction periods. The baseline ground station is Malargüe with New Norcia and Cebreros considered as a backup.

D: During the nominal and extended science mission the in situ instruments will be operating 1596
continuously while the remote sensing instruments will have three 10 day operational periods. These three periods will take place +/- 5 days around perihelion, near the positions of highest northern latitude and of highest southern solar latitude

D: To accommodate synoptic observations with NASA's Solar Probe Plus, limited remote sensing 1597
observations may be accommodated, outside the three nominal science windows, during the joint periods of operation of the two missions. The additional data acquisition will be defined by the mass memory, telemetry and other spacecraft and ground segment capabilities.

D: Five of the six remote-sensing instruments (1- PHI; 2- EUI; 3- SPICE; 4- STIX; 5- METIS; 6- 1598
SOLOHI) will be accommodated behind the heatshield; SOLOHI will be accommodated externally.

D: The in-situ instruments (1- EPD; 2- MAG; 3- RPW; 4- SWA) will be externally accommodated. 1599

D: A spacecraft-provided deployable instrument boom, extending on the anti-sun side of the 1600
spacecraft, will accommodate the following units: MAGOBS and MAGIBS; RPW-SCM; SWA-EAS.

D: At distances to the Sun below 0.8AU, the heatshield will keep the main body of the spacecraft in the shadow in nominal and safe mode operation. In this way all external components will be shielded from direct solar illumination except for some instruments and spacecraft appendages (e.g. the solar arrays, the RPW antennas, parts of the SWA-sensors, and the HGA). 1601

External components mounted away from the spacecraft heatshield can however be exposed to the Sun and need to be able to withstand direct Solar flux. 1602

D: In the event of a (Deep Space) Manoeuvre during the transfer phase, and in general whenever the spacecraft is at distances > 0.8 AU, the spacecraft may change attitude in support of a attitude control manoeuvre. During such a phase any of the normally shielded sides of the spacecraft can be exposed to the Sun for prolonged periods of time. 1603

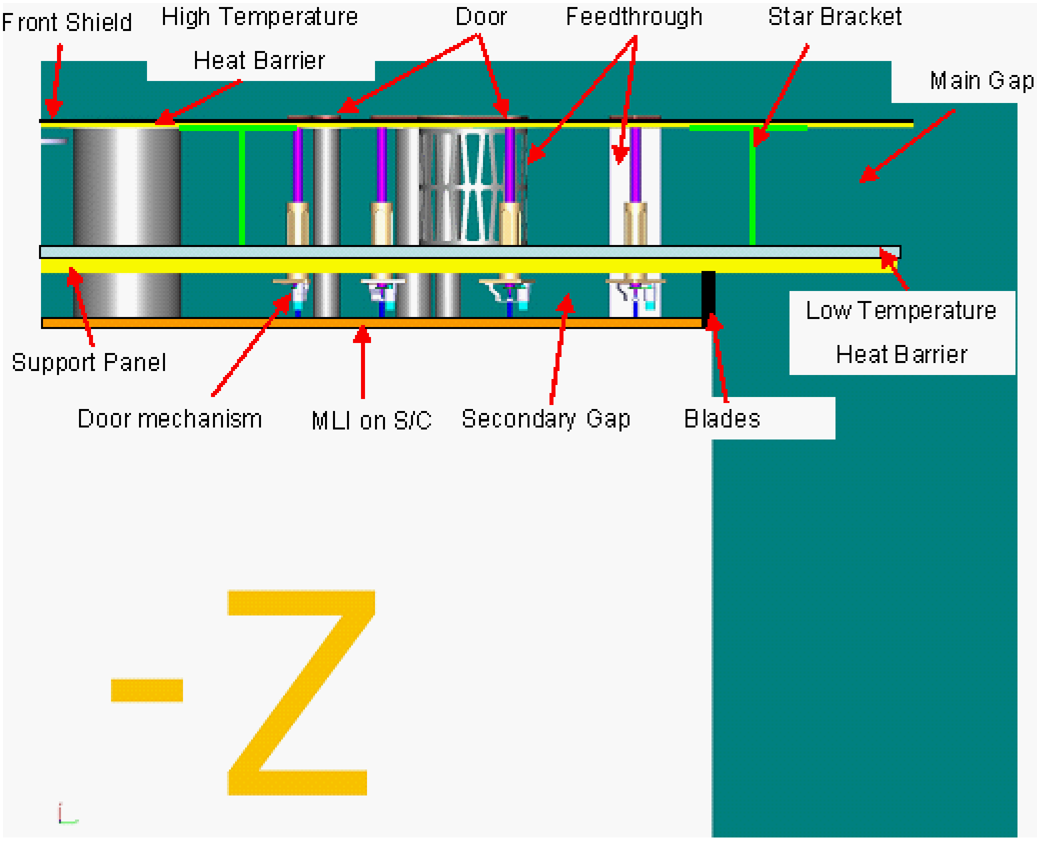
D: The current heatshield design consists of a high temperature heat barrier and support panel structure arranged to provide two gaps between the spacecraft and the front shield. The front layer is supported by star brackets. The feedthroughs, doors and mechanisms required for the payloads are arranged within the heatshield. The heatshield is attached to the spacecraft through a series of blades designed to provide isostatic mounting and minimum heat exchange. 1604

The feedthroughs will provide an unobstructed field of view for solar observation and will limit the out-of-field direct illumination entering the instrument aperture with however limited stray light reduction capabilities. 1605

D: The heatshield with associated feedthroughs and integrated doors will be delivered by the spacecraft Prime Contractor, while any further item like baffles, occulters, heat-rejecting filters, internal instrument doors, for optical, contamination or thermal reasons will be instrument provided. 1606

The figure (Figure 3.3-1) below shows the heatshield conceptual design configuration 1607

1608



1609

Figure 3.3-1: Heatshield Conceptual Design Configuration

D: A 3D view of the spacecraft is shown in the figure (Figure 3.3-2) below 1610

18816

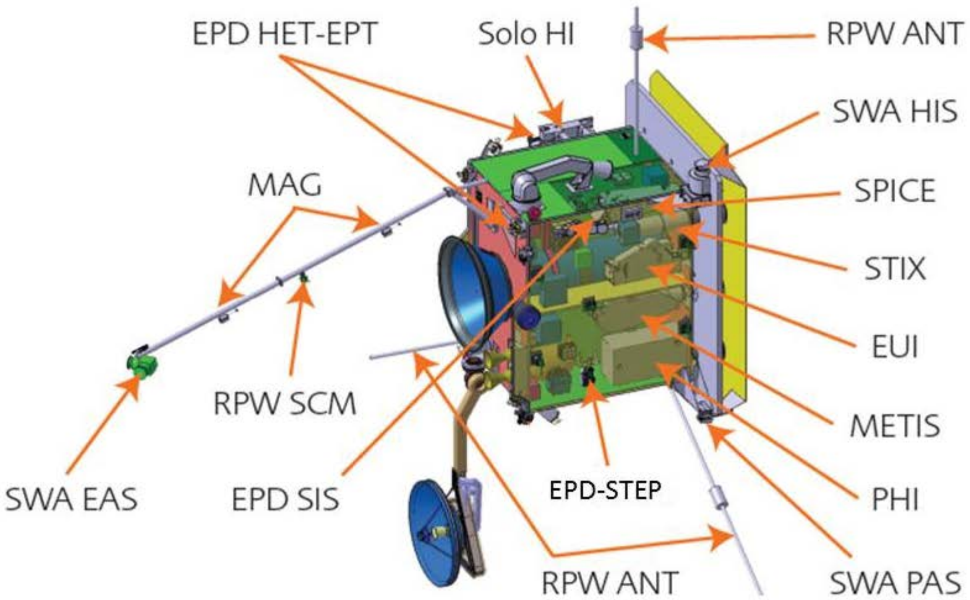


Figure 3.3-2: 3D View of the spacecraft and its payload 1612

D: To minimize the number of mechanisms and the complexity of the heatshield design a single door may be used to cover multiple apertures of a single instrument. The door will be placed at the sun entrance side of the feedthrough due to thermal constraints. 1613

D: Feedthroughs will be provided for the remote sensing instruments since they require an unobstructed view of the sun through the heatshield (SPICE, STIX, EUI, METIS, and PHI). The conceptual design of a feedthrough is shown in the figure (Figure 3.3-3) below. 1614

1615

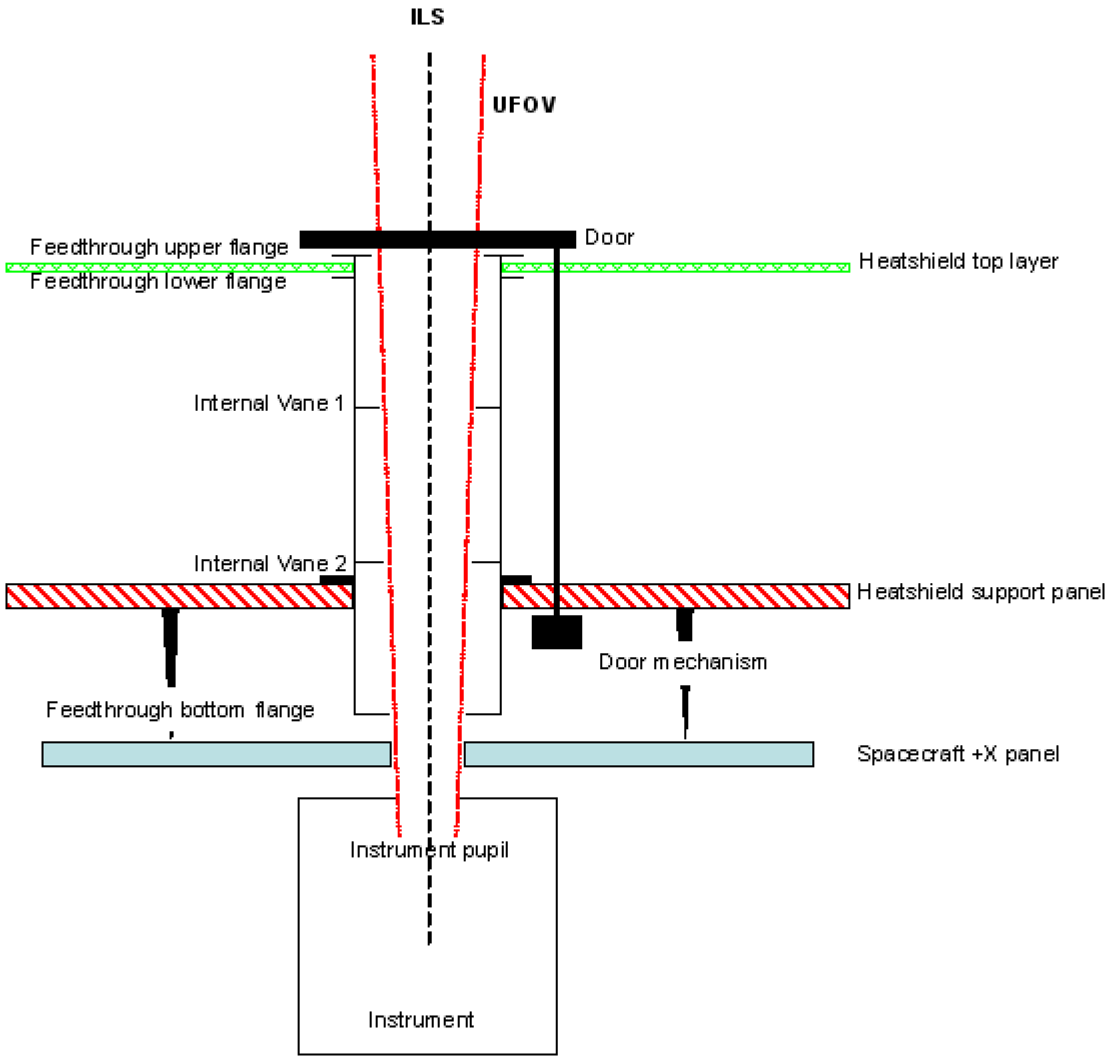


Figure 3.3-3: Generic Feedthrough Layout for Remote Sensing Instruments 1616

D: The feedthrough will be oversized in order to ensure that the unobstructed field of view (UFOV) is provided at all times. This oversizing is necessary to cope with: 1617

- The translation and rotation of the instrument, and thus instrument pupil, due to the thermo-elastic deformation of the spacecraft structure. 1618
- The translation and rotation of the feedthrough due to the thermo-elastic deformation of the heatshield support panel. 1619
- The thermal expansion of the feedthrough. 1620
- The mounting/integration tolerances of instrument and feedthrough. 1621

D: The consequence of this oversizing is that solar flux will impinge directly onto the instrument outside of the instrument pupil as illustrated in the figure (Figure 3.3-4) below. 1622

1623

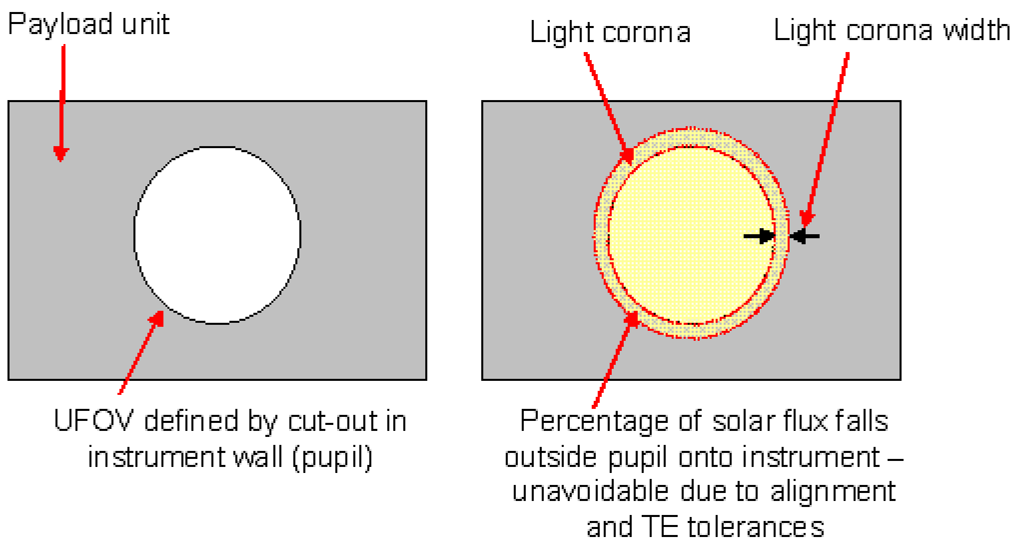


Figure 3.3-4: Solar Flux Impinging on an Instrument Outside of the Instrument Pupil 1624

D: In-situ instruments that require a FOV towards the Sun (SWA-PAS and SWA-HIS) will also have feedthroughs in the heatshield. Both units have been placed at the -Y corners of the heatshield, to minimise the heatshield cut out. These corner feedthroughs are only partially enclosed with two sides open to space. This enables a reduction in the feedthrough temperatures. 1625

D: Some internally mounted detectors will require low temperatures to operate, via a cold element interface to a separate dedicated spacecraft radiator. This cold element interface will be located outside the instrument structure. The spacecraft will provide the required interface temperature using similar hardware as for the hot element interface. 1626

D: Hot Elements, HE, (high temperature), Medium Element, ME, if agreed necessary, and Cold Element, CE, (low temperature) instrument thermal interfaces will be implemented for the relevant instrument units with interface temperatures controlled by the spacecraft Thermal Control System and connected to related spacecraft radiators. 1627

D: In general any externally mounted instrument will be thermally decoupled from the spacecraft structure. 1628

D: More detailed descriptions of the spacecraft and of the instruments characteristics are provided in the Solar Orbiter Space Segment Requirement document [NR-01] and in the 10 instrument EID-Bs [IR-09] to [IR-18]. 1629

4 INSTRUMENT DESIGN AND INTERFACES REQUIREMENTS

4.1 *HW Identification and Labelling*

D: This chapter specifies the design requirements and the interface requirements applicable to the instruments; it also provides the main resources allocated to each instrument. 1630

EIDA-1632//

> ***EIDA R-001:*** *The PI shall ensure that each instrument unit bears a unit identification label containing the following information:*

- Unit identification code 1633
- Instrument model (e.g. STM, EM, PFM, FM, FS) 1634

D: The identification label will be legible with unaided eye from 0.5 m distance. 1635

EIDA-1636//

> ***EIDA R-002:*** *The PI shall ensure that the unit identification code is composed of the following three parts:*

- 3 characters for instrument identification, (e.g. PHI, MAG, EUI, etc.) 1637
- 3 characters for unit identification, (e.g. Digital Processing Unit, DPU) 1638
- 2 characters for model identification (ST for Structural Thermal Model, EM for Engineering Model, QM for Qualification Model, FM for Flight Model, FS for Flight Spare Model, PF for Proto-flight Model) . 1639

EIDA-1640//

> ***EIDA R-003:*** *The PI shall use identification labels also for each unit connector and for units interconnecting harness.*

EIDA-1641//

> ***EIDA R-004:*** *The PI shall ensure that each unit connector identification label is visible and is closely adjacent to the appropriate connector with the following prescriptions:*

- a “J” character is used for each units fixed (hard mounted) connector followed by a 2 digit number 1642

· a “P” character is used for each harness mounted connectors, followed by a 2 digit number. 1643

· after this number, an additional character is used to identify the type of contact: “P” for male and “S” for female contact. 1644

D: Each unit is treated individually in this respect, starting at “J01"for unit fixed connectors. 1645

D: Since the S/C identification code already appears on the unit identification label, unit fixed connectors are not required to bear the full connector identification code. The same rules apply for supplied instrument interconnect harnesses, and harness from an instrument EGSE if it requires connection to test connectors on an instrument unit. 1646

EIDA-1647//

> ***EIDA R-716:*** *The PI shall ensure that all items to be removed prior to test shall be coloured red and tagged stating "REMOVE BEFORE TEST"*

D: These items are known as “red-tag” items 1648

EIDA-1649//

> ***EIDA R-717:*** *The PI shall ensure that all items to be removed prior to flight shall be coloured red and tagged stating "REMOVE BEFORE FLIGHT"*

D: These items are known as “red-tag” items 1650

4.2 *General Design Requirements*

4.2.1 Standard Metric System

EIDA-1653//

> ***EIDA R-005:*** *The PI shall use the International System (SI) Metric Standard, with the exceptions allowed in the ECSS-E-ST-31C [NR-10] for drawings, specifications and engineering data.*

4.2.2 Lifetime Requirements

EIDA-1655//

> ***EIDA R-006:*** *The PI shall ensure that the instrument HW has a nominal life time of 7.1 years in space.*

D: Nominal life time starts at launch and finishes after VGAM-4, which defines the end of the nominal science mission phase. 1656

EIDA-1657//

> ***EIDA R-007:*** *The PI shall ensure that the overall instrument design is compatible with a shelf-life time of two years due to a possible launch delay from the nominal launch date.*

D: The PI should ensure that the overall instrument design is compatible with an extended lifetime of 10.2 years. This extended lifetime includes the nominal lifetime and ends after VGAM-6. 1658

EIDA-1659//

> ***EIDA R-009:*** *The PI shall ensure that for items which degrade with usage and /or storage the life time is 1.5 times the nominal life time.*

D: Exceptions are the mechanisms where specific requirements apply. 1660

4.2.3 Maintainability

EIDA-1662//

> ***EIDA R-010:*** *The PI shall ensure that items requiring integration for safety, logistical or life reasons close to launch, are compliant with accessibility rules defined by the Prime Contractor.*

D: The Prime Contractor will define late-access accessibility rules for the PL units. 1663

4.2.4 Fault Tolerance

EIDA-1665//

> ***EIDA R-012:*** *The PI shall ensure that for an agreed set of instrument failures, the instrument will automatically reconfigure in order to continue science operations*

D: Detail recovery procedure(s) will be verified before FM delivery and launch, for each individual failure/recovery case. 1666

D: It is assumed that automatic reconfiguration is performed internally to the instrument without any need for action or reaction by other Solar Orbiter instruments or by the Solar Orbiter spacecraft. 1667

EIDA-1668//

> ***EIDA R-013:*** *The PI shall ensure that the instrument enters a safe state in the event of a failure and TM records of the fault are transferred to the spacecraft.*

D: Safe mode is a HW & SW status which, in the event of failure, allows the instrument to survive without any impact on its functions and performance. Specific instruments safe mode definitions are described in the EID-Bs 1669

D: As a goal this will only be a single event packet. 1671

EIDA-1672//

> ***EIDA R-014:*** *The PI shall ensure that recovery from Safe Mode is done through ground telecommand.*

EIDA-1673//

> ***EIDA R-786:*** *The PI shall ensure that, if the instrument has not received Service 20 packets for 30 seconds, the instrument take adequate measures to be prepared for a removal of power after 30 seconds .*

D: This is to ensure the instrument is robust to the spacecraft entering survival mode and deciding to remove power from the instrument LCLs. 1674

EIDA-13220//

> ***EIDA R-850:***
>
> *The prime contractor shall, upon entry to survival mode, stop Service 20 distribution to the payload instruments.*

D: This shall indicate to the payload instruments that, according to EIDA R-851, the thrusters will fire after a minimum of 15s, and, according to EIDA R-786, the power will be removed from the instruments in 60s. 13221

EIDA-9443//

> ***EIDA R-825:*** *The PIs shall consider the maximum spacecraft accelerations shown in the table below ([Table 4.2-1](#)) if the spacecraft enters safe mode*

D: This requirement is particularly relevant to the RPW ANT deployment 9444

10226

	Accelerations
Max. Negative (-X) Instantaneous Linear Acceleration (m/s2)	0.023
Max. Positive (+X) Instantaneous Linear Acceleration (m/s2)	0.03
Max. Angular Acceleration (deg/s2) around X	0.85 (stowed) / 0.18 (deployed)
Max. Angular Acceleration (deg/s2) around Y	2.8 (stowed) / 2.41 (deployed)
Max. Angular Acceleration (deg/s2) around Z	1.78 (stowed) / 0.38 (deployed)
Max. Angular Rate (deg/s) after thruster failure (YZ plane)	2.0

10394

Table 4.2-1: Maximum spacecraft accelerations if the spacecraft enters safe mode

EIDA-13224//

> ***EIDA R-851:***
>
> *Those instruments sensitive to thruster firing shall ensure that, upon loss of Service 20, measures necessary to protect themselves from thruster firing are taken within 15s, noting that subsequent switch off will be performed in accordance with EIDA R-786.*

D: The method of detection of loss of Service 20 must be robust to spurious losses of a single packet. 13225

D: This implies that the frequency of receipt of Service 20 is selected by the instruments such that loss can be detected in sufficient time to react within the required time. 13226

D: This is applicable only to external units. 13227

EIDA-13228//

> ***EIDA R-852:***

The prime contractor shall ensure that, in the event of an impending thruster firing, the thruster warning flag contained within the platform data field of Service 20 is set to 1 at least 5 seconds before the actual firing.

EIDA-13229//

EIDA R-853

The prime contractor shall ensure that, after completion of a thruster firing, the thruster warning flag contained within the platform data field of Service 20 is set back to 0.

EIDA-13230//

EIDA R-854:

Upon detection of the thruster warning flag set to 1, those instruments sensitive to thruster firing shall ensure that necessary protection measures are taken within 5s.

D: The method of detection of loss of Service 20 must be robust to spurious losses of a single packet. 13231

D: This is applicable only to external units. 13232

D: This implies that the frequency of receipt of Service 20 is selected by the instruments such that the settings of the thruster warning flag can be detected in sufficient time to react within the required time. 13233

D: This requirement should be implemented in complement to EIDA R-851 for full protection of the instruments in all on-board thruster firing cases. 13234

4.2.5 Autonomy

EIDA-1676//

EIDA R-015: *The PI shall ensure that the instrument is able to operate safely for a minimum of 66 days without ground intervention.*

D: This is the longest non-contact period plus 5 days 1677

4.2.6 Resources

EIDA-1679//

EIDA R-016: *The PI shall ensure that each unit fits within the relevant dynamic envelope, defined by the Prime Contractor and specified for each unit in Annex A1.*

D: Total instrument mass, power and data rate resources, as provided by the Prime Contractor are specified in chapter 9 1680

D: Break down allocations to each instrument of the mass, power and data rate resources are specified in chapter 4. 1681

4.2.7 Venting

EIDA-1683//

EIDA R-017: *The PI shall provide adequate venting of each unit to preserve its structural integrity during launch depressurisation, by the provisions of typically 2mm² venting cross-section per litre volume.*

EIDA-1684//

EIDA R-018: *The PI shall ensure that each instrument unit can operate within a pressure range of 1 bar to 1E-10 bar.*

EIDA-1685//

EIDA R-019: *The PI shall ensure that, for each relevant thermal hardware (MLI, tapes, heatermats, etc), venting provisions are incorporated.*

EIDA-1686//

EIDA R-020: *The PI shall ensure that, unless a cavity is hermetically sealed, the venting method prevent the contamination of the cavity by the external environment and prevent the release of contaminants from the cavity.*

EIDA-1687//

EIDA R-021: *The PI shall ensure that structural element (e.g. honeycomb panels) include provisions to enable venting of any hermetically sealed volumes during launch ascent and during Thermal Balance/Thermal Vacuum test.*

EIDA-1688//

EIDA R-022: *The PI shall demonstrate, for any items that do not include venting provisions, that adequate safety margins are demonstrated by analysis or by a 1.5 atmosphere proof test.*

4.3 Coordinate Systems

4.3.1 S/C Coordinate Systems

D: The spacecraft co-ordinate systems are defined and described in the Solar Orbiter Space Segment Requirements Document [NR-01]. 1691

4.3.2 Unit co-ordinate System

4.3.2.1 *Unit Physical Reference Frame*

EIDA-1694//

EIDA R-023: *The PI shall use the Unit Physical Reference Frame (URF) for describing the relevant physical properties of each unit (e.g dimensions, CoG, MoI)*

D: The URF, shown in figure (Figure 4.3-1) below, is defined in Table 4.3-1 below. 1695

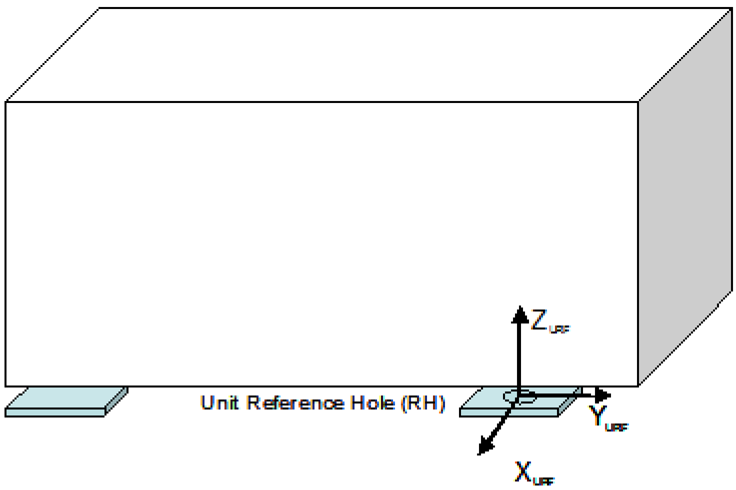
1696

Item	Definition
Origin	Centre of the Reference Hole (RH) at the interface plane. **D:** The interface plane is the unit mounting plane to the spacecraft **D:** The Reference Hole can be freely selected as best suited for the unit.
+ Z_{URF}	The + Z_{URF} shall be pointing from the Origin upwards, perpendicular to the interface plane
$+X_{URF}$, $+Y_{URF}$	The $+X_{URF}$ and the $+Y_{URF}$ complete the Unit Physical Reference Frame **D:** The orientation of the $+X_{URF}$ and $+Y_{URF}$ can be freely selected by the instrument

1709

Table 4.3-1: Unit Physical Reference Frame (URF) definition

1710



1711

Figure 4.3-1: Unit Physical Reference Frame (URF) visualization

4.3.2.2 *Unit Alignment Reference Frame*

EIDA-1713//

> ***EIDA R-024:*** *The PI shall use the Unit Alignment Reference Frame (UARF), for unit internal alignment purposes and for unit (co)-alignment purposes once integrated into the spacecraft*

D: The UARF, shown in figure below, is defined in Table 4.3-2 below.

Item	**Definition**
Origin	Centre of the unit Alignment Reference Cube face.
$+X_{UARF}$	The $+X_{UARF}$ shall be perpendicular to a face of the unit Alignment Reference Cube and shall materialise the $+X_{ILS}$
$+Y_{UARF}$ $+Z_{UARF}$	The $+Y_{UARF}$ and the $+Z_{UARF}$ shall complete the Unit Alignment Reference Frame **D:** The orientation of the $+Y_{UARF}$ and $+Z_{UARF}$ can be freely selected by the instrument

Table 4.3-2: Unit Alignment Reference Frame (UARF) definition

4.3.2.3 *Instrument Line-of-Sight Reference Frame*

EIDA-1730//

> ***EIDA R-025:*** *The PI shall use the Line-of-Sight Reference Frame (ILS), for relevant units, for the definition of the instrument pointing. -*

D: The ILS, shown as well in Figure 4.3-2 below, is as defined in the Table 4.3-3 below.

Item	**Definition**
Origin	Instrument Vertex **D:** The instrument Vertex is the theoretical centre of the Instrument Focal Plane.
$+X_{ILS}$	The $+X_{ILS}$ shall be pointing from the Vertex outward through the centre of the Instrument Field of View towards the target **D:** the $+X_{ILS}$ is the instrument Line-of-Sight (LOS)
$+Y_{ILS}$ $+Z_{ILS}$	The $+Y_{ILS}$ and the $+Z_{ILS}$ shall complete the Instrument Line-of-Sight Reference Frame **D:** The orientation of the $+Y_{ILS}$ and $+Z_{ILS}$ can be freely selected by the instrument

Table 4.3-3: Instrument Line-of-Sight Reference Frame definition

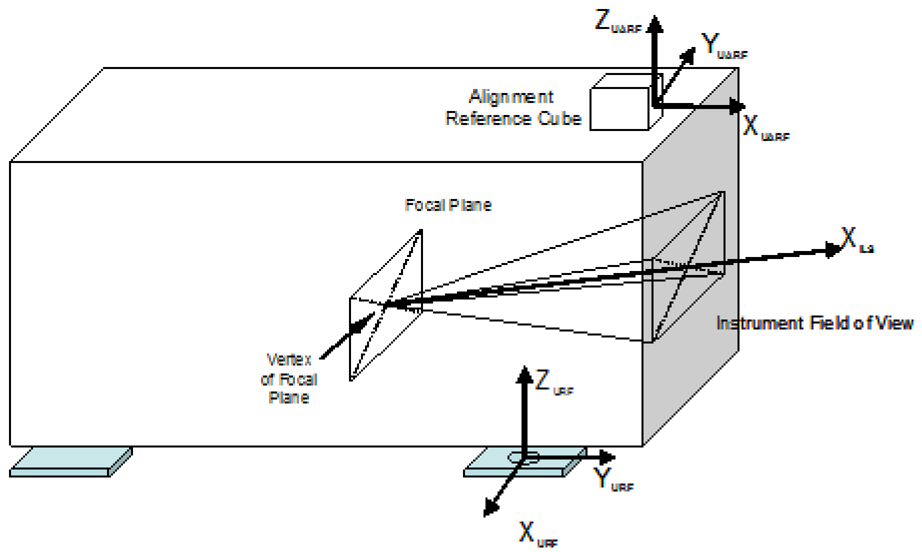


Figure 4.3-2: Unit Alignment Reference Frame (UARF) and Instrument Line-of-Sight Reference Frame (ILS) visualization

4.4 Instrument Location, Alignment, Pointing and Straylight

4.4.1 Instrument Location

D: The location of the instrument units on the spacecraft, including the units mounted on the boom, is shown in Annex A1. Annex 1 also identifies the FoR of the relevant units, the transformation matrices of the externally mounted sensors, the feedthrough dimensions for the relevant units and the instrument units allocated dynamic envelope. 1751

EIDA-1752//

> ***EIDA R-799:*** *The Prime Contractor shall mount the instrument units on the boom in the locations specified in sheet 5 of [NR-31].*

4.4.2 Instrument Alignment

4.4.2.1 *Definitions*

D: The instrument **Vertex** is the theoretical centre of the Instrument Focal Plane, as shown in Figure 4.3-2 above 1756

D: The instrument **Field of View (FoV)** is the volume enclosed by the angular opening of the instrument's viewing field used for scientific observations, measured from the Instrument Vertex, as shown in Figure 4.3-2 above 1757

D: The instrument **Unobstructed Field of View (UFoV)** is the volume enclosed by the angular opening of the instrument's viewing field for scientific observations, measured from the Instrument Vertex, in which no obstructions (especially reflecting materials) is present during the accommodation or later. 1758

D: The instrument **Field of Regard (FoR)** is the volume enclosed by the angular opening of the instrument's viewing field, in which all elements (especially reflecting materials) are kept under configuration control during the design, manufacturing, and integration process of the spacecraft. 1759

D: Pointing and alignment requirements within this specification on the Prime Contractor refer to the instrument alignment cube or other external reference and do not include any error between this reference and the internal line of sight; effects like instrument thermo-elastic distortions, internal slippages, etc. should be taken into account and calculated by the PI between the ILS and the instrument mechanical interface to the S/C. 1760

4.4.2.2 *Instrument (Co)-Alignment Requirements*

EIDA-1762//

> ***EIDA R-026:*** *The PI shall meet all alignment requirements specified in this paragraph over the relevant unit qualification operational temperature range and after application of the mechanical environment as specified in section 6.4.5*

EIDA-1763//

> ***EIDA R-027:*** *The PI shall measure the actual, as built angular offset, if any, between any of the three instrument coordinate frames (URF, UARF and ILS) in the instrument alignment report with a 20 arcsec accuracy.*

EIDA-1764//

> ***EIDA R-028:*** *The PI shall measure the actual, as built linear offset, if any, between the origins of the three instrument coordinate frames (URF, UARF and ILS) in the instrument alignment report with a 0.2 mm accuracy.*

EIDA-1765//

> ***EIDA R-029:*** *The PI shall ensure that the difference between the theoretical and actual angular offset for any of the three instrument coordinate frames shall be ≤ 30 arcsec, full cone*

EIDA-1767//

> ***EIDA R-030:*** *The PI shall ensure that the difference between the theoretical and actual linear offset for any of the origins of the three instrument coordinate frames shall be ≤ 0.1 mm*

EIDA-1768//

> ***EIDA R-031:*** *The PI shall mount alignment cube(s) on a solid part of the unit structure to ensure that alignment stability and repeatability is ≤ 10 arcsec.*

EIDA-1769//

> ***EIDA R-032:*** *The PI shall verify and ensure that the angular and linear stability provided by the optical cube(s) wrt the ILS are commensurate with the instrument alignment and stability requirements, following all environmental exposures (vibration, acoustics, thermal cycling).*

EIDA-1770//

> ***EIDA R-033:*** *The PI shall develop an alignment and alignment stability budget to analyse and quantify the contribution to internal misalignment due to, for example, mechanical loads, thermal cycling, thermo-elastic deformations, aging, etc*

EIDA-1771//

> ***EIDA R-034:*** *The PI shall ensure that the optical cube(s) have a minimum clear aperture diameter of 10 mm during autocollimation and that the optical properties are commensurate with the alignment requirements for his/her instrument*

EIDA-1772//

> ***EIDA R-035:*** *The PI shall ensure that the optical cube(s) incorporate scribed crosshairs within its clear apertures or the visible faces*

EIDA-1773//

> ***EIDA R-036:*** *The PI shall ensure that the optical cube(s) surfaces are orthogonal to within +/- 10 arcsec.*

EIDA-1774//

> ***EIDA R-037:*** *The PI and the Prime Contractor shall agree the locations of the optical cube(s), so as to provide a clear, normal line-of-sight to at least 2 orthogonal cube faces when unit(s) are integrated into the spacecraft.*

D: The Prime will ensure that the spacecraft provides alignment capability for each instrument unit compatible with the instrument co-alignment and pointing requirements. 1775

Typical means for active alignment are shimming/surfacing of the attachment points, and excenter / dowel pin arrangements. 1776

The Prime Contractor will propose the alignment approach for each instrument, for agreement by ESA and PIs 1777

EIDA-1778//

> ***EIDA R-038:*** *The PI shall complete all instrument internal alignment activities before integration of the instrument unit into the spacecraft.*

EIDA-1779//

> ***EIDA R-039:*** *The PI in case of active instrument unit alignment shall not introduce unacceptable stresses in the instrument and in the spacecraft structure.*

EIDA-1780//

> ***EIDA R-040:*** *The Prime Contractor shall co-align the PHI, EUI and SPICE optical units with an accuracy ≤ 2 arcmin full cone by using the instrument optical cubes.*

D: The Prime Contractor will refer to the STIX co-alignment requirements, specified in the STIX EID-B. 1781

4.4.3 Instrument Pointing

D: Pointing definitions and pointing requirements defined by the PIs and driven by the instrument scientific needs and applicable to the spacecraft are specified in chapter 9 1783

4.4.4 Straylight

EIDA-1785//

> ***EIDA R-815:*** *The PI shall ensure that the internally mounted remote sensing optical units are light-tight.*

D: No light exiting the unit except from the optical entrance aperture. 1786

D: requirement rationale: to ensure that no direct Vis & IR radiation is injected inside the SC enclosure where the remote sensing optical units are mounted, potentially causing an extra thermal load 1787

D: Exceptions: SPICE and STIX instruments. 1788

4.5 Mechanical Interfaces and Design Requirements

4.5.1 Mechanical Interface Control Drawing

EIDA-1791//

> ***EIDA R-041:*** *The PI shall produce, deliver and keep up to date for each instrument unit a Mechanical Interface Control Drawing (MICD).*

EIDA-1792//

> ***EIDA R-042:*** *The PI shall ensure that each MICD contains, as a minimum, the following set of interface information:*

- Drawing Identification Code and date of issue 1793
- Dimensions and associated tolerances (at ambient temperatures), including feet, external connectors and their dedicated clearance 1794
- Allocated dynamic volume, as provided by the Prime Contractor. 1795
- Mobile parts in the different configurations. 1796
- Identification of the Unit Physical Reference Frame (URF) and Reference Hole (RH) 1797
- Identification of the thermal Unit Reference Point (URP) 1798
- Identification of the Unit Alignment Reference Frame (UARF) 1799
- Identification of the Instrument Line-of-Sight Reference Frame (ILS), 1800
- Theoretical angular offset, if any, between URF, UARF and ILS) 1801
- Linear offset, if any, between the origins of the (URF, UARF and ILS) 1802
- Field of View (FoV) 1803
- Unobstructed Field of View (UFOV) 1804
- Field of Regard (FoR) 1805
- Instrument Vertex 1806
- Mounting hole pattern dimensions and hole patterns 1807
- Dimensions of mounting feet and contact area (base-plate and mounting feet) 1808
- Spot-faced area for seating of the mounting screw washers (if and where applicable) 1809
- Dimensions and location of dowel pins (where applicable) 1810
- Dimensions of volume below instruments unit for its mounting feet (if applicable) 1811

- Mass and associated tolerances (precise if estimated, calculated or weighted) 1812
- Location, naming, type and function of all connectors 1813
- Location, dimensions of venting holes and indication of venting path 1814
- Connector key shape orientation, the identification of connector contact "1", showing connector in front view and the connector centre line 1815
- Information about connector fixation 1816
- Identification and details of grounding studs and grounding straps 1817
- Identification of non-flight items (i.e red tag items) 1818
- Location of handling points (e.g. threaded bushes) 1819
- Location of unit and connector identification labels 1820
- Details of instrument provided mounting hardware, thermal/electrical isolation provisions like: thermal strap(s) material; dimensions; I/F mounting area location, dimension and flatness; number/type of thermal strap mounting bolts and their torque, presence of filler 1821
- location of operational and non-operational heaters, and temperature sensors (for test and flight purpose) 1822
- Location and routing of any harness interconnecting modules of a "stacked" box configuration 1823
- Identification of free areas for harness fixation 1824
- Centre of Gravity coordinates, calculated and specified wrt URF 1825
- Moments of Inertia coordinates, calculated and specified wrt URF 1826
- Location and type of interface for of transport/storage purging connections (if applicable) 1827
- Material of housing and surface finish 1828
- Flatness and roughness of contact area 1829
- Base plate material and surface treatment 1830
- Surface coating (IR Emissivity and Solar absorptance if external location) 1831
- Specific heat (J/Kg/K) (calculated or measured) 1832
- Locations and dimensions of areas dedicated to temporary installation of test sensors (accelerometers etc). 10206

4.5.2 Mass

EIDA-1834//

EIDA R-043: *The PI shall ensure that the FM instrument measured mass is compliant with the relevant allocated mass specified in the table below (Table 4.5-1).*

Instrument	Allocated Mass [kg]
EPD	17.00
EUI	25.40
MAG	3.40
METIS	29.70
PHI	33.00
PHI filters	4.00
RPW	24.30
SOLOHI	16.70
SPICE (incl. TQCM)	23.60
STIX	7.50
STIX filters	0.50

1835

Instrument	Allocated Mass [kg]
SWA	23.60
TOTAL	**208.70**

Table 4.5-1: Instruments Allocated Masses 1878

EIDA-1879//

EIDA R-044: *The PI shall establish, keep up to date and provide the ESA Solar Orbiter Project office with a mass budget for each instrument unit (including unit interconnecting harness(es).*

EIDA-1881//

EIDA R-045: *The PI shall ensure that each unit mass budget include at least the following elements, as applicable:*

· Structure, mechanisms and optics; 1882

· electronics up to the interfaces with the spacecraft power and data systems; 1883

· thermal control hardware, including any necessary thermal straps or heaters / thermistors, instrument blankets, cold fingers defined by the instrument 1884

· pigtail and interconnecting harness (if instrument consists of more than one unit). 1885

· electrical connectors, but not the mating harness connector 1886

· attachment hardware including instrument-delivered brackets or struts, but excluding standard fixation bolts to the spacecraft structure and washers 1887

· potting compounds used in the units 1888

· alignment references, e.g. mirrors, that are not removed before flight 1889

· internal balance mass (applicable for periodically operating mechanisms) 1890

· electrostatic screens and/or magnetic shielding 1891

· in-flight covers, purge ports, purging pigtails 1892

EIDA-1893//

EIDA R-046: *The PI shall calculate, for each unit mass budget, the Basic Mass of each identified unit element.*

D: Basic Mass is the engineering best estimate without any contingency due to any uncertainty at the time of the issuing of the mass budget. 1894

EIDA-1895//

EIDA R-047: *The PI shall calculate, for each unit mass budget, the Nominal Mass of each identified unit element.*

D: Nominal Mass is the Basic Mass plus contingency due to any uncertainty and/or design maturity considerations at the time of the issuing of the mass budget. 1896

EIDA-1897//

EIDA R-048: *The PI shall apply the following contingency factors due to uncertainty and/or design maturity:*

- > 5 % for “Off-The-Shelf” items (ECSS Category: A / B) 1898
- > 10 % for “Off-The-Shelf” items requiring minor modifications (ECSS Category: C) 1899
- > 20 % for newly designed / developed items, or items requiring major modifications or re-design (ECSS Category: D). 1900

EIDA-1901//

EIDA R-049: *The PI shall calculate and provide the instrument Mass Margin*

D: The instrument Mass Margin is the difference between the total instrument Nominal Mass [i.e. sum of unit(s) Nominal Mass(es) and the instrument allocated mass 1902

EIDA-1903//

EIDA R-050: *The PI shall ensure that the difference between the measured mass of each STM unit and FM unit with the respective nominal mass, specified in the relevant MICD, current at the time of the STM and FM delivery, is less than 1%.*

D: From the initial instrument design up to launch, the PI will control the spacecraft resources allocated to the instrument according to strict rules in order to show adequate margins, at each major instrument review milestones. 1904

D: Such margins are there to ensure that the design can mature adequately and that engineering and schedule risks are minimised due to potential instrument demand increase. The main resources subject to margin control are: Mass, Power, Data Rate 1905

EIDA-1906//

EIDA R-051: *The PI shall ensure that the following margin philosophy for mass, power and data rate nominal values vs. allocated values, are met:*

- 20% margin at PDR 1907
- 10% margin at CDR 1908

EIDA-1909//

EIDA R-052: *The PI shall ensure that throughout the instrument life cycle the following margin philosophy for the actual best estimate of processor load and memory occupation vs allocated resources is met:*

Instruments shall implement the following margins for the current best estimate of processor load and memory occupation of: 1910

- 50 % before/at PDR 1911
- 40 % before CDR 1912
- 25% at FM AR 1913

4.5.3 Centre of Mass

EIDA-1915//

EIDA R-053: *The PI shall calculate and document any variation of Centre of Mass (CoM) for each unit*

D: variations could be due for example to consumables or appendages deployment. 1916

EIDA-1917//

EIDA R-054: *The PI shall ensure that in computing the CoM values, non-flying items (e.g. temporary installation items, etc.) are not taken into account.*

EIDA-1918//

EIDA R-055: *The PI shall ensure that the difference between the measured or calculated CoM coordinates of each STM, FM and FS unit and the respective estimated coordinates, current at the time of the STM, FM and FS delivery, is within a sphere of 3 mm radius.*

4.5.4 Moments of Inertia

EIDA-1920//

EIDA R-056: *The PI shall calculate and document any variation of the Moment of Inertia (MoI) for each unit*

D: due for example to due to mechanisms movements or appendages deployment 1921

EIDA-1922//

> ***EIDA R-057:*** *The PI shall ensure that the calculated or measured CoG and MOI of the STM shall differ by less than 10% from the calculated or measured CoG and MOI of delivered FM and FS units.*

4.5.5 Unit Dimensions

EIDA-1924//

> ***EIDA R-058:*** *The PI shall specify the dimension, d, of each unit in the respective MICD to a tolerance smaller than:*

+ 0.5/-0.0 mm for d < 500 mm 1925

+ 1.0/-0.0 mm for d > 500 mm 1926

4.5.6 Mounting

EIDA-10062//

> ***EIDA R-832:*** *The Prime Contractor shall be responsible for the provision of standard mounting HW for the FM (bolts, washers , pins, etc).*

D: The Prime Contractor will define the mounting hardware under Prime Contractor responsibility based on the information in the instrument MICD (hole sizes, threads etc.). 10207

D: Standard Hardware refers to parts having no special procurement or selection criteria. Specialist mounting hardware selected to achieve instrument performance criteria are to be supplied by the PIs and identified in the instrument MICDs. 10224

EIDA-1928//

> ***EIDA R-059:*** *The PI shall design the attachment points of each unit to guarantee compliance to the following general functional requirements:*

· Ease of accessibility with standard tools to the attachment bolts during (de)integration of the equipment/subsystem to the spacecraft. 1929

· Provision of sufficient accessibility to the position of the connectors and grounding studs to enable easy the mounting and removal of the unit. 1930

· Coherent mechanical design of the mounting attachments with the thermal control of the equipment/subsystem, by taking into account the thermal loads encountered throughout the mission lifetime. 1931

EIDA-1932//

> ***EIDA R-769:*** *The PI shall ensure the following, for units where the attachment points have to fulfil both the load carrying and thermal transfer functions:*

- mounting surface flatness < +/- 0.050 mm per 100 mm length 1933
- mounting feet surface roughness Rz < 1.6 1934
- effective contact area to the S/C interface surface approx 350mm^2 (typically for M5) 1935

EIDA-1936//

> ***EIDA R-770:*** *The PI shall ensure the following, for units where the attachment points have to fulfil only the load carrying function:*

- mounting feet surface flatness < +/- 0.050 mm 1937
- coplanarity between all mounting feet surfaces < 0.050 mm per 100 mm length 1938
- mounting feet surface roughness Rz ~ 6.4 µm 1939

1940

• additional (lateral) contact area for the attachment of thermal straps having the following typical characteristics:

• surface flatness < +/- 0.100 mm 1941

• surface roughness Rz < 1.6 1942

EIDA-1944//

EIDA R-061: *The PI shall ensure that the characteristics of the thermal attachment interface(s) on the instrument side are maintained under all operating conditions.*

EIDA-1945//

EIDA R-062: *The PI shall ensure that any mechanical and thermal mounting contact area interface(s) is free of paint.*

EIDA-1946//

EIDA R-064: *The PI shall typically use M5 bolts for the mounting of each unit to the spacecraft.*

EIDA-1947//

EIDA R-065: *The PI shall seek agreement with the Solar Orbiter ESA Project Office, in case a different bolt size is baselined.*

EIDA-1948//

EIDA R-067: *The PI shall ensure that all equipments/subsystems interface holes comply with the table below (Table 4.5-2)*

10208

Interface Clearance	M4 bolts	M5 bolts	M6 bolts
Hole size (mm)	4.5 (+ 0.1 / -0.0)	5.5 (+ 0.1 / -0.0)	6.5 (+ 0.1 / -0.0)
Positional hole tolerance (mm)	0.1	0.1	0.1
Positional insert tolerance	0.1	0.1	0.1

Table 4.5-2: Interface hole requirements for M4, M5 and M6 bolts 10396

EIDA-8938//

EIDA R-826 *The PI for STIX, EUI, PHI, SPICE and METIS shall ensure that the distance between mounting holes per foot pad for optical units meets the following criteria (see the Figures for EIDA R-821):*

- *2 mounting holes per foot, minimum separation (centre to centre): 45 mm.*
- *3 mounting holes per foot, minimum separation (centre to centre): 25 mm.*

EIDA-1949//

EIDA R-068: *The PI shall abide by the unit interface requirements specified in the table below (Table 4.5-3) and shown in the Figure 4.5-1 below*

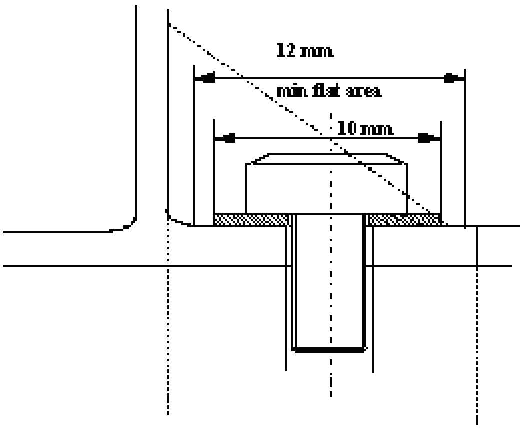
EIDA-1950//

EIDA R-069: *The PI shall ensure that the thickness of the equipment/subsystem mounting feet is ≥ 3.0 mm, as shown in the Figure 4.5-1 below*

1951

Attachment Bolt	M5
Material	Ti; SST (typical)
Washer dimension	Diameter : 10 mm (typical) Thickness : 1 mm (typical)
Distance, d, between mounting holes	100 mm (typical)
Tolerance distance between centre of mounting hole and Reference Hore	⊕ ⌀0.1 R
Diameter of spot face area for bolt head and washer	12 mm (typical)
Attachment lugs	see figure below
Corner radius	< 0.5 mm

Table 4.5-3: Typical Unit Mounting Interface Dimensions for M5



1968

Figure 4.5-1:Unit Mounting Interface Geometry.

EIDA-1969//

EIDA R-071: *The PI shall ensure that each unit can withstand the interface loads even with one bolt missing.*

EIDA-1970//

EIDA R-073: *The PI shall provide isostatic mounts for units requiring APE and/or co-alignment to better than 0.1°.*

EIDA-1971//

EIDA R-074: *The PI shall design, for alignment critical units (APE and / or co-alignment requirement tighter than 0.25deg), the instrument mounting feet such that the shear force generated at any foot does not exceed 500 N in the following conditions :*

- Maximum displacement of the instrument feet at the S/C interface as specified in the table below (Table 4.5-4): 1972

- Instrument subjected to the specified in-orbit thermal environment 1973

1974

Foot	Maximum displacement	
Any	In-plane	Out-of-plane
	1.0 mm (TBC)	0 mm

1986

Table 4.5-4: Instrument foot prescribed displacement at S/C interface

EIDA-1987//

EIDA R-771: *The PI shall insure that, for alignment critical units (APE and / or co-alignment requirement tighter than 0.25deg), the instrument mounting feet include an alignment slot and a close tolerance hole as shown in the Table 4.5-5 and Figure 4.5-2 and Figure 4.5-3 below.*

8949

APE / co-alignment requirement	Unit hole size (M5 basis)	Fixing holes positional tolerance w.r.t. URF "R" (diameter) excluding alignment slot	Alignment slot positional tolerance w.r.t. URF	Alignment slot width	Comment
Above ±0.25°	See EID-A R-067	See EID-A R-067	N/A		
Below ±0.25°	•URF: Ø5H7 (+0.000 / +0.012) •Other holes: Ø5.5 +0.0/+0.1	See EID-A R-067	⊕ | Ø0.1mm | R	5mm +0.000 +0.012	Slot to be located as far as practical from URF origin

Table 4.5-5: Requirements for mounting feet of alignment critical units 10398

8954

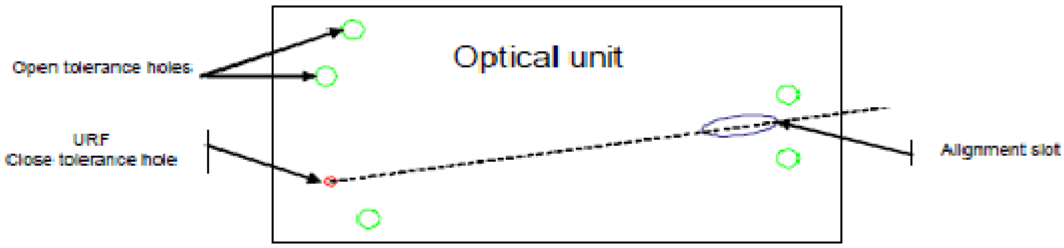
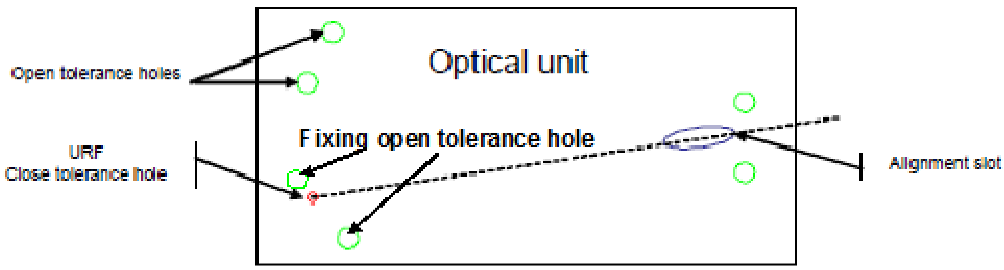


Figure 4.5-2: Diagram illustrating requirements for mounting feet of alignment critical units 10399

D: For EUI, METIS, PHI, SPICE and STIX: The close tolerance hole will not be a fixing hole and will be used for alignment purposes only (see Figure 4.5-3 below). 8952

8953



10397

Figure 4.5-3: Figure showing the closed tolerance hole and the alignment slot

EIDA-8939//

> ***EIDA R-821:*** *The PI shall implement an internal anchor nut/ helicoil or similar to their feet inserts compatible with M5 (or otherwise) bolts, as shown in Figure 4.5-4.*

D: This is applicable to the RS instruments EUI, METIS and SPICE, who will be mounted from the underside of the spacecraft panel. 9445

8947

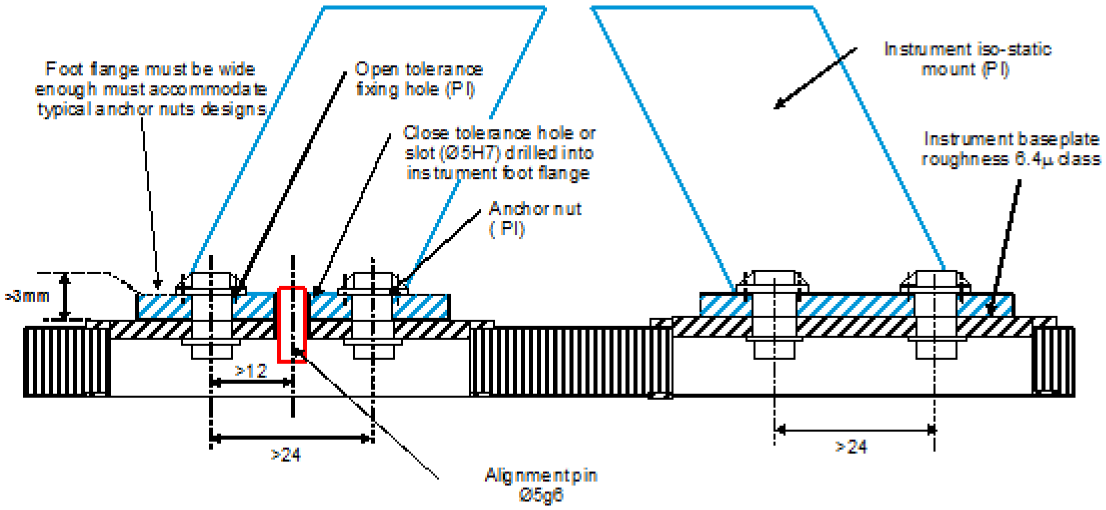


Figure 4.5-4: Diagram illustrating the implementation R-821, applicable to EUI, METIS and SPICE 10400

D: PHI and STIX will be mounted from the instrument side of the panel (see Figure 4.5-5). 8948

8946

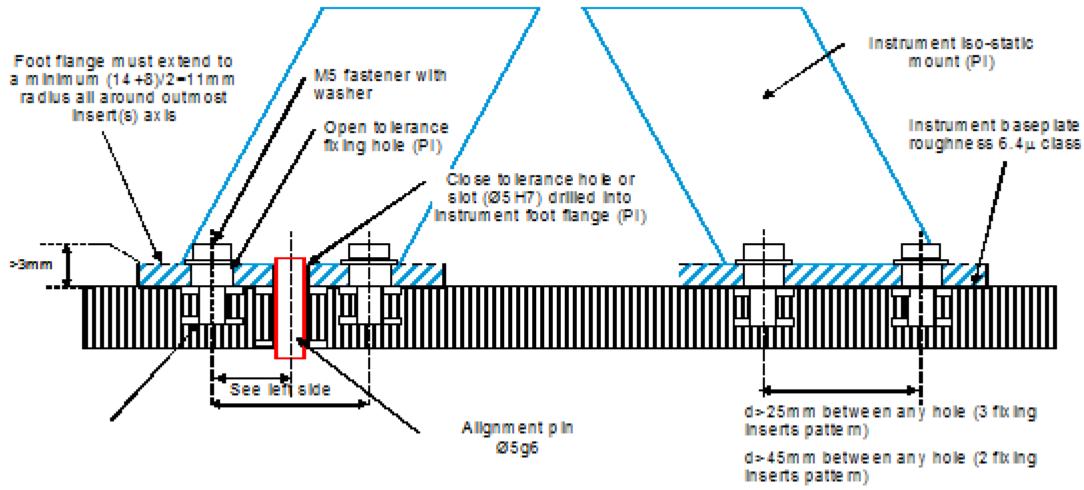


Figure 4.5-5: Diagram illustrating the implementation of the mounting holes for PHI and STIX 10401

EIDA-1989//

> ***EIDA R-340:*** *The PI shall provide handles for units weighing more than 10kg*

D: These handles used only during ground operation will clearly identified as a non-flight item 1990

D: If a handling jig is provided, then this will be detailed in the EID-B and agreed together with the Prime Contractor. 1991

EIDA-1992//

> ***EIDA R-766:*** *The PI shall provide HW lifting interfaces (e.g eye-lids, spreaders, etc) to a single hook crane for units weighing more than 20kg.*

D: Lifting interfaces for EUI, PHI, METIS and STIX need to be at the top to allow vertical lowering onto mounting plane. For SPICE the lifting interfaces may have to be both at the top and on the side. 1993

EIDA-1994//

> ***EIDA R-722:*** *The PI shall ensure that the base plate of the thermally coupled electronic units is conductively coupled with the spacecraft by a flat, full contact surface.*

D: Thermally coupled and insulated electronic units are identified in Annex 3. 1995

D: full contact surface means the full area of the unit baseplate footprint 1996

4.5.7 Feedthroughs

D: The baseline feedthrough dimensions are defined in Annex A1 1998

D: The Prime Contractor will ensure that the thermo-elastic distortions between the feedthrough and the instrument line of sight as illustrated in the diagram will be compatible with the values given in tables below (Table 4.5-6 and Table 4.5-7). 1999

8853

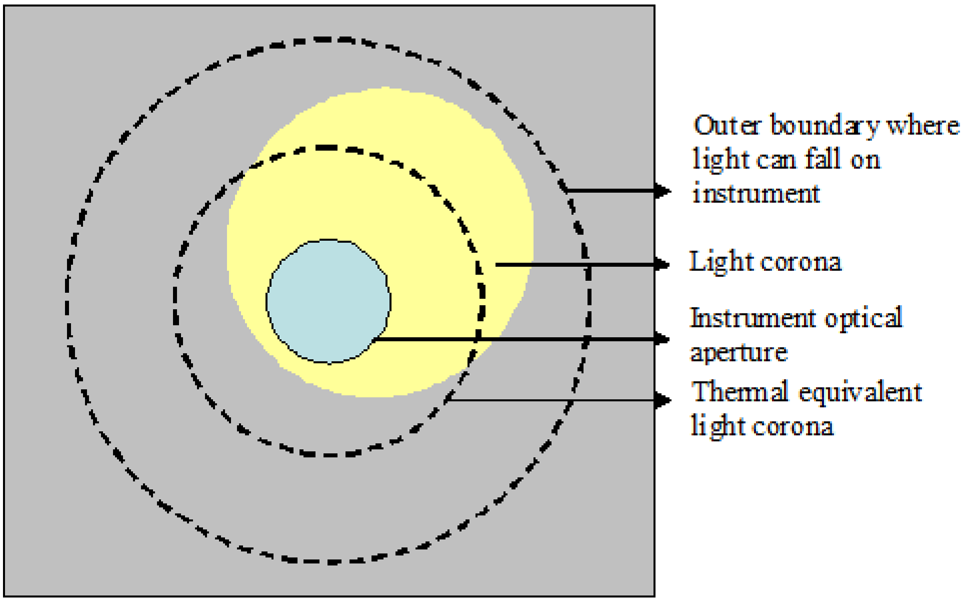


Figure 4.5-6: Illustration of the Outer boundary of asymmetric instrument aperture light corona, specified as a dilatation from the instrument optical aperture and the thermal equivalent light corona 10402

2024

Telescope	Instrument aperture dilation
EUI-HRI	7 mm
EUI-FSI	7 mm
SPICE	10 mm
METIS	N/A
PHI-HRT	10 mm
PHI-FDT	10 mm
STIX	7 mm

2049

Table 4.5-6: Outer boundary of asymmetric instrument aperture light corona, specified as a dilatation from the instrument optical aperture.

2050

Telescope	Instrument aperture dilation

Telescope	Instrument aperture dilation
EUI-HRI	3 mm
EUI-FSI	3 mm
SPICE	3 mm
METIS	N/A
PHI-HRT	3 mm
PHI-FDT	3 mm
STIX	3 mm

Table 4.5-7: Thermally equivalent light corona, specified as a dilation from the instrument optical aperture. 2075

D: The figure below (Figure 4.5-7) shows how to interpret the values specified in the tables above for the specific geometry for the EUI instrument. The other instruments should follow the same approach 2076

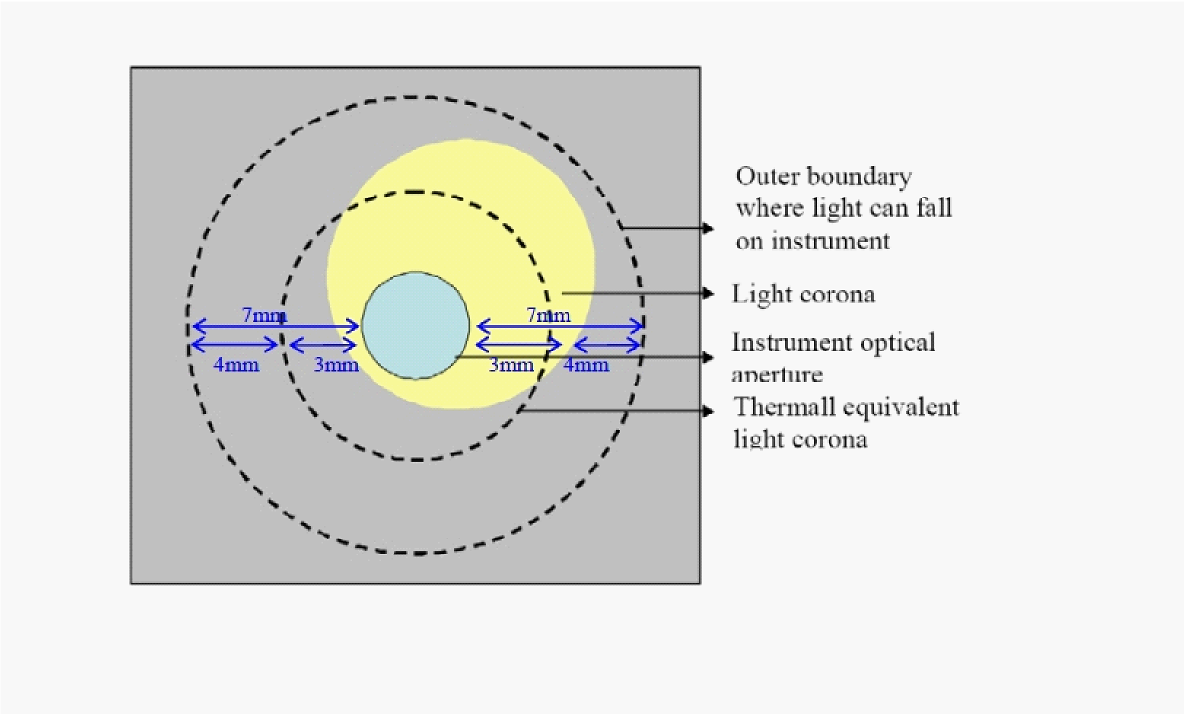
 2077

Figure 4.5-7: Illustration of how to interpret Table 4.5-6 and Table 4.5-7 for the EUI instrument. 10403

EIDA-2078//

> ***EIDA R-341:** The PI shall ensure that any protrusions of the instruments (i.e. METIS) within the feedthroughs have a minimum of 5 mm clearance with the inner wall of the feedthrough.*

D: The feedthrough dimensions will be designed to guarantee the instrument UFoVs under all phases of the nominal mission where the instruments are operational. The UFoV provided by the heatshield feedthroughs will be oversized with respect to the instrument requested UFoV, in order to meet the UFoV requirement in the presence of thermo-elastic distortions, manufacturing tolerances, misalignment between the instrument line of sight and the feed-through aperture, and thermal expansion of the feed-through. 2079

D: The Prime Contractor will provide, for the PHI filters mounted on the feedthrough an alignment of: 2080

- Alignment of window along X: ± 10 mm 2081
- Alignment of window axis with respect to ILS, along Y: ± 3 mm 2082
- Alignment of window axis with respect to ILS, along Z: ± 3 mm 2083
- Window tilt out of Y-Z plane: ± 30' 2084

EIDA-2085//

> ***EIDA R-076:*** *The PHI PI shall provide the PHI Filters and related mechanical mounting to be integrated onto the relevant feedthrough*

EIDA-2086//

> ***EIDA R-077:*** *The STIX PI shall provide STIX windows and related mechanical mounting to be integrated onto the relevant feedthrough*

4.5.8 Doors

EIDA-2088//

> ***EIDA R-344:*** *If an internally accommodated remote sensing instrument requires an internal instrument door, the Prime Contractor shall assess the need to supply a heatshield door to protect the spacecraft in the case the instrument door fails in the closed position.*

EIDA-2089//

> ***EIDA R-345:*** *The spacecraft provided doors, if any, shall be designed to prevent direct sunlight entering the feedthroughs of the instruments.*

4.5.9 Structural Design

4.5.9.1 *Margins of Safety*

The **Limit Load (LL)**, is the load which a unit is expected to experience with a given probability, during the performance of specified missions in specified environments. LL are the maximum loads that result from the flight, ground or test environments. LL also includes combinations of thermally induced loads, preloads, inertia loads (e.g. for mechanisms). 2092

The **Qualification Test Level (QL)** corresponds to the maximum level expected to be encountered during the unit lifetime increased by qualification margins. 2093

The **Acceptance Test Level (AL)** corresponds to the maximum level expected to be encountered during the unit lifetime increased by acceptance margins 2094

The **Test Factors (KA and KQ)** are used to define respectively the acceptance and the qualification test levels. 2095

The **Design Limit Load (DLL)** is the Limit Load multiplied by Coef A (see Table 4.5-8 below). 2096

The **Design Yield Load (DYL)** is the Design Limit Load multiplied by Coef B (see Table 4.5-8). 2097

The **Design Ultimate Load (DUL)** is the Design Limit Load multiplied by Coef C (see Table 4.5-8). 2098

The **Yield Strength,** is the maximum load or stress that a structure or material can withstand without incurring specified permanent deformation or yield (conventionally taken at a unit strain of 0.002 or 0.2% proof/stress). 2099

The **Ultimate Strength**, is the maximum load or stress that a structure or material can withstand without incurring rupture or collapse. 2100

EIDA-2101//

> ***EIDA R-801:*** *The PI shall insure that DLL, DYL and DUL, for the design of units, are calculated from the LL as specified in the Figure 4.5-8 and Table 4.5-8 below.*

D: The mechanical environment loads defined in Section 6.4.5 are Qualification (QL) and Acceptance Test Levels (AL). They already include KQ and KA as required. Therefore, DLL can be obtained from QL by applying the KM and KP factors only. 2102

2105

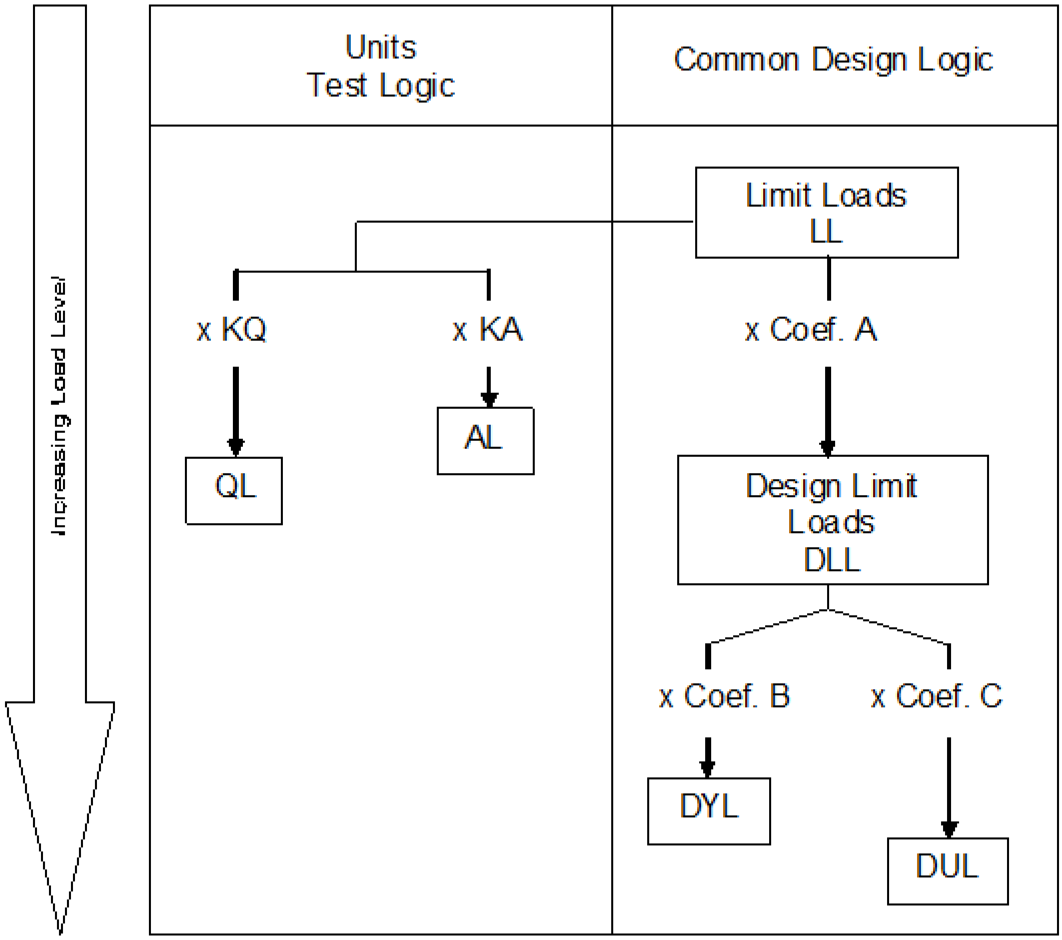


Figure 4.5-8: Definition of loads 2106

2107

Coefficient	Satellite
Coef A or Design factor	$KQ \times K_P \times K_M$
Coef B	$FOSY \times K_{LD}$
Coef C	$FOSU \times K_{LD}$

Table 4.5-8: Relationship among (structural) factors of safety, design factors and additional factors. 2108

EIDA-2109//

> ***EIDA R-802:*** *The PI shall insure that a "model factor" K_M is applied to the LL to account for uncertainties (e.g. hyperstaticity, junction stiffness uncertainty, non correlated dynamic behaviour,...) when predicting dynamic response, loads, and evaluating load paths.*

EIDA-2110//

> ***EIDA R-803:*** *The PI shall insure that K_M is equal to 1.1, if design loads are generated using FE analyses and > 1.2 if design loads are not generated using FE analyses*

D: K_M will be agreed with ESA and the Prime Contractor 2111

EIDA-2113//

> ***EIDA R-804:*** *The PI shall insure that a "project factor" K_P is applied to account for the maturity of the development programme (e.g. stability of the mass budget, heritage, etc).*

2114

D: K_P will be agreed with ESA and the Prime Contractor

EIDA-2115//

> ***EIDA R-805:*** *The PI shall insure that K_P is equal to 1.0 in the case of non-protoflight approach and ≥ 1.1 in case of proto-flight approach.*

D: K_P will be agreed with ESA and the Prime Contractor 2116

EIDA-2117//

> ***EIDA R-806:*** *The PI shall insure that a Local Design Factor (K_{LD}) is applied when the sizing approach or local modelling are complex and is ≥ 1.0.*

D: K_{LD} will be agreed with ESA and the Prime Contractor 2118

EIDA-2119//

> ***EIDA R-816:*** *The PI shall apply the Factors of Safety (FOS) as defined in the table below (Table 4.5-9).* 2120

Structure type	Requirements			
	Verification by test		Verification by analysis only	
	FOSY	FOSU	FOSY	FOSU
Metallic parts	1.1	1.25	1.25	2.0
Fibre Reinforced Plastic parts	N/A	1.50 **a)**	N/A	2.0
Joints and inserts: b) - Failure - Gapping - Sliding	N/A	1.50	N/A	2.0
Sandwich parts: b) - face wrinkling - intracell buckling - honeycomb shear	N/A	1.50	N/A	2.0
Glass and ceramic structural parts c)	N/A	2.5	N/A	5.0
Buckling d)	N/A	1.25	N/A	2.0

Table 4.5-9: Factors of safety. 10404

a) If material and design allowables are statistically verified by means of a test programme agreed with the customer, e.g. considering also proof tests, the FOSU may be reduced to FOSU = 1.25 9458

b) These factors are not applied on the bolts preload - see threaded fasteners handbook (ECSS-E-HB 32-23).

c) These materials have strength properties which are highly dependant on the manufacturing process, the size of the part and of the surface quality. Therefore the stress/strength allowables must be derived from representative samples, to be agreed by the customer.

d) These factors of safety do not cover the knock-down factors commonly used in buckling analyses, see ECSS-E-HB-32-24

4.5.9.2 *Design Loads*

EIDA-2173//

> ***EIDA R-088:*** *Removed*

Removed 2177

4.5.9.3 *Stiffness Requirements*

EIDA-2179//

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

4.5.9.4 *Payload and S/C Generated Disturbances*

EIDA-2181//

> ***EIDA R-090:*** *The PI shall analyze and quantify the instrument generated disturbances (e.g. due to mechanisms movements) vs. frequency.*

D: The analysis will include the moving mass and the movement frequencies and characteristics. 2182

EIDA-2183//

> ***EIDA R-719****: The PI shall declare and characterise for approval any microvibration load higher than 0.1N and/or 0.1 Nm generated by the unit at its baseplate interface.*

EIDA-2184//

> ***EIDA R-715****: To PI shall insure that the maximum shock response spectrum induced by the instruments for launch lock release at the mechanical interface with the spacecraft (i.e. base of the feet) shall be less than the spectrum values shown in the Figure 4.5-9 below.*

D: The spectrum also applies for launch lock release during NECP and is not a tolerable vibration spectrum for internal mechanisms during nominal mission phase. 2185

2186

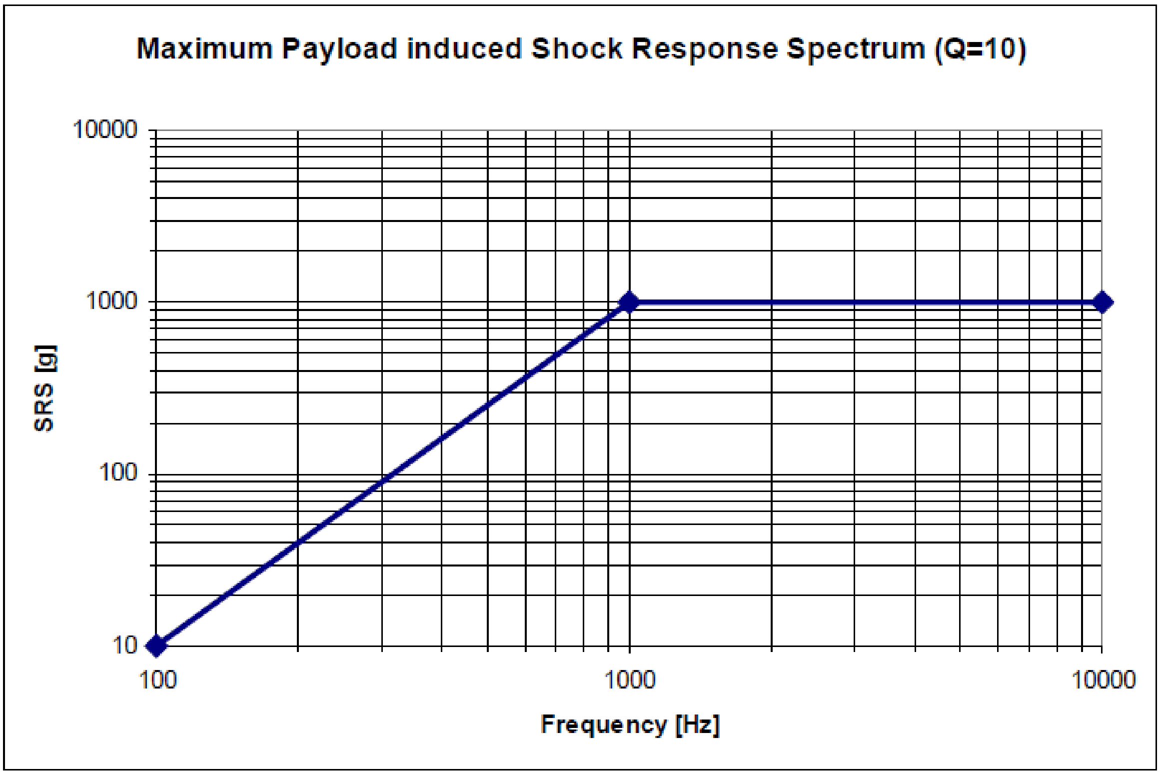


Figure 4.5-9: Maximum Payload Induced Shock Response Spectrum. 10405

EIDA-2187//

> ***EIDA R-761***: *The Prime Contractor shall provide the PIs with microvibration data at the mechanical interfaces of the instrument units.*

D: The data will be provided upon request of the PIs for relevant units. 2188

4.6 *Thermal Interface and Design Requirements*

4.6.1 Definitions

D: Coupled Unit: A unit with a strong thermal link to the spacecraft. Typically, an electronics unit is a "coupled unit" because it is hard mounted and it radiates towards the spacecraft internal parts. 2191

D: Insulated Unit: A unit with a weak thermal link to the spacecraft. As an example, a sensor attached to the structure with low conductive feet and wrapped in MLI is an insulated unit. 2192

D: Internally Mounted Unit: A unit located inside the S/C main body and not radiatively coupled to deep space except through any existing aperture. 2193

D: Externally Mounted Unit: A unit located outside the S/C main body and radiatively coupled to deep space. 2194

D: The figure below (Figure 4.6-1) show possible units configurations 2195

2271

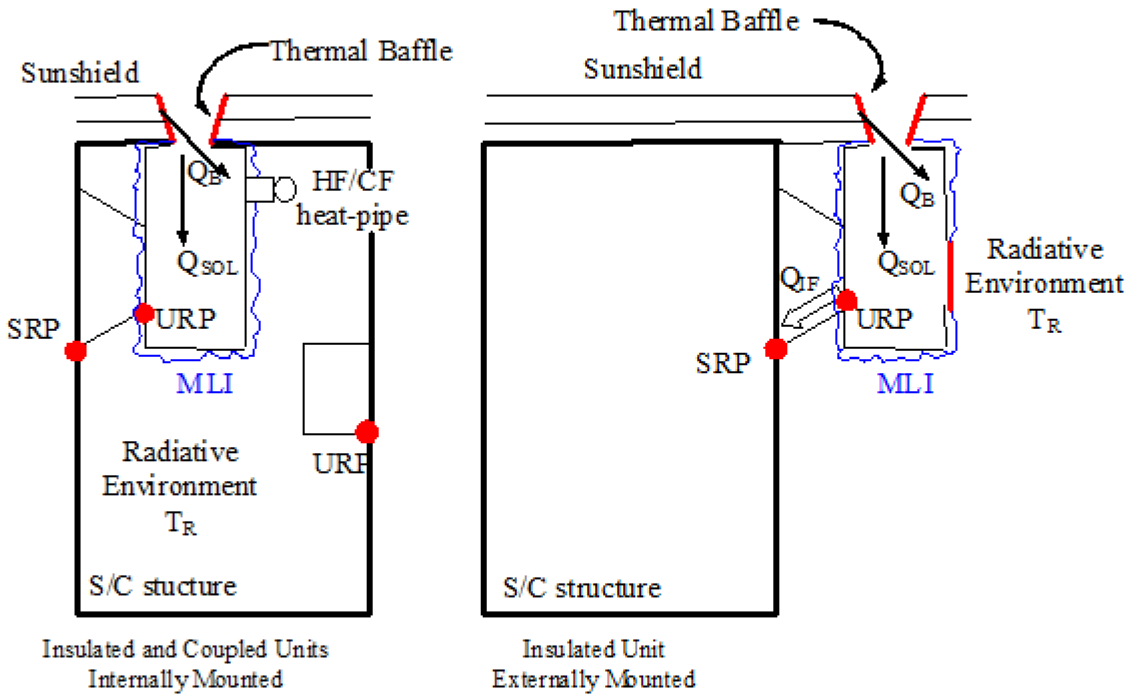


Figure 4.6-1: Possible Unit Configurations

D: Unit Reference Point (URP): physical point defined by the unit supplier. It is located on the unit external surface. In addition, for thermally coupled units it is located on the mounting plate close to the mounting bolt. The URP provides a simplified representation of the unit's thermal status. The URP will be used as reference for coherent verification at unit, instrument and S/C levels (for thermal analysis, acceptance and qualification testing activities). 2272

In case of thermally coupled units, the URP will be maintained within the specified temperature limits by the S/C thermal control (see Annex 3). 2273

D: System Reference Point (SRP): physical point located on the spacecraft structure close to a unit 2274
mechanical interface. It is used to evaluate the thermal interaction between an insulated unit and the spacecraft.

D: Radiative Sink Temperature (T_R): virtual black body radiation temperature used to define the 2275
equivalent radiative thermal load on a unit.

D: Unit Temperatures: unit temperatures defined at the URP or the SRP as appropriate. 2276

D: Design Temperature Range: maximum range of temperature experienced by a unit throughout 2277
the mission and during ground phases. In the absence of any specification indicating otherwise, the ground range is assumed to coincide with the flight range.

D: Calculated Temperature Range: unit temperature range obtained by analysis excluding 2278
uncertainties.

D: Predicted Temperature Range: temperature range obtained by adding the uncertainties to the 2279
calculated temperature range.

D: Switch-on Temperature Range: temperature range at which a unit can safely be switched-on 2280
throughout the mission and during ground phases. In absence of specification, the ground range is assumed to coincide with the flight range.

D: Acceptance Temperature Range: temperature range obtained by enlarging the design 2281
temperature range by the acceptance margin at both ends.

D: Unit Acceptance Test Temperature Range: an extension of the acceptance range by the test 2282
uncertainties. All flight units will be tested prior to delivery to the spacecraft at this extreme temperature range.

D: Qualification Temperature Range: temperature range obtained by enlarging the acceptance 2283
temperature range by the qualification margin at both ends.

D: Unit Qualification Test Temperature Range: an extension of the qualification range by the test 2284
uncertainties. This is the extreme test temperature range at which a unit shall be tested to qualify its design.

D: Internal Design Temperature Range: max temperature for which unit components or parts are 2285
selected.

D: The following definitions, represented in Figure 4.6-2 below will be used in defining the instrument 2286
interface with the spacecraft:

2287

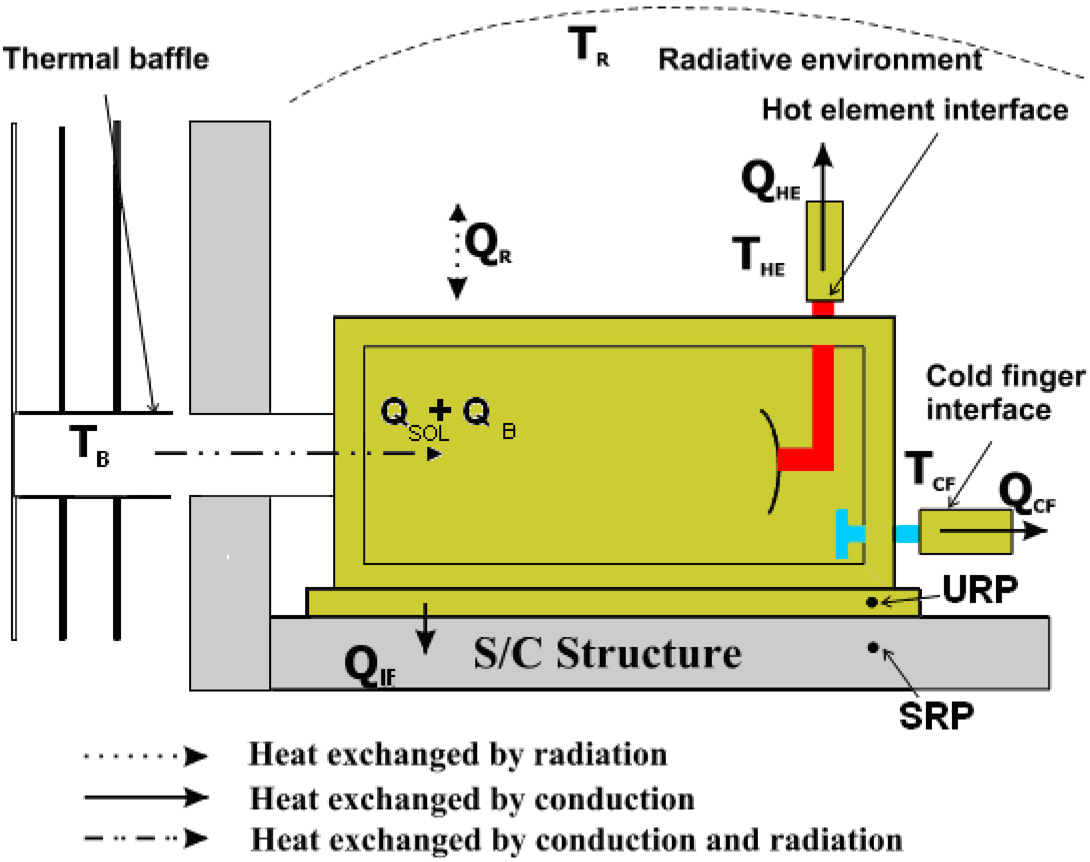


Figure 4.6-2: Temperature and Heat Load Definitions. 2289

D: Conductive Interface Temperatures 2290

The **TURP** is the temperature at the URP interface 2291

The **TSRP** is the temperature at the SRP interface 2292

D: Net Conductive Heat Flux, $\mathbf{Q_{IF}}$ 2293

The $\mathbf{Q_{IF}}$ is the net conductive heat flux flowing at this interface into or out of the spacecraft. 2294

D: Radiative Sink Temperature, $\mathbf{T_R}$ 2295

The $\mathbf{T_R}$ is the temperature of the global radiative environment 2296

D: Net Radiative Heat flux from the environment, $\mathbf{Q_R}$ 2297

The $\mathbf{Q_R}$ is the net radiative flux exchanged with the global environment 2298

D: Cold Element Interface Temperature, $\mathbf{T_{CE}}$ 2299

The $\mathbf{T_{CE}}$ is the temperature of the cold element interface used to define the conductive heat exchange to the spacecraft. 2300

D: Net Conductive Heat Flux, $\mathbf{Q_{CE}}$ 2301

The $\mathbf{Q_{CE}}$ is net conductive heat flux through the cold element interface 2302

D: Hot Element Interface Temperature, $\mathbf{T_{HE}}$ 2303

The $\mathbf{T_{HE}}$ is the temperature of the hot element interface used to define the conductive heat exchange to the spacecraft. 2304

D: Net Conductive Heat Flux, $\mathbf{Q_{HE}}$ 2305

2306

The $\mathbf{Q_{HE}}$ is the net conductive heat flux through the hot element interface

D: Total Solar Heat Load, $\mathbf{Q_{SOL}}$ 2307

The $\mathbf{Q_{SOL}}$ is the solar flux in the visible wavelength including any incident energy via multi-reflections. 2308

D: Total IR Heat Flux from any aperture, $\mathbf{Q_B}$ 2309

The $\mathbf{Q_B}$ is the total net infrared flux exchanged between any instrument aperture and the respective feedthrough. 2310

D: The above definitions are also applicable for boom mounted units. 2311

4.6.2 Thermal Control Margins

EIDA-2313//

> ***EIDA R-091:*** *The PI shall ensure that the required **URP** temperature and margin are in line with the [Figure 4.6-3](#) below.*

EIDA-2314//

> ***EIDA R-092:*** *The PI shall apply the acceptance and qualification margins given in the Figure 4.6-3 below during the unit thermal vacuum tests on all the instrument interfaces (radiative and conductive) and in all functional modes (operating, non-operating, start-up)*

EIDA-2315//

> ***EIDA R-093:*** *The PI shall define in the EID-B, for thermally insulated units, the design temperature ranges shown in the Figure 4.6-3 below at the URP, including all the instrument margins and uncertainties due to the design and analysis maturity.*

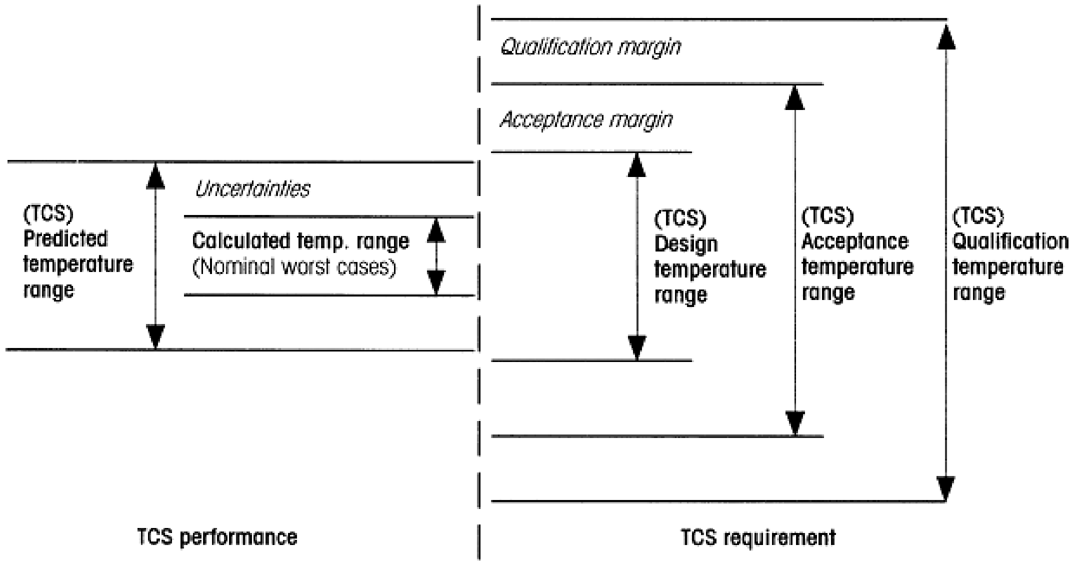
D: [NR-10] and [NR-04], provide relevant guidelines to assess these uncertainties. In the hot cases, the absolute value of the uncertainty will be added while, in the cold cases, the absolute value of the uncertainty will be subtracted. 2316

D: in case of thermally coupled units, the URP design temperature ranges are defined in Annex 3. 2317

EIDA-2318//

> ***EIDA R-094:*** *The PI shall assess the thermal uncertainties with a 99% confidence level.*

2319



2320

Figure 4.6-3: URP temperatures and Margins requirements

D: The acceptance margin is 5 deg C in addition to the design temperature range. 2321

D: The qualification margin is 5 deg C in addition to the acceptance temperature range. 2322

4.6.3 Thermal Design Requirements

EIDA-2324//

> ***EIDA R-095:*** *The PI shall ensure that the unit thermal design maintain all the internal parts within their allowed limits at any time of the mission, during the unit level acceptance tests, during the unit level qualification tests and during the ground satellite tests.*

EIDA-2325//

> ***EIDA R-096:*** *The PI shall ensure that the thermo-optical and thermal property values used in the thermal design are based on process qualification report(s) or on sample measurement(s) or on the equipment measurement(s) itself. PI shall explicitly identify the cases if this is not possible.*

EIDA-2326//

> ***EIDA R-733:*** *The PI shall ensure that coatings retain required performance (thermo-optical, cleanliness, adhesion, etc) in the applicable space environment.*

EIDA-2327//

> ***EIDA R-097:*** *The PI shall ensure that the thermal design of each unit comply with the temperature ranges, thermal dissipations, CE / HE heat rejection capabilities and survival heater power limits defined in Annex 3 and with the margins specified in paragraph. 4.6.2.*

D: The PI has to consider that the CE and HE temperatures will remain within the specified limits but can cycle in a range of 5 deg C during all the mission phases, due to heaters operations. 2328

EIDA-2329//

> ***EIDA R-098:*** *The PI shall ensure that FM unit electronic components do not exceed the de-rated temperature range during all mission and ground operations including acceptance testing.*

EIDA-2330//

> ***EIDA R-099:*** *The PI shall ensure that QM unit electronic components do not exceed the rated temperature range during all qualification testing.*

EIDA-2331//

> ***EIDA R-100:*** *The PI shall ensure that PFM unit electronic components do not exceed the de-rated temperature range during all mission and ground operations including acceptance and qualification testing.*

EIDA-2332//

> ***EIDA R-101:*** *The PI, when performing the unit thermal analysis, shall regard an analysis uncertainty margin of 10 °C for all electronic parts junction temperatures against the derated Temperature Limits defined for the respective components.*

EIDA-2333//

> ***EIDA R-695:*** *The PI shall ensure that the surface resistance of space-exposed surfaces is less than or equal to 3 kOhm/sq.*

EIDA-2334//

> ***EIDA R-102:*** *The PI shall ensure that, if used, thermal blankets (SLI or MLI) carry at least one conductive layer and that each conductive layer, if MLI are used, is grounded to the structure to avoid electrical charge differential.*

EIDA-2335//

> ***EIDA R-103:*** *The PI shall ensure that, if used, thermal blankets (SLI or the MLI) grounding points are as a minimum in 2 locations (opposite corners), such that no piece of blanket is more than 1m away from a grounding point.*

EIDA-2336//

EIDA R-104: *The PI shall ensure that no blanket (SLI or MLI) exceeds 2 m^2 in size, and that each blanket is individually grounded to the structure.*

EIDA-2338//

EIDA R-105: *The PI shall ensure that the resistance between each grounding point and the structure is lower than 100 mOhm*

EIDA-2339//

EIDA R-106: *The PI shall ensure that the resistance between each grounding point and each point of a conductive layer is lower than 100 Ohm.*

EIDA-2340//

EIDA R-107: *The PI shall ensure that heaters, thermistors and other discrete thermal components are isolated from structure with a resistance higher than 10 MOhm*

EIDA-2341//

EIDA R-108: *(now moved to section 4.7.1.3 Electrical Harness Requirements)*

EIDA-2342//

EIDA R-109: *(now moved to section 4.7.1.3 Electrical Harness Requirements)*

EIDA-2343//

EIDA R-110: *The PI shall ensure that the hemispherical emissivity (εh) of the external finish for coupled units is ≥ 0.80.*

EIDA-2344//

EIDA R-111: *The PI shall ensure that the hemispherical emissivity (εh) of the external finish for the units listed below is ≤ 0.20.*

D: This requirement applies to the following units: EUI-OBS, PHI-OU, SPICE-SOU and METIS-MOU. 10338

4.6.3.1 *Unit Thermal Design Guidelines*

D: The following are thermal design guidelines. 2346

- Junction temperature gradient (difference between part junction temperature and URP) should be minimised. 2347
- Good thermal design for electronic boards should provide the heat flow toward the mounting edge of the board. 2348
- Highly dissipating elements should be placed as close as possible to the baseplate. 2349
- Highly dissipating components should not be placed in the innermost boards. 2350
- Electronic components that require higher thermal conductance than normal assembly methods can support should be mounted with thermally conductive material. 2351
- Stud mount or screw mount devices should be used whenever possible. 2352
- Thermal straps, large tracks and printed circuit boards with metal planes should be considered to reduce hot spots. 2353
- Heat spreading effectiveness of PC board thermal design should be verified by IR thermographic mapping. 2354
- Large baseplate(s) will not have a uniform thermal contact conductance with the spacecraft sink: baseplate area closer to the perimeter bolts will conduct much more efficiently than the centre. 2355
- Where a HE or a CE is required to cool an insulated unit component, the thermal control design should insulate the component from the rest of the unit in order to minimize the heat loads to the HE/CE. 2356

- The PI will design the unit thermal control primarily by passive means (i.e., coating, MLI, conductive paths, insulating washers, etc.), supplemented by heaters and thermistors.The use of devices using moving masses or fluids, such as cryo-coolers, heat pipes or fluid loops will be avoided as far as possible. 2357

4.6.3.2 *General Thermal Interface Design Requirements*

EIDA-2359//

> ***EIDA R-113:*** *The PI shall locate the URP on the unit mounting baseplate or on one of the mounting feet.*

EIDA-2360//

> ***EIDA R-696:*** *The PI of PHI and STIX shall ensure that conductive interface between their filter and respective feedthroughs are able to cope with a conductive fluxes defined in Annex 3.3 while the filter mounting temperatures are within the temperature range defined in Annex 3.3*

4.6.3.3 *Conductive Interfaces*

D: The $\mathbf{T_{CE}}$ temperature ranges are defined in Annex A3. 2362

D: The $\mathbf{Q_{CE}}$ is defined in Annex A3. 2363

D: The $\mathbf{T_{HE}}$ temperature ranges are defined in Annex A3. 2364

D: The $\mathbf{Q_{HE}}$, is defined in Annex A3. 2365

EIDA-2366//

> ***EIDA R-734:*** *The PI shall ensure that the coupled unit defined in Annex 3 are designed to dissipate at least 80% of their thermal dissipation through the baseplate.*

EIDA-2367//

> ***EIDA R-115:*** *The PI shall ensure that the maximum net conductive heat flux is ≤ 500 W/m^2 averaged over the unit total contact area of a coupled unit.*

EIDA-2368//

> ***EIDA R-735:*** *For the coupled units defined in Annex 3, the PI shall ensure that the peak in the heat dissipated via the conductive interface is <= 750 W/m^2 over each 40 mm x 40 mm area of the baseplate.*

D: The base plate heat flux is defined as the ratio of the thermal dissipation versus effective contact area when the unit is in the flight configuration. 2369

EIDA-2370//

> ***EIDA R-736:*** *The PI shall ensure that the maximum temperature difference between any point of the baseplate of coupled units is ≤ 3 K when assuming an ideally isothermal S/C plate and a contact conductance of 300W/m^2/K.*

EIDA-2371//

> ***EIDA R-737:*** *The PI shall ensure that the interface between thermally insulated units and the S/C comply with the maximum heat flux requirement given in Annex 3.*

EIDA-2372//

> ***EIDA R-122:*** *The PI shall ensure that no direct conductive coupling is implemented between the feedthrough and the instrument, unless agreed otherwise.*

4.6.3.4 *Radiative Interfaces*

EIDA-2374//

> ***EIDA R-116:*** *The PI shall ensure that the thermal design of the externally-mounted, thermally insulated units complies with the radiative environment specified in Annex 3.7.*

EIDA-2375//

EIDA R-739: *The PI shall ensure that the thermal design of the internally mounted insulated units complies with the radiative environment specified in Annex 3.1 (indicated with "R").*

EIDA-2376//

EIDA R-740: *The PI shall ensure that the thermal design of the coupled units complies with the radiative environment specified in Annex 3.1*

D: the radiative environment temperatures to be used are identical to the URP values. 2377

D: (deleted) 2378

EIDA-2379//

EIDA R-763: *The RPW PI shall insure that radiative flux from each of the three RPW ANT to a "black body box" is less than 12 W.*

D: The "black body box" represents the spacecraft platform enveloping geometry at a boundary temperature of -20 deg C. 2380

EIDA-2381//

EIDA R-121: *The PI shall ensure that the instrument thermal design is compatible with the absorption of solar flux and IR flux from the feedthrough that falls outside of the edge of the payload pupil.*

D: The size of the light spot is described in paragraph 4.5.7 2382

D: The outer boundary where the light spot can fall is described in paragraph 4.5.7 2383

EIDA-2384//

EIDA R-764: *(deleted)*

EIDA-2387//

EIDA R-765: *(deleted)*

EIDA-2391//

EIDA R-117: *The PI shall design the units with optical aperture(s) taking into account the solar flux in the visible range passing through the relevant feed-through.*

EIDA-2392//

EIDA R-118: *(deleted)*

EIDA-2394//

EIDA R-119: *The PI shall thermally simulate the feedthrough as specified in Annex 3.4- Annex 3.6.*

EIDA-2395//

EIDA R-120: *The PI shall specify the power dissipated by each unit for all mission phases, in terms of:*

· Steady state levels corresponding to all modes of operation of the unit, at BOL and EOL conditions; 2396

· Representative timelines for variable power dissipations, corresponding to all modes of operation of the unit, at BOL and EOL conditions 2397

4.6.4 Thermal Hardware Interfaces

4.6.4.1 *Temperature Sensor Interfaces*

D: Instrument Internal Sensors: Temperature sensors under PI responsibility. They are part of the unit design. 2400

2401

D: The URP temperature of thermally coupled units will be monitored by a sensor installed on the URP under spacecraft TCS responsibility and the reading will be available in the spacecraft telemetry.

D: in case a spacecraft heater line is used to thermally condition a coupled unit, three sensors will be installed on the URP for heater control (majority voting). 2402

D: the temperatures of HE, ME and CE interfaces will be monitored by a sensor installed on the interface under spacecraft TCS responsibility and the reading will be available in the spacecraft telemetry. 2403

D: in case a spacecraft heater line is used to thermally condition a HE, ME or CE interface, three sensors will be installed at the interface for heater control (majority voting). 2404

D: the SRP temperature of insulated units will be monitored by a sensor under spacecraft TCS responsibility and the reading will be available in the spacecraft telemetry. 2405

EIDA-2406//

> ***EIDA R-741:*** *The PI shall procure, install and test 3 thermistors at each control point defined by the PI, for thermally insulated units that require spacecraft control and monitoring of survival heating.*

D: Temperature values will be acquired by the spacecraft. 2407

D: The characteristics of thermistors will be agreed with ESA and the Prime Contractor. 2408

D: For MAG, there are 3 thermistors for each of the 2 MAG sensor units (OBS and IBS). 2409

EIDA-2410//

> ***EIDA R-759:*** *The PI shall, for thermally insulated units, procure, install at the URP location and test 1 thermistor to be used for the monitoring of the thermally insulated units, when operating.*

D: The characteristics of thermistors will be agreed with ESA and the Prime Contractor. 2411

D: This does not apply to RPW-ANT. 12707

D: For MAG this is not applicable, see EIDA R-756 & EIDA R-857. 13235

EIDA-2412//

> ***EIDA R-760:*** *The PI shall, for thermally insulated units, acquire and provide the URP temperature in HK telemetry.*

D: This does not apply to RPW-ANT. 12708

D: For MAG this is not applicable, see EIDA R-756 & EIDA R-857. 13236

EIDA-2419//

> ***EIDA R-744:*** *The MAG PI shall procure, install and test the redundant heaters in the OBS and IBS and the thermistors needed for the control of these heaters.*

D: (deleted) 2420

EIDA-2421//

> ***EIDA R-745:*** *(deleted)*

EIDA-2423//

> ***EIDA R-747:*** *The PI shall route to external connector(s) the thermistors harness which shall be isolated from any other electronics within the unit.*

D: For RPW-ANT these interfaces shall be at the spacecraft skin connectors. 12705

D: For MAG, the thermistor interface is at the connectors of the MAG sensor units (OBS and IBS). The Prime Contractor will provide all harness and connectors from the MAG OBS and IBS to the spacecraft RIU. 13237

4.6.4.2 *Heaters Interfaces*

D: Heaters are classified as follows : 2425

D: Spacecraft TCS Heaters: Heaters under the spacecraft TCS responsibility. They are intended to maintain the interface temperature reference points within the ranges specified in Annex 3. 2427

The Spacecraft TCS heaters are always located externally to an instrument housing or on the supporting spacecraft panel 2428

The TCS heaters may be subject to cycling, typically 5 deg C. 2429

D: Instrument Heaters: Heaters under the PI responsibility intended to support the unit operations profile. They are part of the unit design. 2430

EIDA-2431//

> ***EIDA R-123:*** *The PI shall ensure that instrument heaters are redundant.*

D: Instrument Survival Heaters: Heaters under the PI responsibility intended to support the unit when not powered. The heater power is provided by the spacecraft through a dedicated connector external to the unit. The control of the heater is performed by the spacecraft electronics based on thresholds defined by PI. 2432

D: In the case of MAG see req EIDA R-756 and EIDA R-857 2433

D: In the case of RPW-ANT, see EIDA R-753 12709

EIDA-2434//

> ***EIDA R-748:*** *The PI shall size, procure, install and test redundant survival heaters that are needed to meet the survival and switch-on temperatures limits of externally insulated units in line with the resources specified in Annex 3.2*

D: relevant ECSS provide design rules for sizing the survival heaters. 2435

EIDA-2436//

> ***EIDA R-731:*** *The PI shall ensure that the power density for termofoil heaters is ≤ 0.27 W / cm^2 ; if other types of heaters are used, than 50 % derating shall be applied*

EIDA-2437//

> ***EIDA R-749:*** *The PI shall route to external connector(s) the survival heaters harness which shall be isolated from any other electronics within the unit*

D: For RPW-ANT these interfaces shall be at the root of the antennas 12706

D: For MAG, the heater interface is at a connector on the MAG electronics box (ELB). MAG will provide all harness and connectors from the MAG sensor units (OBS & IBS) to the MAG ELB, but with the exception of the boom harness that is provided by the boom supplier. 13238

EIDA-2438//

> ***EIDA R-750:*** *The PI shall define the temperature thresholds for the survival heaters, to be agreed on a case by case with the Prime Contractor.*

D: The survival heaters will be operated by S/C. 2439

D: In the case of MAG see EIDA R-859. 13239

EIDA-2440//

> ***EIDA R-751:*** *The PI shall ensure that the survival heaters are operated by the 28V bus.*

EIDA-2441//

> ***EIDA R-752:*** *The PI shall ensure that the survival heater lines are sized for a minimum primary bus voltage of 27V.*

EIDA-2442//

> ***EIDA R-753:*** *The RPW-ANT shall use the survival heaters also during operations. These combined survival and operational heaters shall be controlled by the spacecraft independent of whether the RPW-ANT is ON or OFF. In operational mode the operational heater power is counted within the operational power consumption (see EIDA R-145).*

D: The RPW PI shall ensure that the survival/ operational heaters for the RPW-ANT will not require switching at intervals shorter than 64 seconds. 11400

D: The RPW PI shall ensure that the survival/operational heaters for the RPW-ANT are compatible with the EMC requirements during all phases of the mission. 11401

EIDA-2445//

> ***EIDA R-754:*** *The PI shall verify the correct sizing and operation of the survival heaters during the Instrument Thermal Balance and Thermal Vacuum Test.*

EIDA-2446//

> ***EIDA R-755:*** *The PI shall support the Prime Contractor in the verification of the survival heaters during the S/C Thermal Balance and Thermal Vacuum Test.*

EIDA-2447//

> ***EIDA R-756:*** *The PI shall ensure that the survival heaters are entirely separated from any operational heaters that may be required.*

D: MAG is allowed to merge survival and operating heating functions. 2448

D: RPW-ANT is allowed to use combined survival and operational heaters controlled by the spacecraft, see EIDA R-753. 12710

EIDA-2449//

> ***EIDA R-746:*** *The Prime Contractor shall provide a single prime and redundant decontamination heater line for the relevant instruments.*

D: The decontamination heater line will be permanently enabled from 6 hours after launch until 3 months after launch. 2451

D: The total allocation for the decontamination heater line is 50 W, but is included in the 250 W of power allocated for the payloads. 10225

EIDA-2452//

> ***EIDA R-762:*** *The PI shall ensure that, for the software controlled instrument heaters, the heaters' thresholds can be modified via telecommand.*

4.6.4.3 *Hot Element and Cold Element Interfaces*

EIDA-2454//

> ***EIDA R-124:*** *The PI shall ensure that each Cold Element (CE) interface provide a single attachment point at the instrument side for a spacecraft-provided thermal strap that conductively links the instrument to the CE radiator.*

EIDA-2455//

> ***EIDA R-125:*** *The PI shall ensure that each Hot Element (HE) interface provide one or more attachment points for spacecraft-provided thermal straps that conductively link the instrument to the HE radiator.*

EIDA-2456//

> ***EIDA R-126:*** *The PI shall ensure that the I/F-attachment-points are at the instrument structure and mechanically coupled to the instrument.*

D: Subsequent to agreements with ESA and the Prime contractor, intermediate attachment points (e.g. on brackets) may be agreed. In this case, the position and size of this intermediate location must 18682 be unambiguously defined by the PI in an accepted MICD. In such a case, the thermal strap between the instrument structure and this intermediate location shall be under the responsibility of the PI.

EIDA-2457//

> ***EIDA R-127:*** *The PI shall ensure that the I/F-attachment-points, be it on the instrument structure or at the intermediate location, consist of flat surfaces with a size of maximum 60 x 60 mm having 3 to 4 I/F bolts. This information shall be properly documented in MICDs accepted by the Prime contractor.*

D: (deleted - out of date) 2458

EIDA-2459//

> ***EIDA R-128:*** *The PI shall ensure that access to the interface points is sufficient to attach or decouple the thermal interfaces without removing the instrument from the mounting panel.*

D: In order to allow for short thermal straps outside the instrument, and to facilitate instrument 2460
integration, the I/F-points should be at a side-wall as close as possible to bottom (to be understood as side of the instrument feet/brackets), or at a side-bottom-edge.

D: In case it is agreed with ESA that an instrument can make use of a specific thermal strap for 2461
evacuating thermal power at an intermediate temperature, this interface will follow the same rules as for the HE and CE interface. This interface will be referred to as Medium Element (thermal) interface, ME interface.

EIDA-2462//

> ***EIDA R-129:*** *The Prime Contractor shall be responsible for the thermal straps from the thermal interface points of an instrument to the radiators.*

EIDA-2463//

> ***EIDA R-130:*** *The Prime Contractor shall be responsible for the thermal coupling across the interface between the thermal straps and the attachment points at the instruments*

D: The definition of the allowable interface temperatures will relate to these attachment points at the 2464
instruments.

EIDA-2465//

> ***EIDA R-131:*** *The PI shall demonstrate that the attachments of the thermal straps do not cause any stresses on the instrument that affect the instrument alignment by more than 0.5 arcseconds: this shall include all mechanical and thermal environments that the instrument is subjected to during AIV test and mission.*

EIDA-13258//

> ***EIDA R-855:*** *(now moved to section 4.7.1.3)*

EIDA-2466//

> ***EIDA R-767:*** *The PI shall assume a local force and torque generated by the thermal straps on the thermal interface attachment points of respectively 100 N in any direction and 20 Nm in any direction.*

4.6.5 Environment Requirements

4.6.5.1 *AIV Clean Room and Transport Environment*

EIDA-2469//

> ***EIDA R-132:*** *The PI shall design each unit and transport container to be compatible with the following clean-room environmental conditions:*
>
> - Ambient temperature 22°C ± 3°C 2470
> - Relative humidity 55 % ± 10% 2471
> - Cleanliness class 8 2472

- Pressure atmospheric conditions 2473

EIDA-10248//

***EIDA R-839:** The PI shall identify parts, materials and processes which are sensitive to humidity.*

EIDA-2474//

***EIDA R-725:** The PI shall design each unit to be compatible with the following transport container environmental conditions:*

- Ambient temperature 25°C ± 5°C 2475
- Relative humidity < 60 % 2476
- Pressure 10 kPa to 110 kPa 2477
- Rate of pressure change < 2 kPa/sec 2478

EIDA-2479//

***EIDA R-133:** The PI shall identify those units which are sensitive to operating on ground above ambient temperature.*

D: During system functional tests in air, units dissipating inside the S/C can reach considerably higher temperatures than the surrounding ambient temperature. 2480

D: There are no plans to cool down CE or HE on ground. 2481

4.6.5.2 *Launch Thermal and Pressure Environment*

EIDA-2483//

***EIDA R-135:** The PI shall design each unit to cope with the thermal fluxes given below, during launch and ascent.*

· Under fairing 2484

- Duration: 5 min 2485

– Direction non any surface of the satellite 2486

– Flux < 1000 W/m^2 2487

· After fairing jettison (aerothermal) 2488

– Direction: perpendicular to velocity vector 2489

– Duration 20 s 2490

– Flux < 1135 W/m^2 (nominal value) 2491

· Until S/C separation (aerothermal) 2492

– Direction: any 2493

– Duration 1 hour 2494

– Flux Solar + Earth albedo + Earth infrared radiations 2495

· After S/C separation and before S/C acquisition 2496

– Direction any 2497

– Duration up to 4 hours 2498

– Flux Solar + Earth albedo + Earth infrared radiations 2499

D: For most of the instrument units this should not be a design driver, since they are internally mounted. 2500

EIDA-2501//

EIDA R-136: *The PI shall design each unit to cope with a peak pressure decay rate of 6200 Pa/s during ascent and while still under the fairing,*

4.6.5.3 *Cruise and In-Orbit Thermal Environment*

EIDA-2503//

EIDA R-137: *The PI shall analyze the environmental heat loads and heat exchanged with the spacecraft surfaces by considering the following inputs:*

- Deep space temperature -270°C 2504
- Solar intensity at 1 AU SC=1366 ± 3 W/m^2 2505
- Sun collimation Half-cone angle = $\tan^{-1} R_s/d_s$ 2506

EIDA-2507//

EIDA R-139: *The PI shall ensure that each unit survives steady state illumination by direct sunlight at a distance of > 0.95AU.*

D: this requirement applies to OCM type 1 manoeuvres only 18936

D: this requirement applies to those units which are not fully enclosed by the spacecraft 2508

EIDA-2509//

EIDA R-140: *The PI shall ensure that each unit survives illumination by direct sunlight at distances ≥ 0.28 AU in the following conditions:*

- Worst case up to 3.5 degrees, steady state 18683

- Worst case up to 6.5 degrees for 50 seconds 18684

D: this requirement applies to those units which are not fully enclosed by the spacecraft. 2512

D: the worst attitude angle of the relevant unit(s) will be identified by the PIs. 2513

D: the sun angular radius has to be taken into account in the analysis for the definition of the worst case. 2514

EIDA-13253//

EIDA R-856: *The PI shall ensure that each unit survives illumination by direct sunlight at distances ≥ 0.7 AU in the following conditions:*

- *Worst case up to 4.5 degrees, steady state of the +X spacecraft axis with respect to the sunline*

D: this requirement applies to those units which are not fully enclosed by the spacecraft. 13254

D: the worst attitude angle of the relevant unit(s) will be identified by the PIs. 13255

D: the sun angular radius has to be taken into account in the analysis for the definition of the worst case. 13256

D: this requirement covers the case of an AOCS failure during the Venus fly-by. In such situation the accuracy of the sun sensor is negatively affected by the stray-light from the planetary albedo, causing a degraded off-pointing detection threshold. Duration is expected to be up to 3 hours, which is assumed to be equivalent to steady state for the instruments. 13257

EIDA-2515//

EIDA R-831: *The PI shall agree with the Prime Contractor the radiative interfaces and geometry of those units which protrude outside the shadow cone of the heatshield. This also pertains to solar flux that is passed through an instrument. The shadow cone of the heat shield is defined in [NR-42].*

4.6.5.4 *Fly-Bys Thermal Environment*

EIDA-2517//

EIDA R-723: *The PI shall ensure that the instrument survives the environment specified below during fly-by of Earth and Venus*

2518

Solar Constant (W/m²)		Albedo Coefficient (-)		Earth Temperature (K)	
Min	Max	Min	Max	Min	Max
1320	1420	0.2	0.4	245	265

2537

2538

Solar Constant (W/m²)		Albedo Coefficient (-)		Venus Temperature (K)	
Min	Max	Min	Max	Min	Max
2570	2655	0.72	0.78	229	229

D: the S/C attitude will be sun pointing during VGAM and EGAM 2557

4.6.6 Thermal Control Responsibilities

D: The Prime Contractor will : 2559

· design the spacecraft TCS 2560

· define (if required) the SRP location for insulated units in cooperation with the PI 2561

· maintain the coupled unit URP and insulated unit SRP temperatures within design limits during the whole of the mission, and within ground limits during ground operations 2562

· monitor the thermally-coupled unit URP and the thermally insulated unit SRP temperatures as applicable 2563

· provide (if necessary) the cooling capacity at the required temperature levels for the HE and CE interfaces 2564

· monitor the temperature of the HE and CE interfaces on the SC side. 2565

· define, procure and install the necessary thermal control H/W (heaters, thermostats, temperature sensors, heat-pipes) and control S/W that are necessary to comply with all the relevant thermal interface requirements 2566

· provide interface data to all appropriate parties e.g. temperatures, fluxes 2567

· demonstrate the performance of the TCS by analysis and test, including all uncertainties 2568

· provide the resources (monitoring and electrical power lines, control) for the external thermally insulated units survival heaters 2569

EIDA-2570//

EIDA R-141: *The PI shall define and describe the unit internal thermal design with attention to:*

· the thermal control principles 2571

· the baffle (if appropriate), the cold element and the hot elements of the unit 2572

· the thermal interfaces 2573

EIDA-2574//

EIDA R-347: *The PI shall define the URP location of all units, coupled or insulated, and the associated temperature limits of the insulated unit at the URP in the EID-B.*

EIDA-2575//

EIDA R-768: *(deleted)*

EIDA-2577//

EIDA R-142: *The PI shall demonstrate by analysis that for coupled units, the URP temperature is representative of the unit average interface temperature.*

EIDA-2578//

EIDA R-143: *The PI shall provide, in the case of an insulated unit, the analysis characterizing the relationship between the URP and the temperature distribution inside the unit.*

EIDA-2579//

EIDA R-348: *The PI shall define the temperature requirements of critical internal parts in particular those linked to the HE and CE interfaces*

EIDA-2580//

EIDA R-144: *The PI shall maintain the URP of any insulated units and the internal parts within their allowed temperature limits during:*

- the mission i.e. launch and flight, 2581
- the ground phases, 2582
- the unit level acceptance and qualification tests. 2583

EIDA-2584//

EIDA R-349: *The PI shall procure and install the necessary instrument thermal H/W such as MLI, heaters, temperature sensors etc. to maintain the payload unit within the specified temperature limits.*

EIDA-2585//

EIDA R-350: *The PI shall provide all data on the heat dissipated by the unit and report the interface heat flux in all relevant environments.*

EIDA-2586//

EIDA R-351: *The PI shall demonstrate the performance of the unit internal thermal design by analysis and test including uncertainties.*

EIDA-13241//

EIDA R-857: *The spacecraft shall perform the monitoring acquisition of the thermistors in the MAG sensor units (OBS & IBS) and control the combined survival and operational heaters in the MAG OBS & IBS, independent of whether the MAG electronics box (ELB) is ON or OFF. The temperature readings from the thermistors in the MAG OBS & IBS will be made available in spacecraft HK telemetry.*

EIDA-13243//

EIDA R-858: *The MAG PI shall ensure that the in-rush current / charge for the MAG heater line is limited according to the following values :*

current < 20.0 A

charge <3 mC

EIDA-13242//

EIDA R-859: *The Prime Contractor shall control the MAG heaters based on the temperature at a single URP (in OBS or IBS) that can be switched by telecommand. The prime contractor shall set the switching thresholds so that the temperature limits specified by the MAG PI will not be exceeded in either MAGIBS or MAGOBS.*

EIDA-13244//

EIDA R-860: *It shall be possible to update the MAG temperature thresholds by telecommand.*

4.7 *Electrical Interface and Design Requirements*

D: A list of discrete electrical interfaces provided by the spacecraft in listed in Annex A13 9920

4.7.1 Power

4.7.1.1 *Power Generation and Distribution Architecture*

D: The satellite Electrical Power Subsystem (EPS) will generate, condition, control, monitor, and distribute electrical power to the spacecraft users from the regulated bus, and manage battery charge and discharge to fulfil the power demands throughout all mission phases. 2590

D: Independently of the mission phase instrument units will receive regulated 28V D.C. electrical power from the solar array and/or the batteries through the Power Conditioning and Distribution Unit (PCDU). The PCDU will provide the following types of power interfaces normally in cold redundancy: 2591

- Latching Current Limiters (LCL) for instrument power supply and switching. 2592
- Non-Explosive Actuators Interfaces 2596
- Pyro Actuator Interfaces (not applicable for instruments) 2601
- Solid State Switches (TS) for control of heaters 2602

D: Simplified diagram of a typical power interface of an instrument is shown in Figure 4.8-2 at end of Section 4.8.9. 2605

D: For RPW-ANT deployment actuators the PCDU provides at the PCDU output a voltage of 24.5 V +/- 0.5V for a current load up to 1.5A for between 10 and 640 seconds, and an output current protection of 3A +/- 25%. Voltage drop due to harness loss (~1V) must also be taken into account. 13245

4.7.1.2 *Instrument Power Supply*

D: The instrument average power is the maximum power drawn from its dedicated power lines in the worst case voltage conditions (defined in this paragraph) averaged during a period of 5 minutes shifted to any point in time where this average will yield a maximum and does not include peak power defined hereafter. 2607

D: The instrument Long Peak power is the maximum power drawn from its dedicated power lines in the worst case voltage conditions (defined in this paragraph) integrated during a period of 100 ms shifted to any point in time where the integral will yield a maximum. 2608

D: The Short Peak power is the maximum power drawn from its dedicated power lines in the worst case voltage conditions (defined in this paragraph) integrated during a period of 1 ms shifted to any point in time where the integral will yield the maximum. To be defined as a short peak, the power demand will last less than 100 ms. 2609

EIDA-2610//

EIDA R-408: *The PI shall calculate average power value per power line.*

EIDA-2611//

EIDA R-409: *The PI shall calculate long and short peak power values per power line.*

EIDA-2612//

EIDA R-145: *The PI shall ensure that the FM instrument measured average power is compliant with the relevant allocated power specified in the table below (Table 4.7-1).*

2613

Instrument	Allocated Average Power [W]
EPD	27.00
EUI	30.00
MAG	9.00
METIS	28.00
PHI	46.00
RPW	23.00

Instrument	Allocated Average Power [W]
SOLOHI	13.00
SPICE	30.00
STIX	8.00
SWA	31.00
Total	**245.00**

Table 4.7-1:Instrument Allocated Average Power. 2650

D: Allocated average power values are applicable only during the nominal and extended mission phase with the exclusion of eclipses and OCMs. 13246

D: (deleted) 11418

D: (deleted) 11419

EIDA-2651//

__EIDA R-146:__ The PI shall develop, keep up to date and provide the ESA Solar Orbiter Project office with a power budget for each instrument unit specifying the average, the long peak power and the short peak powers over each instrument mode.

EIDA-2652//

__EIDA R-147:__ The PI shall specify, for each unit power budget, the Basic Power.

D: Basic Power is the engineering best estimate without any contingency due to any uncertainty at the time of the issuing of the power budget. 2653

EIDA-2654//

__EIDA R-148:__ The PI shall specify, for each unit power budget, the Nominal Power.

D: Nominal Power is the Basic Power plus contingency due to any uncertainty and/or design maturity considerations at the time of the issuing of the power budget. 2655

EIDA-2656//

__EIDA R-149:__ The PI shall apply the following contingency factors due to uncertainty and/or design maturity:

- > 5 % for “Off-The-Shelf” items (ECSS Category: A / B) 2657
- > 10 % for “Off-The-Shelf” items requiring minor modifications (ECSS Category: C) 2658
- > 20 % for newly designed / developed items, or items requiring major modifications or re-design (ECSS Category: D). 2659

EIDA-2660//

__EIDA R-150:__ The PI shall specify, for each unit power budget, the power margin

D: The Power Margin is the difference between the total instrument Nominal Power [i.e. sum of unit(s) Nominal Powers] and the instrument allocated power 2661

D: Power margin philosophy is specified in EID-A R-051 2662

EIDA-2663//

__EIDA R-151:__ The PI shall ensure that the instrument switches-on by receiving the regulated voltage input plus a dedicated HV-HPC telecommand which acts on an Instrument internal switch.

D: This should be a solid state switch for magnetic cleanliness. 2664

D: This approach ensures that it will be always possible to power off the Instrument in case either a LCL or an internal switch fails closed. 2665

EIDA-2667//

EIDA R-792: *Instrument shall remain off at LCL switch on and until commanded by the pulse command to switch on.*

D: This is to ensure that the in the power on sequence , first the power is applied and then a command to switch on the instrument is sent. 2668

EIDA-2669//

EIDA R-152: *The PI shall ensure that the instruments operate with nominal performance within the following steady state voltage limits provided by the PCDU:*

- Power Bus Voltage = 28 V: 2670
  - o Min: 26 V 2671
  - o Max: 29 V 2672

D: This applies for both Main and Redundant Lines. 2673

EIDA-2674//

EIDA R-153: *The PI shall ensure that each unit safely survive any standing or fluctuating voltage in the full range 0 V to 32 V of the power lines.*

EIDA-2675//

EIDA R-154: *The PI shall ensure that each unit survives without failure or performance degradation, in case of failure in the power sub-system which will generate a transient of 1 msec and 33 V.*

EIDA-2676//

EIDA R-155: *The PI, in case of power off/on cycling, shall ensure that instrument computers reset and restart operations in line with **EIDA R-270**.*

EIDA-8959//

EIDA R-822: *The PI shall treat HV within their instrument that could potentially be encountered by personnel as a critical hazard and shall define the HV in the safety and AIT plans with appropriate protections e.g. arm and fire commands for the HV supplies, HV enables/ disables.*

D: HV is defined as > 50 V. 8960

4.7.1.3 *Power Interface Requirements*

EIDA-2678//

EIDA R-156: *The PI shall design the instrument power interfaces assuming that the spacecraft will provide two independent power lines routed via two dedicated connectors.*

D: In case of failure, both the nominal and the redundant power lines may be applied simultaneously. 2679

EIDA-2680//

EIDA R-157: *The PI shall design the power input interface of the instrument to protect against failure propagation, in order to avoid loss of one power source by a failure in the other power source.*

EIDA-2681//

EIDA R-158: *The PI shall ensure that the instrument survives an instantaneous short circuit occurring on the external power line.*

EIDA-2682//

EIDA R-160: *The PI shall ensure that each unit survives an instantaneous intentional or unintentional switch-off on the external power line at any time in any configuration without degradation of nominal performance.*

EIDA-2683//

EIDA R-162: *The PI shall ensure that this initial electrical status is safe (i.e. no degradation of nominal performance, caused if this initial electrical status is kept for an unlimited time) .*

EIDA-2684//

EIDA R-163: *The Prime Contractor shall ensure that the PCDU output line LCL limits the output current to the values listed in the table below (Table 4.7-2), within 50µs after any fault load conditions.*

D: See interface diagram in para 4.8.9 2685

D: The LCL class allocation for flight is shown in Table 4.7-3. 12954

2686

LCL	Nominal Current	Output current limit (I_{TRIP})	Lcl Trip-Off Time
Class 1	≤1.0 A	1.08 - 1.32 A	9 - 20 msec
Class 2	≤2.0 A	2.16 - 2.64A	9 - 20 msec
Class 3	≤3.0 A	3.24 - 3.96 A	5 - 20 msec
Class 5	≤5.0 A	5.40 - 6.60 A	4 - 8 msec
Class 6	≤6.0 A	6.48 - 7.92A	3 - 8 msec

Table 4.7-2: LCL nominal current and maximum limited current 2707

12856

Item	Description	Flight LCL
EPD	EPD-A_LCL	2
EPD	EPD-B PWR_LCL	2
EUI	EUI-A_LCL	2
EUI	EUI-B_LCL	2
MAG	MAG-A_LCL	1
MAG	MAG-B PWR_LCL	1
METIS	METIS-A_LCL	2
METIS	METIS-B_LCL	2
PHI	PHI-A_LCL	2
PHI	PHI-B_LCL	2
RPW	RPW-A_LCL	2
RPW	RPW-B PWR_LCL	2
SoloHi	SoloHi-A_LCL	1
SoloHi	SoloHi-B_LCL	1
SoloHi	SoloHI-A_Deploy_LCL	6
SoloHi	SoloHI-B_Deploy_LCL	6
SPICE	SPICE-A_LCL	2
SPICE	SPICE-B_LCL	2
STIX	STIX-A_LCL	1
STIX	STIX-B PWR_LCL	1
SWA	SWA-A_LCL	2
SWA	SWA-B PWR_LCL	2

Table 4.7-3: LCL class allocation for flight. 12953

EIDA-2708//

EIDA R-800: *The PI shall insure that the instrument input has a differential inductance ≤ 500 microH*

D: this requirement is applicable to all LCL classes listed in Table 4.7-2 above 2709

EIDA-2710//

EIDA R-165: *The PI shall ensure that at switch-on/off and for any mode change, the inrush charge (current x time) to any unit, with a power bus raised to 28 V at a rate of 600 V/msec, is limited to:*

Max peak current (I_{peak}) < 20 A 2711

dI/dt < 2 A/ µsec 2712

Max input charge (Q_{max}) ≤ 3msec I_L 2713

D: I_L is the LCL class 2714

EIDA-2715//

EIDA R-166: *The PI shall measure the I_{peak}, the dI/dt and inrush charge considering the maximum and the minimum bus voltage to the loads*

EIDA-11420//

EIDA R-847: *The PI shall measure the I_{peak}, the dI/dt and inrush charge for the following cases:*

· When the instrument is connected to a LISN and switched on using an external (test) relay. 11421

· If the instrument includes an internal power-on switch, when the instrument is connected to a LISN and this internal switch is operated. 11423

· When any other significant transient is expected to be generated, as per PI's assessment. 11424

EIDA-2716//

EIDA R-167: *The PI shall measure the inrush current according to the following set-up*

· positive power line of each user connected to LCL. 2717

· current probe connected near the load 2718

· load connections with a limited length. 2719

· voltage measure performed near the LISN outlet; performed for engineering analysis / investigation. 2720

EIDA-2721//

EIDA R-168: *The PI shall ensure that the unit is powered by using a Line Impedance Stabilisation Network (LISN) with an external bounce-free relay (e.g. laboratory mercury relay) installed between the LISN and the user on the positive power line, as shown in Figure 4.7-1 below.*

D: The PI is responsible for providing the LISN and switch. 11395

2723

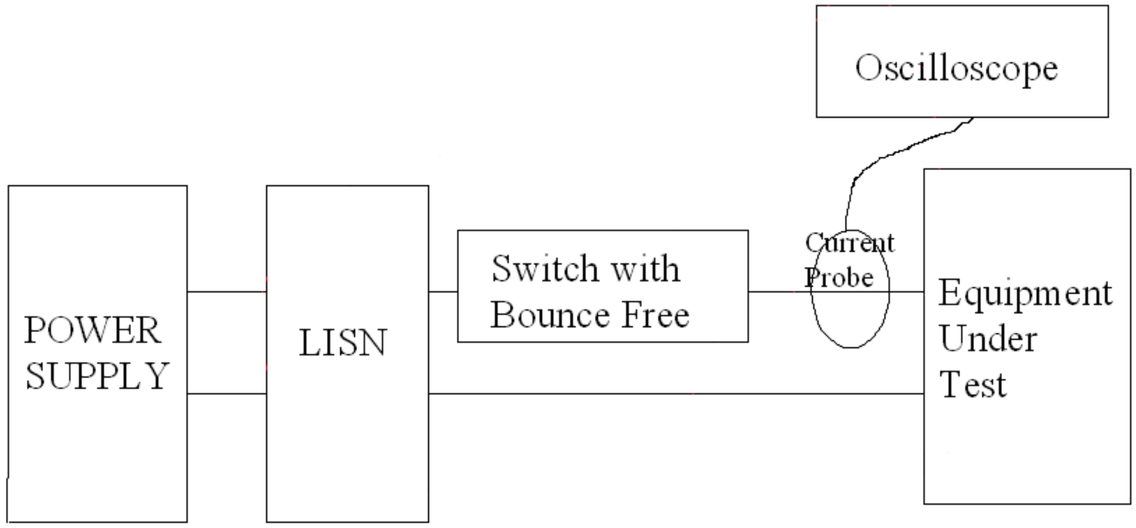
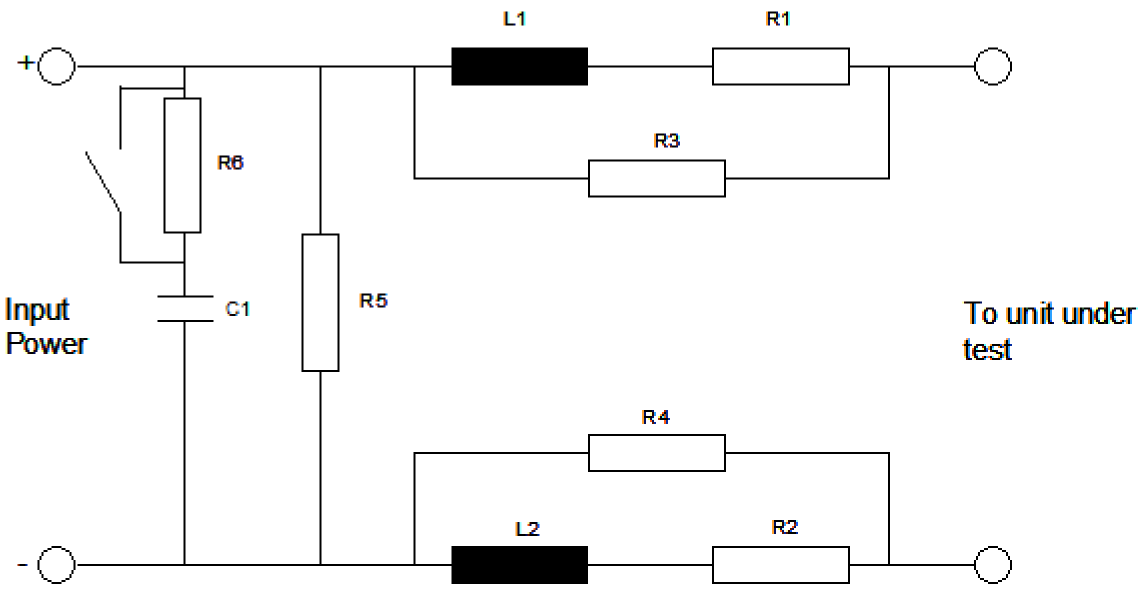


Figure 4.7-1: In-rush Current Test Setup. 2724

D: The characteristics of the LISN are defined below: 2722

11396



R1 = R2 = 0.3 Ohm +/- 5%

R3 = R4 = 50 Ohm +/- 5%

R5 = 50k Ohm +/- 5%

R6 = 10 Ohm precharge resistor (details decided by PI)

C1 = 20 mF +/- 5%

L1 = L2 = 2 uH +/- 5%

D: The values are fully applicable for users with a current load of 1A or less. For higher power loads the low frequency impedance may be modified by agreement with ESA/Prime. 11398

D: R6 is to be designed to ensure compatibility with the power supply. It is to be removed from the circuit for the period of testing by means of the parallel switch.

EIDA-2725//

> ***EIDA R-169:*** *The PI shall ensure the stability of current limiters inside the instruments for the actual load characteristics.*

D: All power lines are protected by LCLs. The use of current limiters at this interface should be avoided in order to prevent oscillations. The intended use of current limiters will be agreed with ESA. 2726

D: If current limiters are used within an instrument, requirements R-170 and R-171 shall apply. 2727

EIDA-2728//

> ***EIDA R-170:*** *The PI shall verify the stability of current limiters by analysis under worst case conditions*

EIDA-2729//

> ***EIDA R-171:*** *The PI shall test the stability of current limiters.*

EIDA-2730//

> ***EIDA R-172:*** *The PI shall ensure that the phase margin of converters and regulators not belonging to the spacecraft power system are at least 50° and the gain margin is at least 10 dB for worst case end–of–life conditions with representative loading.*

D: The Figure 4.7-2 below shows the maximum impedance at the input to the instruments. For Solar Orbiter only the red curve below for the regulated power bus is relevant. 2731

2732

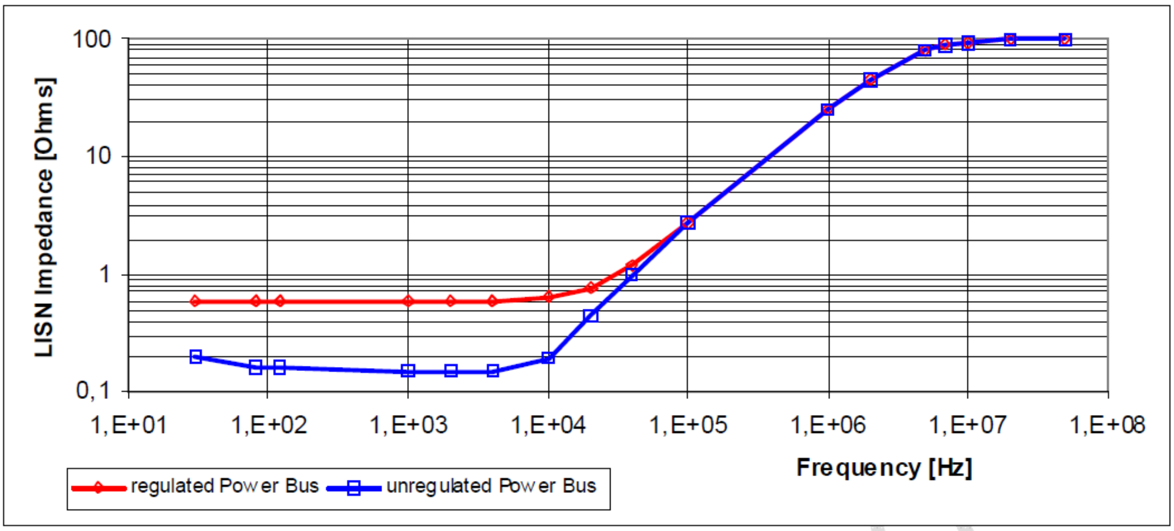


Figure 4.7-2: Output Impedance for unregulated and Regulated Bus (worst case). 2733

EIDA-2734//

> ***EIDA R-173:*** *The PI shall ensure that the cross over of the 0 dB line in open loop measurement is in one single point only.*

EIDA-2735//

> ***EIDA R-174:*** *The Prime Contractor shall ensure that the power distribution system does not generate a ripple voltage at the main bus or at other distribution points with a peak-to-peak magnitude greater ±250mVp.*

EIDA-2736//

> ***EIDA R-175:*** *The Prime Contractor shall ensure that the power distribution system does not generate spike with peak greater than ±3Vp.*

D: The spikes are defined as transitory high frequency oscillations with duration lower than 10ms and without a repetitive period. 2737

EIDA-2738//

EIDA R-176: *The PI shall ensure that for all conducted emission and susceptibility tests on subsystem and unit level a LISN is used, simulating the Solar Orbiter primary power bus impedance.*

EIDA-2739//

EIDA R-177: *The PI shall use, if necessary, only Non-Explosive Actuators, NEAs (i.e. no explosive pyro actuators).*

EIDA-2740//

EIDA R-178: *The PI shall ensure that the isolation between primary and secondary power lines in the instrument is ≥ 1 MOhm Ohms.*

EIDA-2741//

EIDA R-793: *The PI shall taken provisions , for equipments supplying secondary power to sensor units, that this unit can be powered without the presence of the sensor units.*

D: During AIV activities it may be necessary for partial integration of an instrument and testing of individual units done separately. 2742

D: It is recommended to protect against short circuits on these secondary outputs. 2743

18639

EIDA-18644//

EIDA R-855: *The Principal Investigator shall provide the harnesses between the instrument electronics box and the sensor units or boom root using one of the following options for the overshields, after agreement with ESA: Instruments shall specify in their EID-B which option they have agreed to implement with ESA.*

(a) Aluminium tape is preferred, but results in a rigid harness.

(b) Silver-over-copper braid with outer aluminised kapton wrap is allowed. The wrap is required to prevent contamination by particle shedding. The harness shall be baked out before the wrap is put on.

(c) For exceptionally long harnesses that still have rigidity issues with option (b), the instrument supplier may deliver a cable with silver-over-copper braid that is clean and bagged.

D: *for point (c) the Prime Contractor will apply the aluminised kapton wrap during integration to the spacecraft.*

In all 3 options, the instrument team shall bake out the harness.

D: The boom harnesses will be provided by the Prime Contractor, see description under requirement EIDA R-586. 18643

EIDA-18640//

EIDA R-108: *The PI shall ensure that each unmated connector is completely capped with conductive covers*

EIDA-18641//

EIDA R-109: *The PI shall ensure that no dielectric parts of disconnected electrical conductors are exposed to space*

4.8 *Data Management Interface and Design Requirements*

4.8.1 General

D: The Data Management Subsystem (DMS) manages all the data associated with the operation of the spacecraft. The main supported functionalities are: 2746

- Mission control (including Mission Timeline, FDIR, OBCPs) 2747

· Receiving and Dispatching Telecommands (from both Ground and onboard sources) 2748

· Platform S/Ss management (including power, thermal and TTC) 2749

· Collecting, storing and transmitting to Ground all telemetry data (i.e. science data and non-science data originated both from the Platform and the Instruments). 2750

· Time Management, including onboard time distribution (Service 9) 2751

D: Non-science data include the following: Housekeeping and Diagnostic data (service 3); Event Reports (Service 5), TC Acknowledgement Reports (Service 1) and other specific reports and memory dumps (Service 6). 2752

D: The DMS consists of the On-Board Computer (OBC), the Solid State Mass Memory (SSMM) and the SpaceWire point-to-point network. 2753

D: The Figure 4.8-1 below shows the basic DMS architecture 2754

2755

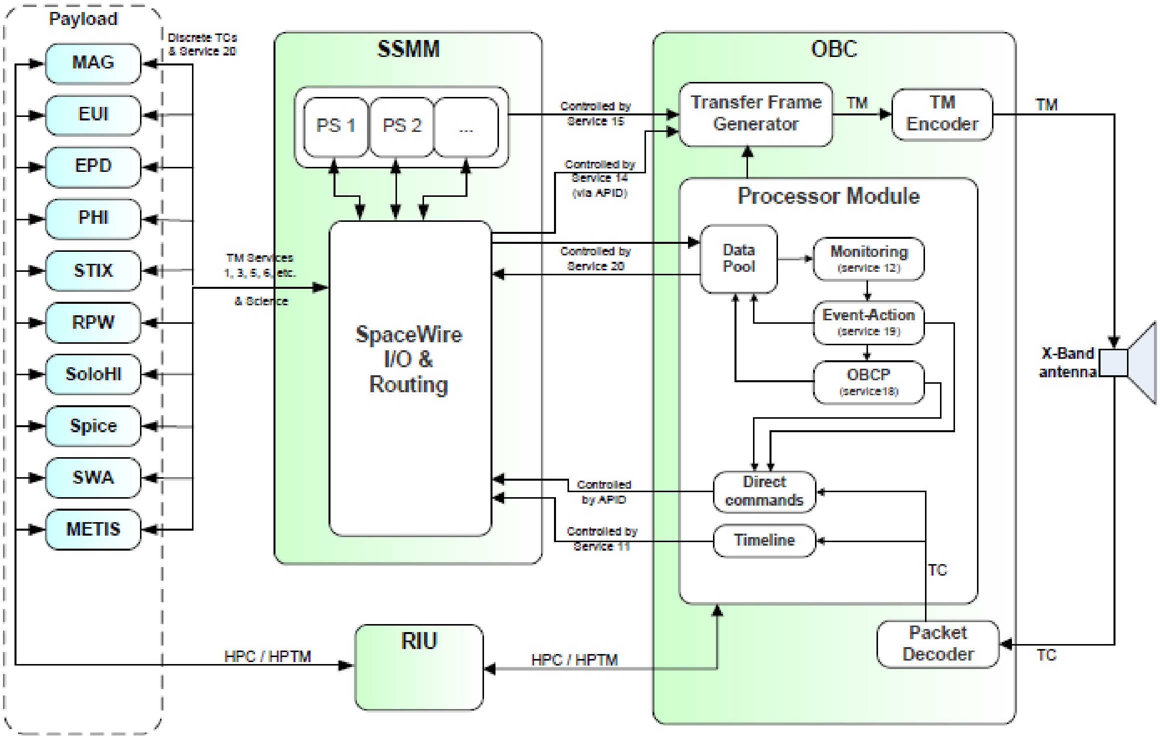


Figure 4.8-1: Basic DMS architecture. 10406

EIDA-2756//

> ***EIDA R-179:*** *The PI shall ensure that all instrument data to be routed from/to the OBC and/or from/to the SSMM are formatted as TM- or TC-packets according to [NR-28].*

EIDA-2757//

> ***EIDA R-180:*** *The PI shall ensure that the instrument comply to the associated TM-/ TC-Packet Services specified as mandatory for the payload in [NR-28].*

D: The TM-/ TC-Packet Services consist of a minimum subsets for each service, which is mandatory, as well as optional generic service-extensions. Global requirements about applicability and use of these subsets for the Solar Orbiter spacecraft are given [NR-28]. 2758

D: The mandatory services are as follows: 2759

· Service 1: Telecommand Verification Service 2760

· Service 3: Housekeeping and Diagnostic Data Reporting Service 2761

2762

- Service 5: Event Reporting Service
- Service 6: Memory Management Service 2763
- Service 9: Time Management Service 2764
- Service 17: Test Service 2765
- Service 20: Information Distribution Service 2766
- Service 21: Science Data Transfer 2767

EIDA-2768//

> ***EIDA R-397:*** *The PI shall comply with the specifications for an optional or offered Service, as specified in the Solar Orbiter Operations Requirements Document [NR-27], if those Service(s) are adopted.*

EIDA-2769//

> ***EIDA R-181:*** *The PI shall be in general compliant to and implement the specific physical interface between the DMS and the instrument using SpaceWire links according to ECSS-E-ST-50-12C (SpaceWire - Links, nodes, routers and networks), [NR-16]*

D: The MIL-STD 1553 bus is reserved for platform subsystems. 2770

D: All commands and TM data relevant for the instruments are carried in cargo data fields as defined for SpaceWire, using the 'CCSDS packet transfer protocol' as defined in ECSS-E-ST-50-53C (SpaceWire protocols) [NR-18]. This includes potential inter-instrument-messages. 2771

EIDA-2772//

> ***EIDA R-182:*** *The PI shall be compliant to the 'CCSDS packet transfer protocol' [NR-18].*

EIDA-2773//

> ***EIDA R-183:*** *The PI shall implement own computing functions, without relying on any Orbiter OBC support for all required functionality not covered by the services stated in [NR-27]*

EIDA-2774//

> ***EIDA R-184:*** *The PI shall implement at least the following modes (modes naming only given for illustrative purposes):*
>
> - OFF 2775
> - STANDBY/SAFE 2776
> - CONFIGURATION 2777
> - OPERATIONAL 2778

D: In the OFF mode the instrument is not powered. The Payload will be in OFF mode during launch. Status telemetry (e.g temperatures measured at the SRPs or at the URPs, as agreed on a case by case basis) will be monitored through the RIU. 2779

D: The STANDBY/SAFE mode is a safe mode in which the instrument is powered but in a Safe configuration, which can be maintained indefinitely (e.g. main control unit powered but detector assembly off). In this mode the instrument will generate only non-science telemetry. The configuration of the instrument in Safe mode will be unambiguous (i.e. only one defined configuration). 2780

D: The CONFIGURATION mode shall be used for required operations to activate the instrument. In this mode science data as well as non-science may be generated, depending on the instrument configuration (e.g. detectors activated or not). 2781

D: The OPERATIONAL mode is the mode in which the instrument is fully operative and generates non-science as well as science data 2782

D: For TC packets and TM packets the APID is broken up into a Process ID (PID) [7 bits] and Category ID (Cat) [4 bits]: see [NR-28] 2783

D: The ranges and allocations for these will be defined in [NR-28]. 2784

D: The Process Identifiers (PIDs) are assigned to each instrument in [NR-28]. 2785

4.8.2 Instrument Commanding

EIDA-2799//

> ***EIDA R-398:*** *The PI shall comply with the requirements regarding commanding as specified in section 2.1.4.2 of [NR-27]*

EIDA-2800//

> ***EIDA R-185:*** *The Prime Contractor shall ensure that the spacecraft DMS processes (i.e. check the format and protocol validity) and distributes both ground and on-board generated/stored commands to each instrument according to [NR-28].*

EIDA-2801//

> ***EIDA R-186:*** *The PI shall ensure that telecommands are sent to each instrument as Telecommand Source Packets according to [NR-28], with a maximum length of 228 octets, corresponding to 216 octets of application data.*

D: This is to ensure all instrument commands can be handled as time-tagged (Service 11 requires 8 Octets) commands for which executable TC packets become encapsulated in time-tagged TC packets. 2802

D: The PI will agree with the SO Project Office the maximum telecommand rate to be supported by the instrument 2803

D: presently the maximum telecommand rate is 10 telecommands /sec, TBC. 2804

D: The PI will agree with the SO Project Office the timing constraints in commanding the instrument 2805

EIDA-2806//

> ***EIDA R-728:*** *The PI shall ensure that the instrument can fulfil its scientific objective with Telecommand rate of 150 Telecommand / day from ground/ MTL.*

D: The actual number of TCs received by the instrument may be greater due to e.g. execution of OBCPs. 10335

EIDA-2807//

> ***EIDA R-730:*** *Removed*

D: removed 2808

EIDA-2809//

> ***EIDA R-187:*** *The PI shall validate, prior to their execution, the received telecommands by*

- Checking the correct TC packet APID, Type, Subtype 2810
- Checking that the Telecommand is valid vs the current mode and/or state of the instrument 2811

EIDA-2812//

> ***EIDA R-188:*** *The PI shall manage and perform their nominal mode-transitions without needing more than one telecommand.*

EIDA-2813//

> ***EIDA R-189:*** *The PI shall implement the execution of vital instrument functions by 2 separate commands (i.e. arm and fire).*

D: Vital instrument functions are those functions that, if not executed or wrongly executed, could cause permanent degradation), 2814

EIDA-2815//

__EIDA R-190:__ The PI shall ensure that telecommand are available in order to command all instruments units, functions and devices under all nominal and foreseen contingency conditions.

EIDA-2816//

__EIDA R-191:__ The PI shall ensure that each telecommand packet contain one and only one telecommand function, as specified in [NR-28].

EIDA-2817//

__EIDA R-192:__ The PI shall ensure that the on-board reception, processing and execution of telecommand does not affect other independent instrument processes.

EIDA-2818//

__EIDA R-399:__ The PI shall insure that if a telecommand is found to be invalid, the Instrument generate an error report in the form of a Service 1 or Service 5 packet, in line with the specifications in [NR-27].

EIDA-2819//

__EIDA R-400:__ The PI shall insure that mode transitions to Safe mode from a higher mode will be implemented for each instrument by means of a single telecommand to the instrument, which will effect the complete Safe configuration of that instrument, including individual units and subassemblies.

D: The Safe Mode command should be executed immediately irrespective of the instrument mode or of any other ongoing command execution. 2820

EIDA-2821//

__EIDA R-401:__ The PI shall implement __c__ommand counters for accepted and rejected telecommands. __D:__ The value of these counters will be reported in periodic telemetry. In addition, the SSC values of the last accepted and last rejected telecommand will be reported in telemetry.

EIDA-2822//

__EIDA R-402:__ The PI shall ensure that the execution of every telecommand is verifiable through a resulting change in the value of a Telemetry parameter."

4.8.3 Instrument Telemetry

EIDA-2824//

__EIDA R-403:__ The PI shall comply with the requirements regarding telemetry as specified in the section 2.1.4.3 of the [NR-27].

EIDA-2825//

__EIDA R-193:__ The PI shall ensure that telemetry is routed from the instrument as Telemetry Source Packets according to ECSS-E-70-41A, [NR-19], with a maximum length of 4112 octets, corresponding to 4096 octets of application data.

EIDA-2826//

__EIDA R-194:__ The PI shall ensure that the FM instrument average data rate for telemetry (Science + Non-Science TM) is compliant with the relevant allocated telemetry rates specified in the table below (Table 4.8-1)

2827

Instrument	Allocated Data Rate [kbps]
EPD	3.6
EUI	20.5
MAG	1.3
METIS	10.5

Instrument	Allocated Data Rate [kbps]
PHI	20.5
RPW	5.5
SOLOHI	20.5
SPICE	17.5
STIX	0.7
SWA	14.5
Reserve	4.9
Total	**120**

Table 4.8-1: Allocations for Average Data Rate Telemetry. 2864

D: The data rate will be determined at the TM-TC-packet-interface (i.e. including Packet-Header/ -Trailer-overhead, excluding SpaceWire-protocol, or other coding-overhead). This rate is also referred to as Information Rate. 2865

D: For In-Situ Instruments the specified average data rates are available over one science-orbit (about 168 days) 2866

D: For Remote-Sensing Instruments, the specified average data rates are available over the duration of the three R-S Science Windows (30 days per orbit). 2867

D: Data Rate margin philosophy is specified in EID-A R-051 2868

D: For spacecraft memory sizing reference scenarios, the data rate can be assumed to be constant and equal to the average. 2869

D: The 'reserve' data rate specified in the table will be available throughout the orbit. 11425

EIDA-2870//

> ***EIDA R-195:*** *The PI shall generate, during initialisation and during Stand-by / Safe mode, periodic HK TM-packets at a rate of 50 bps maximum*

EIDA-2871//

> ***EIDA R-720:*** *The PI shall generate, in any mode different from initialisation and Stand-by / Safe mode, periodic HK TM-packets at a rate of 500 bps maximum.*

D: This excludes the inter-instrument periodic packets as they are not sent to ground. 2872

EIDA-2873//

> ***EIDA R-729:*** *The PI shall generate, in any mode different from initialisation and Stand-by / Safe mode, non-science TM packets that are routed to the OBC, at a rate of 50 bps maximum and a rate of 450bps maximum of packets routed to the SSMM.*

D: This excludes the inter-instrument periodic packets as they are not sent to ground. 2874

D: The overall allocated data rate for each instrument stays constant irrespective of the total amount of non-science packets. 2875

EIDA-2876//

> ***EIDA R-196:*** *The PI shall ensure that no science telemetry is generated during initialisation and during Stand-by / Safe mode*

EIDA-2877//

> ***EIDA R-197:*** *The PI shall support the generation of periodic HK-telemetry at any time they are switched on.*

D: Any instrument may be switched off as needed for compliance with available spacecraft resources, and in line with operational agreements. 2878

EIDA-2879//

EIDA R-198: *The PI shall provide ground with the data, in raw form, required for the execution and analysis of all instrument nominal operations and foreseen contingency operations. These data shall be included in non-science telemetry packets.*

EIDA-2880//

EIDA R-199: *The PI shall ensure that the availability of telemetry information is compatible with the required response times which have been identified for any control loops.*

EIDA-2881//

EIDA R-200: *The PI shall provide telemetry data to the ground such that complete and unambiguous assessment of the instrument status and functional (non-science) performance is possible without the need for reference to the telecommand history to interpret the data.*

EIDA-2882//

EIDA R-201: *The PI shall ensure that the Instruments can fully operate, compatibly with the available resources.*

D: If necessary, data compression algorithms can be used for science data only to fulfil the allocated telemetry bandwidth. 2883

EIDA-2884//

EIDA R-202: *The PI shall run these algorithms in the instrument Central Processing Unit (CPU).*

EIDA-2885//

EIDA R-203: *The PI shall include in the periodic housekeeping (HK) telemetry data all parameters necessary to have full observability of the instrument status and operations (e.g. health status, operating mode, SW parameters, etc).*

EIDA-2886//

EIDA R-204: *The PI shall provide instrument HK TM packets with a frequency ≤ 1Hz.*

D: This requirement does not apply to the inter-instruments communication packets, described in paragraph 4.8.5 2887

EIDA-2888//

EIDA R-205: *The PI shall provide unit(s) status information in telemetry from direct unit(s) measurements, rather than from secondary effects.*

EIDA-2889//

EIDA R-206: *The PI shall ensure that the values of telemetry parameters are self-contained.*

EIDA-2890//

EIDA R-207: *The PI shall transmit the value of a telemetry parameter in contiguous bits within one packet.*

EIDA-2891//

EIDA R-208: *The PI shall ensure that, if compression is applied, all data also in raw format can be downloaded.* ***D:*** *This implies the need to have the possibility to disable the compression functionality*

4.8.4 Onboard Time Distribution

EIDA-2893//

EIDA R-405: *The PI shall comply with the requirements regarding Timing as specified in section 2.1.4.4 of [NR-27]*

2894

D: The DMS maintains a time code pattern as Spacecraft Elapsed Time (SCET), according to the format in the table below (Table 4.8-2): 2895

Coarse Time				**Fine Time**	
0 7	8 15	16 23	24 31	32 39	40 47
Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
2^{31} 2^{24}	2^{23} 2^{16}	2^{15} 2^{8}	2^{7} 2^{0}	2^{-1} 2^{-8}	2^{-9} 2^{-16}

Table 4.8-2: DMS Time Code Pattern. 2920

D: The SCET is considered as the Central Time Reference (CTR) and it is used as on-board reference for the correlation of time on Ground. 2921

D: The Central Time Reference (CTR) is maintained at spacecraft level and distributed to the Instruments in order to synchronize instruments with the DMS and AOCS and allow instruments to time-stamp their telemetry packets. 2922

EIDA-2923//

> ***EIDA R-209:*** *The Prime Contractor shall distribute the system time, CTR, with an accuracy of 350 µs.*

D: A systematic, known bias can be excluded from this requirement. 2924

4.8.4.1 Instrument Time Synchronisation

EIDA-10211//

> ***EIDA R-834:*** *The PI shall ensure that the Payload Instrument time synchronisation is performed by using the SpaceWire Time Code Protocol specified in [NR-16].*

D: The Time Code will contain the 6 Least Significant Bits of the seconds field the SCET. 10212

EIDA-10213//

> ***EIDA R-835:*** *When an instrument receives a valid SpaceWire Time Code, and when no Service 9 TC has been received since the last Time Code, the PI shall:*
>
> - *zero the sub-seconds field of its local time*
> - *make any necessary adjustments to ensure that its local time is synchronised with system time.*

D: The Time Code contents may be used to update the local time or as a consistency check 10214

D: See below for operation when a Service 9 TC has been received. 10215

EIDA-2925//

> ***EIDA R-210:*** *Removed*

4.8.4.2 Instrument Time Setting

D: In order to update all of the instrument local time, an enhance protocol is provided using Service 9 Telecommands and SpaceWire Time Codes is implemented. 10216

EIDA-10219//

> ***EIDA R-836:*** *The PI shall ensure that when the DMS sends a time synchronisation (Service 9) TC to each instrument containing the CTR (for the purposes of instrument time setting), the CTR is applied on receipt of the next SpW time code.*

D: This allows the synchronisation of the instrument local time 10220

EIDA-10221//

EIDA R-837: *The PI shall ensure that following receipt of the Service 9 TC, at receipt of the next SpW time code the instrument shall:*

- *zero the sub-seconds field*
- *ensure that its local value of Coarse Time (bits 0 to 31) is equal to the value delivered by the DMS in the TC packet.*

EIDA-10222//

EIDA R-838: *The Prime Contractor shall ensure that for instrument time setting, the service 9 TC is received by each instrument a minimum of 300 msec prior to the corresponding time code.*

D: It is accepted that a Service 9 TC arriving less than 300 msec before the corresponding time code may lead to an incorrect time update. 10223

EIDA-2927//

EIDA R-211: *Removed*

EIDA-2928//

EIDA R-212: *Removed*

EIDA-2930//

EIDA R-213: *The PI shall increment its local time autonomously.*

EIDA-2931//

EIDA R-214: *The PI shall set, at instrument switch on, the MS bit of the instrument time field to 1 and all other bits of the instrument time field to 0.*

EIDA-2932//

EIDA R-788: *The PI shall set, on successful execution of the TC9 Synchronise command, the MS bit of the instrument time field to 0.*

EIDA-2933//

EIDA R-789: *The PI shall set, if no SpaceWire timecode has been received for 1 minute, the MS bit of the instrument time field to 1.*

EIDA-2934//

EIDA R-215: *The PI shall report, on request, the instrument local time.*

D: Further details are defined in reference NR-28 (service 9) 2935

4.8.5 Inter-instruments communication

D: Two types of potential direct inter-instrument communication may be implemented after approval by the agency: 2937

· Periodic inter-instrument messages, allowing receiving instruments to adapt their scientific settings in near real-time. 2938

· Sporadic event-trigger-information-messages, on which receiving instruments may react with major changes of their instrument configuration. 2939

A more detailed description of inter-instrument communication is provided in [IR-19]. 2940

EIDA-2941//

EIDA R-216: *The Prime Contractor shall ensure that:*

2942

· Messages from the OBC to any instrument (e.g. service 20 packets and TCs in general) is not delayed by more than 250 millisecond in any nominal or non-nominal instrument situation

· Housekeeping- and science-telemetry from any instrument is not delayed by more than 250 millisecond in any nominal or non-nominal instrument situation. 2943

EIDA-2944//

> ***EIDA R-218:*** *The PI shall ensure that the exchange of periodic inter-instrument messages is not used for instrument reconfigurations or mode changes with impact on power consumption or thermal dissipation.*

D: Changes in data generation rate have to stay within the boundaries agreed for the current instrument configuration. 2945

EIDA-2946//

> ***EIDA R-219:*** *The PI shall ensure that periodic inter-instrument messages and sporadic event-trigger-information-messages shall be routed to the OBC of the spacecraft for re-rerouting to a predetermined list of receiving instruments.*

D: The requirement addresses 'messages'; not TM/TC-packets. The requirement can be fulfilled by the OBC-SW through extracting parameters from HK- or Event-packets, which go to the data pool, and which become re-compiled into S20-packets, which are re-routed back to the instruments. 11427

EIDA-13248//

> ***EIDA R-861:*** *The PI shall ensure that the instrument can disable (and enable) both its reaction to Service 20 triggers, and its reaction to its own internal burst trigger when present.*

4.8.6 Solid State Mass Memory

EIDA-2949//

> ***EIDA R-220:*** *The Prime Contractor shall store all the scientific data generated by the instruments, as well as the housekeeping data and non-periodic report-data in a Mass Memory for their downloading.*

D: Immediate transmission to ground of the stored data is not guaranteed during nominal science operation. 2950

EIDA-2951//

> ***EIDA R-221:*** *The PI shall ensure that the instrument design complies with the data storage volume specified in the table (Table 4.8-3) below:*

2952

Instrument	Allocated Data Storage Volume per orbit [Gbits]
EPD	18.7
EUI	53.2
MAG	6.7
METIS	27.2
PHI	53.2
RPW	28.5
SOLOHI	53.2
SPICE	45.4
STIX	1.8
SWA	75.2
Total	**363.1**

Table 4.8-3: Instrument Data Storage Allocated Volume. 2992

D: In-Situ instruments SSMM memory allocation based on storage capability for 60 days, corresponding to an expected maximum conjunction time of 40 days plus margin, with an average data rate specified in R-194; 2993

D: Remote-Sensing instruments assumed operating for 30 days during each orbit with average data rate specified in R-194. 2994

D: The assignment of storage volume in the SSMM per instrument should be understood as the reserved allocation, for which each instrument shall foresee a partitioning into Instrument Packet Stores. Nominal instrument operations (i.e. disregarding external constraints like limited downlink capacity or conjunction periods) shall be compatible with this memory space. 13249

D: The total usable data storage capacity is 532 Gbits. 2995

D: The in table 4.8-3 unallocated storage volume of 165 Gbits will be managed by the SOC, and will be assigned as needed to instruments as part of the science planning process. 13250

4.8.7 Electrical Interfaces and Redundancy

EIDA-2997//

> ***EIDA R-222:*** *The PI shall support, for redundancy, two independent SpaceWire lines addressed and routed separately from/ to the spacecraft DMS.*

D: Only one of the two SpaceWire link will be active at a given time. 2998

4.8.8 SpaceWire Interface

EIDA-3000//

> ***EIDA R-223:*** *The PI shall comply with the electrical specifications of a SpaceWire Link Interface as defined by the ECSS-E-ST-50-12C [NR-16] for:*

- Link assembly, based on cables and connectors 3001
- LVDS drivers 3002
- SpaceWire Codec 3003

D: The clock rate to be used across all SpaceWire links will be 10 Mbps 3004

D: the effective data rate to be used across all SpaceWire links will be ≤ 1 Mbps 3005

D: See interface diagram in para 4.8.9 3006

EIDA-3007//

> ***EIDA R-797:*** *The PI shall ensure that the SpaceWire drivers and receivers use a nominal supply voltage of 3.3V.*

EIDA-3008//

> ***EIDA R-798:*** *The PI shall ensure that, following a single failure, the equipment does not emit a voltage outside the range of 0 - 3.6V including the failure modes of the power supply.*

EIDA-3009//

> ***EIDA R-224:*** *The PI shall implement transmission buffers compatible with:*

- their data generation rate, 3010
- the applicable link speed, 3011
- an acquisition scheme where a wait time between each packet of up to 100 msec may occur. 3012

D: This is necessary in order to avoid data losses 3013

EIDA-3014//

> ***EIDA R-225:*** *The PI shall establish a connection on the S/C SpaceWire link after power ON.*

EIDA-3015//

EIDA R-226: *(deleted)*

EIDA-3016//

EIDA R-227: *The PI shall implement an instrument SpW link initialisation based on SpW Codec in Autostart configuration. This includes setting the Autostart flag to "Enabled, =1, and the LinkStart flag to "Not Started", =0.*

EIDA-3017//

EIDA R-228: *The payload shall always be able to receive SpW packets on both nominal and redundant SpW links, if supporting both SpW links regardless of the power I/F being used.*

D: (deleted) 3018

EIDA-13251//

EIDA R-862: *The PI shall implement cold sparing capabilities in the Instrument SpW interfaces.*

D: The SSMM will nominally be powered on before the instruments. 13252

EIDA-3019//

EIDA R-229: *The PI shall try to establish a connection on both prime and redundant SpaceWire link, if supporting both SpaceWire links (prime and redundant) regardless of the power I/F being used, if a persistent SpaceWire link error happens (e.g. preventing the instrument to transmit TM packets).*

EIDA-3020//

EIDA R-230: *The PI shall be able to send/route each SpaceWire data packet to any allowed and agreed SpaceWire destination, after being configured accordingly by command.*

EIDA-3021//

EIDA R-231: *The Prime Contractor shall ensure that the DMS, during periods of real-time ground contact, can route all instrument data or any needed subset in real-time to the RF-downlink interface of the spacecraft, as needed.*

D; This applies as well for routing of any TC- or TM-data to a test-interface during spacecraft AIV. 3022

D: Packets stored in the SSMM may be subject to on-board latencies of up to 10s. 3023

4.8.9 Discrete Signals

EIDA-3025//

EIDA R-232: *The PI shall implement all standardized discrete electrical signals, as listed below, according to ECSS-E-ST-50-14C, Spacecraft discrete interfaces [NR-17]*

EIDA-3026//

EIDA R-233: *The PI shall implement two Main plus two Red. HV High Power Pulse Commands (HV-HPC) with interface characteristics as defined in ECSS-E-ST-50-14C, Spacecraft discrete interfaces [NR-17]*

D: These commands will be used to switch ON/OFF the main power of the Instrument. 3027

D: Pulse lengths will be in the range of 32 - 64 ms. 3028

EIDA-3029//

EIDA R-234: *The PI shall implement one Main plus one Red. Bi-level Switch Monitor interfaces (BSM) with interface characteristics as defined in ECSS-E-ST-50-14C, Spacecraft discrete interfaces [NR-17]. In case optopcouplers are used, the PI will comply with the specific interfaces defined in the table below:*

11430

Characteristic	Value
Circuit type	Floating optocoupler

Characteristic	Value
Transfer	DC coupled
Operating current, Iop	Up to 2 mA
Operating voltage (open circuit), Vop	Up to 16.5 V
Switch closed voltage	< 1.0 V (at Iop max)
Switch open leakage current	< 100 µA (at Vop max)
Fault voltage tolerance, Vsft	-16.5 V to +16.5 V with a source impedance of 1.5 kohm.

Table 4.8-4: Specific interfaces related to optocouplers. 11455

D: Bi-level Switch Monitor interfaces will be used to report the status of the above commands (status ON/OFF). 3030

EIDA-3031//

> ***EIDA R-235:*** *The PI shall route all other signals related to commanding and telemetry reporting (Digital Telemetry, Analogue Input, Analogue Thermistors, etc) from/to an instrument as digital application data, which are included as parameters in Telemetry- or Telecommand-packets in line with [NR-28].*

D: The Prime Contractor will provide for each instrument the power and data handling inputs as shown in the figure below (Figure 4.8-2). 3032

D: (*)The internal implementation of redundancy within the instrument is the responsibility of the PI. 3033

D: (**) : see paragraph 4.7.1.3, 4.8.8 and 4.8.9 3034

9460

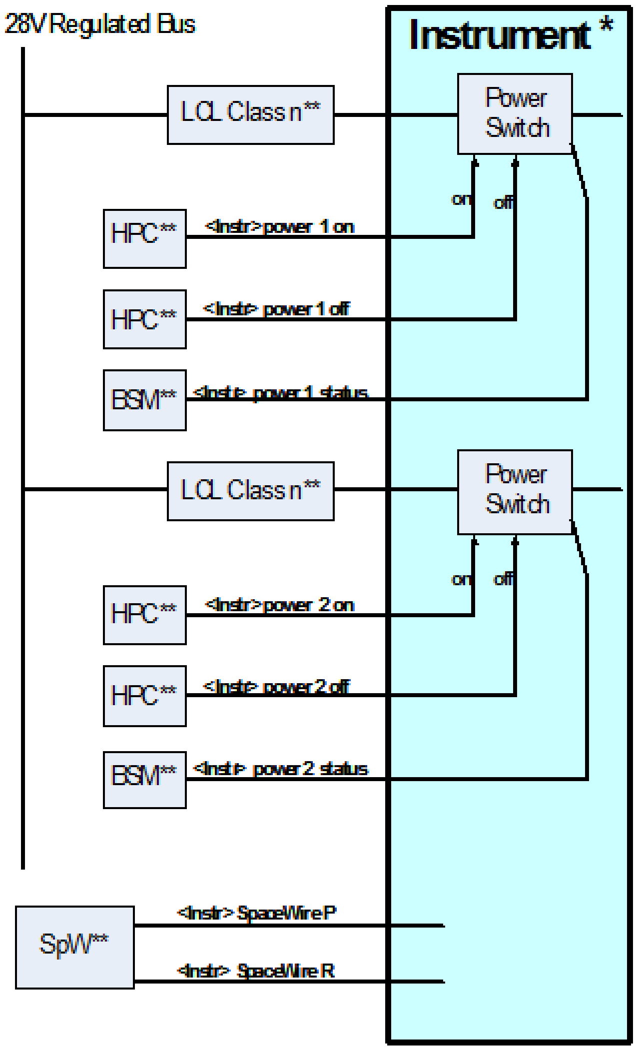


Figure 4.8-2: Instrument interfaces to and from the spacecraft for power and data handling. 3036

9439

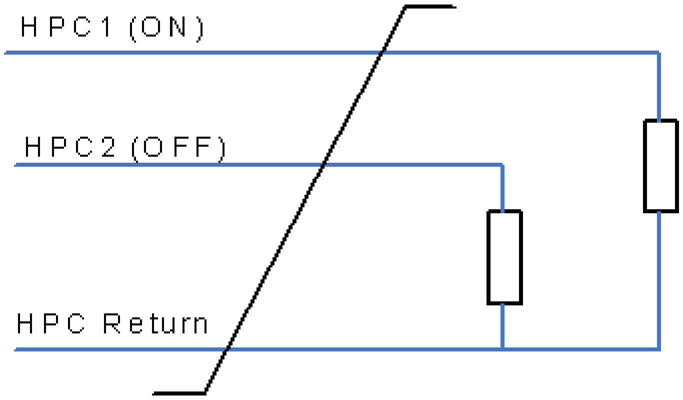


Figure 4.8-3: Recommendations for implementation of the discrete interface HPC return lines. 9440

9441

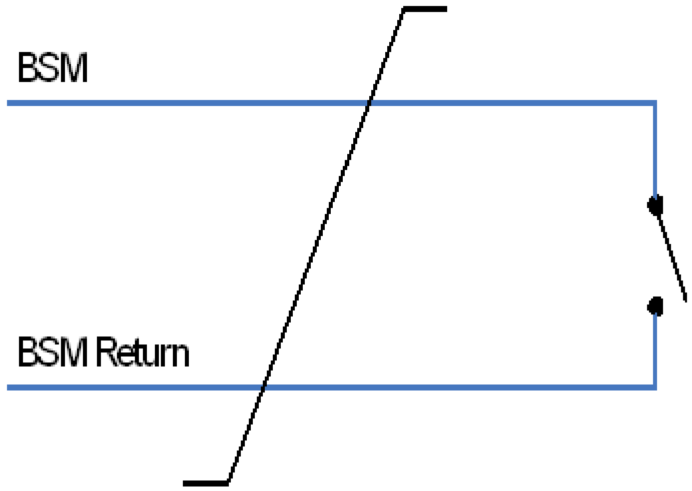


Figure 4.8-4: Recommendations for implementation of the discrete interface BSM return lines. 9442

4.9 Software Design and Interface Requirements

EIDA-3038//

EIDA R-406: *The PI shall comply with the requirements regarding Onboard Processors, Software and Memory Management as specified in section 2.3.2 of [NR-27].*

4.9.1 Software Design Requirements

EIDA-3040//

EIDA R-236: *The PI shall ensure that all on-board software complies with [NR-38], a tailored version of the software standard ECSS-E-ST-40C.*

D: [NR-38] provides a tailored version also of ECSS-Q-ST-80, a normative document listed in [NR-25]. 10336

EIDA-3041//

EIDA R-237: *The PI shall assign functionally distinct areas of memory to:*

- code; 3042
- fixed constants; 3043
- variable parameters. 3044

D: Needed in view of the in-flight software maintenance 3045

EIDA-3046//

EIDA R-238: *The PI shall ensure that minimum boot software reside in PROM.*

EIDA-3047//

EIDA R-239: *The PI shall ensure that the instrument system and application software reside in non-volatile memories.*

EIDA-3048//

EIDA R-240: *The PI shall ensure that all instrument functions are accessible after loading of the application software and instrument initialisation, including EEPROM updates.*

EIDA-3049//

EIDA R-241: *The PI shall structure the on-board S/W such that modifications can be made to a software module without affecting other module positions in the memory.*

EIDA-3050//

> ***EIDA R-242:*** *The PI shall ensure that on-board S/W maintenance activities do not cause a blockage of the instrument and can be cleared by a power cycling of the instrument.*

EIDA-3051//

> ***EIDA R-243:*** *The PI shall ensure that the instrument software do not cause erroneous operation creating a safety hazard.*

EIDA-3052//

> ***EIDA R-244:*** *The PI shall ensure that individual software parameters or constants can be modified by dedicated command from Ground (i.e. patch has to be avoided in these cases).*

EIDA-3053//

> ***EIDA R-245:*** *The PI shall make available information indicating all actions of operational significance taken by on-board software in non-science telemetry, along with any other significant instrument parameter.*

D: The PI will report in telemetry, as a goal, the resources utilized by on-board software (e.g. memory usage, central processor unit (CPU) usage and I/O usage). 3054

EIDA-3055//

> ***EIDA R-246:*** *The PI shall provide the capability to check that on-board software has been correctly uploaded before enabling it.*

D: The PI will ensure that enabling of on-board software is carried out by a single telecommand. 3056

EIDA-3057//

> ***EIDA R-247:*** *The PI shall ensure that any communication between the ground and an on-board software function or software task is carried out by specifically designed telecommand and telemetry source packets. .*

EIDA-3058//

> ***EIDA R-248:*** *The PI shall generate an event report prior to enforcement of the reset, whenever a condition that forces a processor reset is detected by software,*

EIDA-3059//

> ***EIDA R-249:*** *The PI shall generate an event report whenever a processor overload condition is detected,*

EIDA-3060//

> ***EIDA R-250:*** *The PI shall generate an event report whenever an unexpected arithmetic overflow condition is detected.*

EIDA-3061//

> ***EIDA R-251:*** *The PI shall generate an event report whenever an illegal program instruction is encountered during execution of a program code.*

EIDA-3062//

> ***EIDA R-252:*** *The PI shall generate an event report whenever a data bus error is detected by software.*

EIDA-3063//

> ***EIDA R-253:*** *The PI shall generate an event report whenever a memory corruption is detected by an error detection and correction mechanism.*

EIDA-3064//

> ***EIDA R-254:*** *The PI shall generate an event report whenever a checksum error is detected. .*

EIDA-3065//

EIDA R-255: *The PI shall ensure that the software is structured in modules.*

EIDA-3066//

EIDA R-256: *The PI shall ensure that the software can load and check redundant memory prior to operational utilization.*

EIDA-3067//

EIDA R-257: *The PI shall ensure that the software can be modified either by modifying the image on non-volatile memory or by patching the image in working memory, while the unit affected is operational.*

4.9.2 Software Implementation Requirements

EIDA-3069//

EIDA R-258: *The PI shall ensure that the SpaceWire Link implementation up to the packet & network levels is compliant with the relevant SpaceWire ECSSs, [NR-16, 17, 18, 19].*

EIDA-8936//

EIDA R-818: *The PI shall ensure that the Flight Procedures are defined following the guidelines summarised in SOL.S.ASTR.ICD.00009 [NR-33, SOLAR ORBITER FLIGHT PROCEDURES GENERATION PLAN].*

EIDA-3070//

EIDA R-259: *The PI shall develop the on-board software using a high level language.*

D: 'C' or 'ADA' languages are recommended. 3071

4.9.3 Instrument Autonomy and FDIR

4.9.3.1 *General*

EIDA-3074//

EIDA R-407: *The PI shall comply with the requirements regarding FDIR and Onboard Reconfiguration Handling as specified in the section 2.2.2 and section 2.2.3 of [NR-27].*

EIDA-3075//

EIDA R-260: *The PI shall ensure that internal safety logic are implemented to prevent inadvertent commanding of mode transitions, in case forbidden mode transitions are identified*

EIDA-3076//

EIDA R-261: *The PI shall implement a connection test service (Service 17) according to the specifications given chapter 3 of [NR-27].*

EIDA-3077//

EIDA R-262: *The PI shall ensure that the Instrument provides the capability to perform self checks on command and at power on.*

EIDA-3078//

EIDA R-263: *The PI shall ensure that entering a test mode does not require (or imply) disabling of fault management functions.*

EIDA-3079//

EIDA R-264: *The PI shall ensure that anomaly Instrument reports, if any, are generated only once per anomaly occurrence even if the anomaly is detected during successive cycles.*

D: It is recommended that all parameters used for Instrument autonomous operations are updateable by dedicated telecommand and available in Instrument HK telemetry. 3080

EIDA-3081//

EIDA R-265: *The PI shall define distinct instrument operation modes if any of the following conditions apply:*

· Mode results in a significant change in demand on spacecraft resources (e.g. power; data rate) 3082

· Mode requires a specific spacecraft operational status (e.g. thermal environment; pointing; specific DMS functions) 3083

· Mode results in a functionally distinct operating mode of the unit (e.g. calibration function; standby; software maintenance) 3084

D: An operational mode represents an operationally well defined and, within certain limitations, a stable configuration as concerns mechanical, thermal, electrical and functional conditions. 3085

EIDA-3086//

EIDA R-266: *The PI shall identify instrument modes in terms of both hardware and software*

EIDA-3087//

EIDA R-267: *The PI shall provide for each defined mode, the corresponding average and/or peak power consumption and nominal/average science data rate.*

EIDA-3088//

EIDA R-268: *The PI shall provide the peak data rate and typical / peak duration in case science data are generated in burst.*

EIDA-3089//

EIDA R-269: *The PI shall ensure that telemetry provides unambiguous identification of the modes in periodic HK telemetry and mode transitions in event telemetry.*

EIDA-3090//

EIDA R-270: *The PI shall ensure that after power-up, each instrument have a safe and well-defined initial mode that is fully reproducible.*

EIDA-3091//

EIDA R-271: *The PI shall provide in a dedicated section of the EID-B an overall description of the instrument autonomy concept, including:*

· description of the required autonomy functions and selected implementation 3092

· description of the hierarchical structure of the autonomous fault management functions 3093

· identification of the autonomy functions implemented in the instrument and of those for which spacecraft autonomy support is required. 3094

· justification of the above selection 3095

· identification of mission-phase related autonomy functions and their relation with ground control 3096

EIDA-3097//

EIDA R-272: *The PI shall ensure that the instrument is ready to accept command within 1 second after the boot event has been generated.*

D: The time between instrument switch-on and completion of booting initialisation may last several seconds. 3098

EIDA-3099//

EIDA R-273: *The PI shall ensure that each unit enables the generation of its default housekeeping report, after successful boot-up and time synchronization*

EIDA-3100//

EIDA R-274: *The PI shall ensure that each unit initiate the generation of its default housekeeping packet using a non-synchronised time value, if no time update has occurred within 1 minute.*

EIDA-3101//

EIDA R-275: *The PI shall report successful boot up via an event packet.*

4.9.3.2 *Instrument FDIR at Equipment Level*

EIDA-3103//

EIDA R-276: *The PI shall provide autonomous faults detection and recovery capabilities for all failures which can be managed internally at unit/equipment level by the HW/SW.*

D: It is recommended that the management of anomalies within an instrument is handled in a hierarchical manner such that resolution is sought on the lowest level possible. 3104

EIDA-3105//

EIDA R-277: *The PI shall report in event packets anomalies and autonomous actions taken to recover from them.*

EIDA-3106//

EIDA R-278: *The PI shall report in instrument HK telemetry all the mode transitions and reason of them*

EIDA-3107//

EIDA R-279: *The PI shall ensure that the conditions leading to the generation of an event, can be reconstruct from HK telemetry.*

EIDA-3108//

EIDA R-280: *The PI shall ensure that each individual Instrument fault management function can be enabled / disabled from ground.*

EIDA-3109//

EIDA R-281: *The PI shall report in periodic HK telemetry the current status of each individual instrument fault management function.*

EIDA-3110//

EIDA R-282: *The PI shall ensure that all parameters used for autonomous fault management (e.g. thresholds for limit checks) can be updated by telecommand and are available in telemetry.*

EIDA-3111//

EIDA R-283: *The PI shall ensure that telecommands can enable/disable autonomous entry and can force manual entry into Standby Mode (or Safe Mode).*

EIDA-3112//

EIDA R-284: *The PI shall ensure that autonomous entry to Standby (or Safe) mode is enabled by default at power on.*

EIDA-3113//

EIDA R-285: *The PI shall ensure that instrument Fault management functions are not trigger by one single sample of a parameter.*

EIDA-3114//

EIDA R-286: *The PI shall ensure that redundancy switching at instrument level does not require changes in telecommands directed to the active part of the experiment.*

EIDA-3115//

EIDA R-287: *The PI shall ensure that no fault management function is trigger on test data generated while running in diagnostic/test mode.*

4.9.3.3 *Instrument FDIR at System Level*

EIDA-3117//

EIDA R-288: *The PI shall ensure that during periods of ground contact there is no need for the ground to send telecommands to an instrument in nominal or contingency cases with a response time of less than 1 hour.*

EIDA-3118//

EIDA R-289: *removed*

EIDA-3120//

EIDA R-290: *The PI shall define (if any) the set of events to be monitored by the DMS autonomously, together with the associated reactions.*

D: Both events and reactions will be documented in the EID-B. 3121

EIDA-3122//

EIDA R-291: *removed*

EIDA-3124//

EIDA R-292: *The PI shall ensure the instrument can cope with a latency time of intervention of 10 seconds in case of recovery actions demanded to system level FDIR (managed by on-board computer)*

EIDA-3125//

EIDA R-293: *The PI shall define the basic instrument safety requirements related to unexpected interruption of nominal operations due to spacecraft entering safe mode.*

D: They will address, for example, possible conflict with safe mode operations (e.g. thrusters firing), compatibility with a deactivation at LCL level, required activities for a possible graceful deactivation and required timing for deactivation. 3126

D: These requirements will be documented in the EID-B. 3127

4.10 Electromagnetic Design and Interface Requirements

4.10.1 General Concept

D: The EMC requirements are levied to guarantee the system performances and the required electromagnetic environment at payload level. 3130

D: Instrument driven EMC requirements necessary to achieve the scientific goals and levied on the spacecraft and on the instruments themselves are described in chapter 9 3131

D: Generic EMC requirements are described in the following paragraphs 3132

4.10.2 General EMC requirements

D: The requirements herein specified are a baseline, not necessarily comprehensive, which should be used as a starting point to tailor the EMC specification. 3134

EIDA-3135//

EIDA R-352: *The PI shall develop an instrument EMC Control Plan according to ECSS-E-ST-20C, [NR-07].*

EIDA-3136//

EIDA R-295: *The Prime Contractor shall define a grounding and isolation concept for the spacecraft.*

EIDA-3137//

EIDA R-296: *The PI shall implement electromagnetic interference safety margins as specified in ECSS-E-ST-20C [NR-07] for all critical signals, pyrotechnics, and power circuits under all operating conditions.*

D: The minimum acceptable safety margins shall be 6 dB for power and signal circuits and 20 dB for pyrotechnic circuits. 3138

EIDA-3139//

EIDA R-297: *The PI shall implement electrical bonding measures for management of electrical current paths and control of voltage potentials to ensure required spacecraft performance and to protect both personnel and platform.*

EIDA-3140//

EIDA R-298: *The PI shall ensure that bonding provisions are compatible with other requirements imposed on the spacecraft for corrosion control.*

EIDA-3141//

EIDA R-299: *The PI shall ensure that electrostatic discharge at high voltage units (more than 200V) is avoided according to the rules of par. 5.10 ECSS-E-ST-20C, [NR-07].*

D: Note that EID-A R-822 defines HV differently for the purposes of safety. 10270

4.10.2.1 *Launch environment*

EIDA-3143//

EIDA R-300: *The Prime Contractor shall comply with the relevant requirements, as defined in paragraphs 4.2.2 and 4.2.3 of ECSS-E-ST-20-07C [NR-07].*

EIDA-3144//

EIDA R-301: *The Prime Contractor shall ensure that the spacecraft is compatible with 6dB margin with the launch environment and its launcher, including the guarantee that all systems are not damaged even in off condition when exposed to the:*

- *indirect effects of lightning;*
- *high power RF energy emitted by antennas installed on the launcher and in proximity of the launch facilities.*

4.10.2.2 *Spacecraft charging*

EIDA-3148//

EIDA R-302: *The Prime Contractor shall exercise control on spacecraft charging according to paragraph 4.2.4 of ECSS-E-ST-20-07C [NR-09] which calls the application of ECSS-E-ST-20 [NR-07] and ECSS-E-ST-20-06 [NR-08].*

4.10.2.3 *Spacecraft dc magnetic emission*

EIDA-3150//

EIDA R-303: *Removed. Superseded by requirements in Chapter 9.*

4.10.2.4 *Radio Frequency compatibility*

EIDA-3152//

EIDA R-304: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in paragraph 4.2.6 of ECSS-E-ST-20-07C [NR-09].*

EIDA-3153//

EIDA R-305: *The Prime Contractor shall prepare an RFC analysis as part of the EMC control plan, identifying risk frequencies.*

EIDA-3154//

EIDA R-791: *The PI shall provide relevant inputs, in order to allow the Prime Contractor to prepare an RFC analysis as part of the EMC control plan,.*

EIDA-3155//

EIDA R-306: *The Prime Contractor shall verify the absence of intermodulation interference by a combination of analysis and test.*

4.10.2.5 *EMC with ground support equipment*

EIDA-3157//

EIDA R-307: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in paragraph 4.2.9 of ECSS-E-ST-20-07C [NR-09].*

4.10.2.6 *Grounding and Isolation*

EIDA-3159//

EIDA R-308: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in paragraph 4.2.10 in ECSS-E-ST-20-07C [NR-09].*

EIDA-3160//

EIDA R-777: *The PI shall ensure that each electrical equipment chassis can be bonded to structure with a resistance of less than 5mOhm.*

4.10.2.7 *Electrical Bonding and Case shielding*

EIDA-3162//

EIDA R-309: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in paragraph 4.2.11 of ECSS-E-ST-20-07C [NR-09] and Paragraph 6.3 of ECSS-E-ST-20-06C [NR-08].*

EIDA-3163//

EIDA R-778: *For the purpose of electrostatic protection, the PI shall ensure that all items without any electrical function are bonded to the structure, such that the resistance between any point on the surface and the spacecraft ground shall be less than 3kOhm. This includes all structural items, including CFRP and thermal blankets.*

D: Note: Measurement of bond resistance values should be made as a 4 pole measurement or 3164
measured in both directions across the bond.

EIDA-3165//

EIDA R-779: *For the purpose of electrostatic protection, the PI shall ensure that all external/internal metallic parts without area consideration (such as metallic labels, baseplates, straps, insulated electrical circuits, etc), and intrinsically conductive parts (like carbon) that do not perform any electrical function, are grounded to the main structure by a DC resistance lower than 1kOhm. Floating metallic parts are strictly prohibited without any area consideration.*

EIDA-3167//

EIDA R-781: *The PI shall ensure that no harness dielectric is directly exposed to space plasma environment.*

4.10.2.8 *Cable Shielding and Separation*

EIDA-3169//

EIDA R-310: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in paragraphs 4.2.12 and 4.2.13 in ECSS-E-ST-20-07C [NR-09].*

4.10.3 UNIT EMC Requirements

4.10.3.1 *General*

EIDA-3172//

EIDA R-311: *The PI shall meet the requirements specified in the following paragraph in any operating mode of the instruments.*

D: Intentional signal emissions are not subject of the emission requirements below. 3173

EIDA-3174//

EIDA R-817: *The PI shall measure the equivalent magnetic dipole of every unit belonging to an instrument in all three axes while the instrument is powered off, and while operating in the relevant modes.*

EIDA-3175//

EIDA R-772: *For units using permanent magnets, the PI shall provide to ESA/Astrium a sample of the magnet for evaluation.*

EIDA-3176//

EIDA R-773: *The PI shall conduct demagnetisation at the level of 5 mT of every unit as part of the DC magnetic testing performed prior to delivery. In case that a unit is not suitable for demagnetisation, the PI shall inform ESA and the Prime and agree an alternate test approach.*

EIDA-3177//

EIDA R-774: *The PI shall design the instrument such, that under constant thermal conditions, constant bus voltage and no commanding, the unit DC consumption shall not change by more than 100 mA over a 4 hour period (to minimise current loop variations over 1 hour periods).*

EIDA-3178//

EIDA R-775: *The PI shall design the instrument such, that both primary and secondary power supplies have a switching frequency greater than 120kHz.*

EIDA-3179//

EIDA R-776: *The PI shall design the instrument such, that during all normal, non-transient operating modes, and at a constant temperature and power bus input voltage, all electrical frequencies generated by the unit shall be stable to within +/- 50ppm over a period of 60 minutes.*

D: the Prime Contractor shall specify and tailor, but not necessarily be limited to the following generic EMC requirements on spacecraft units. 3180

EIDA-3181//

EIDA R-796: *The PI shall ensure that the maximum magnetic moment and magnetic disturbances of each instrument unit on the spacecraft comply with the table below (Table 4.10-1):*

10918

Subsystem	Unit	Maximum permitted magnetic dipole - Ref R-796 (mAm^2)	Maximum permitted transient measured at 1m - Ref R-842 (nT)	Maximum permitted periodic transient measured at 1m - Ref R-842 (pT)
SWA	SWA EAS	5	0.5	3
	SWA PAS	10	69	410
	SWA HIS	10	62	360
	SWA DPU	20	50	290
EPD	EPD SIS	40	31	180

Subsystem	Unit	Maximum permitted magnetic dipole - Ref R-796 (mAm^2)	Maximum permitted transient measured at 1m - Ref R-842 (nT)	Maximum permitted periodic transient measured at 1m - Ref R-842 (pT)
	EPD HET-EPT 1	10	18	110
	EPD HET-EPT 2	10	30	170
	EPD-STEP	10	28	160
	EPD ICU	20	31	180
MAG	MAGIBS	0	N/A	N/A
	MAGOBS	0	N/A	N/A
	MAG ELB	20	34	200
RPW	RPW ANT 1	15	46	270
	RPW ANT 2	15	55	330
	RPW ANT 3	15	57	340
	RPW SCM	1	1	3
	RPW MEB	20	22	130
PHI	PHI Optics Box	100	47	270
	PHI EBOX	20	24	140
EUI	EUI Optics Box	100	42	250
	EUI EBOX	20	19	110
STIX	STIX Imager	5	47	280
	STIX Detector and Electronics Module	20	37	220
METIS	METIS MOU	100	43	250
	METIS MPPU	20	20	120
SOLOHI	SoloHI Optics box	10	42	250
	SoloHI Power box	40	40	240
SPICE	SPICE SOU	100	41	240
	SPICE SEB	20	41	240

10913

Table 4.10-1: DC Magnetic moment and magnetic disturbances allocations per instrument.

4.10.3.2 *Conducted emissions on power lines, differential mode, frequency domain*

EIDA-3217//

EIDA R-313: *The PI and Prime contractor shall ensure that the conducted narrowband current emissions (differential mode) in the frequency range 30 Hz - 50 MHz appearing on the unit's primary power lines does not exceed the following limits:*

- *70dBuA rms in the frequency range 30Hz to 100kHz,*
- *Reducing at 20dB per decade to 30dBuA rms in the frequency range 100kHz to 10MHz*
- *30dBuA rms in the frequency range 10MHz to 50MHz*

D: *These limits are applicable to units demanding up to 1A. For units demanding more than 1A the levels may be scaled proportionally to the current demand over the whole frequency range with an increase in dB given by 20 log(I_DC).*

EIDA-11391//

EIDA R-844: *The PI and Prime contractor shall measure the conducted emission (differential mode) up to 100MHz.*

D: *The range 50MHz to 100MHz is for information only.*

4.10.3.3 *Conducted emissions on power and signal lines, common mode, frequency domain*

EIDA-3219//

EIDA R-314: *The PI and Prime contractor shall ensure that the conducted narrow band current emissions (common mode) in the frequency range 30 Hz - 50 MHz appearing on the unit's primary power lines does not exceed the following limits:*

- *60dBuA rms in the frequency range 30Hz to 100kHz,*
- *Reducing at 15dB per decade to 30dBuA rms in the frequency range 100kHz to 10MHz*
- *30dBuA rms in the frequency range 10MHz to 50MHz*

D: *These limits are applicable to units demanding up to 1A. For units demanding more than 1A the levels may be scaled proportionally to the current demand over the whole frequency range with an increase in dB given by 20 log(I_DC).*

EIDA-11392//

EIDA R-845: *The PI and Prime contractor shall measure the conducted emission (common mode) up to 100MHz.*

D: *The range 50MHz to 100MHz is for information only.*

4.10.3.4 *Conducted emissions on power lines, differential mode, time domain*

EIDA-3221//

EIDA R-315: *The PI and Prime Contractor shall ensure that current ripple and spikes on the primary power bus inputs of the units, measured on positive and return lines, are ≤ 20 mApp when measured with at least 50 MHz bandwidth.*

EIDA-3222//

EIDA R-316: *The PI and Prime Contractor shall ensure that voltage ripple / spikes on the primary power bus inputs of the units, measured between positive and return lines, are ≤ 150 mVpp (ripple) and ≤ 280 mVpp (spikes) when measured with at least 50 MHz bandwidth.*

4.10.3.5 *Conducted emissions on power lines, common mode, time domain*

EIDA-3224//

EIDA R-317: *The PI and Prime Contractor shall ensure that current ripple and spikes are ≤ 5 mApp when measured with at least 50 MHz bandwidth.*

4.10.3.6 *Conducted emissions on power lines, inrush current*

EIDA-3226//

EIDA R-318: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in Annex A, paragraph A.3 of ECSS-E-ST-20-07C, [NR-09].*

4.10.3.7 *Conducted emissions on antenna ports*

EIDA-3228//

EIDA R-319: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in Annex A, paragraph A.5 ECSS-E-ST-20-07C [NR-09].*

4.10.3.8 *Conducted susceptibility on power lines, differential mode, frequency domain*

EIDA-3230//

EIDA R-320: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in Annex A, paragraph A.10 with limit in fig. A-4 and not A-5 of ECSS-E-ST-20-07C [NR-09].*

4.10.3.9 *Conducted susceptibility on power lines, common mode, frequency domain*

EIDA-3232//

EIDA R-321: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in Annex A, paragraph A.11 of ECSS-E-ST-20-07C [NR-09].*

4.10.3.10 *Conducted susceptibility on power lines, differential mode, transient*

EIDA-3234//

EIDA R-322: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in Annex A, paragraph A.12 of ECSS-E-ST-20-07C [NR-09].*

4.10.3.11 *Conducted susceptibility on signal lines, common mode*

EIDA-3236//

EIDA R-323: *Removed*

4.10.3.12 *Radiated emissions, electric field*

EIDA-3238//

EIDA R-324: *The PI and Prime contractor shall ensure that the narrow band radiated emissions from the unit in the frequency range 14kHz to 18GHz do not exceed the following limits:*

- *40dBuV/m in the frequency range 14kHz to 100MHz*
- *Increasing at 20dB per decade to 60dBuV/m in the frequency range 100MHz to 1GHz*
- *60dBuV/m in the frequency range 1GHz to 18GHz*
    - *Notch 1: The following notch applies to protect the on-board command receiver.*
    - *Notch 2: 42dBuV/m over the frequency range 1127-1327 MHz (Launch site GPS L2) applicable to equipment ON during launch.*

D: For non RF units which do not feature high frequency clocks, testing of the upper frequency may be limited to 1 GHz or the 10th harmonic (whichever is greater), as long as the 5th - 10th harmonics are at least 10 dB below the limit. However, regardless of this relaxation, Notch 1 shall be verified in all cases. 13260

18233

Frequency in MHz	Limit for Internal unit in dBuV/m	Limit for External unit in dBuV/m
7072	53	23
7122	53	23
7122	38	8
7162	38	8
7162	8	-22
7182	8	-22
7182	38	8
7222	38	8
7222	53	23
7272	53	23

4.10.3.13 *Radiated emissions, ac magnetic field (f >10÷100Hz up to 1MHz)*

EIDA-3241//

EIDA R-353: *Removed. Superseded by requirements in Chapter 9.*

4.10.3.14 *Radiated susceptibility, electric field*

EIDA-3243//

EIDA R-325: *The PI and Prime contractor shall ensure that the unit, when powered, will not suffer permanent degradation in performance when subjected to the following fields:-499*

18279

Frequency Range (MHz)	Field Strength (V/m)	(Peak) or (rms)	Modulation	Source of Interference	Unit ON During Launch	Unit OFF During Launch
100 - 20000	20	rms	Pulse Modulation Pulse Width: 1ms Duty Cycle: 0.5	Generic Wideband Range	X	X
8400 - 8450	32	rms	Frequency Modulation with High Modulation Index Ramp Function, f = 100 kHz, Amplitude 500 mV pp, FM DC coupled, 10MHz/volt.	X-Band TM & Data Downlink	X	X
Launch Site Requirements						
2865	31	peak	Pulse Modulation Pulse Width: 3μs Duty Cycle: 0.006	WSR-88D	X	X
5525	357	peak	Pulse Modulation Pulse Width: 3μs Duty Cycle: 0.004	NDR(NMIS)	X	X
5625	27	peak	Pulse Modulation Pulse Width: 3μs Duty Cycle: 0.0064	WSR-74C	X	X
5400 – 5900	40	peak	Pulse Modulation Pulse Width: 3μs Duty Cycle: 0.0016	Range Radar	X	X
9410	140	peak	Pulse Modulation Pulse Width: 0.72μs Duty Cycle: 0.00072	Misc radar	X	X
Launch Vehicle Requirements						
2211	30	rms	Frequency Modulation with High Modulation Index Ramp Function, f = 100 kHz, Amplitude 500 mV pp, FM DC coupled, 10MHz/volt.	Launch Vehicle S-Band	X	

Frequency Range (MHz)	Field Strength (V/m)	(Peak) or (rms)	Modulation	Source of Interference	Unit ON During Launch	Unit OFF During Launch
5765	113	peak	Pulse Modulation Pulse Width: 5µs Duty Cycle: 0.0005	Launch Vehicle C-Band	X	

D: Generic level , covers the launch site electromagnetic environment. 13308

EIDA-11393//

EIDA R-846: *For the externally-mounted instruments listed below an additional notch shall be taken into consideration for the verification of EIDA-325 : -*

18646

18648

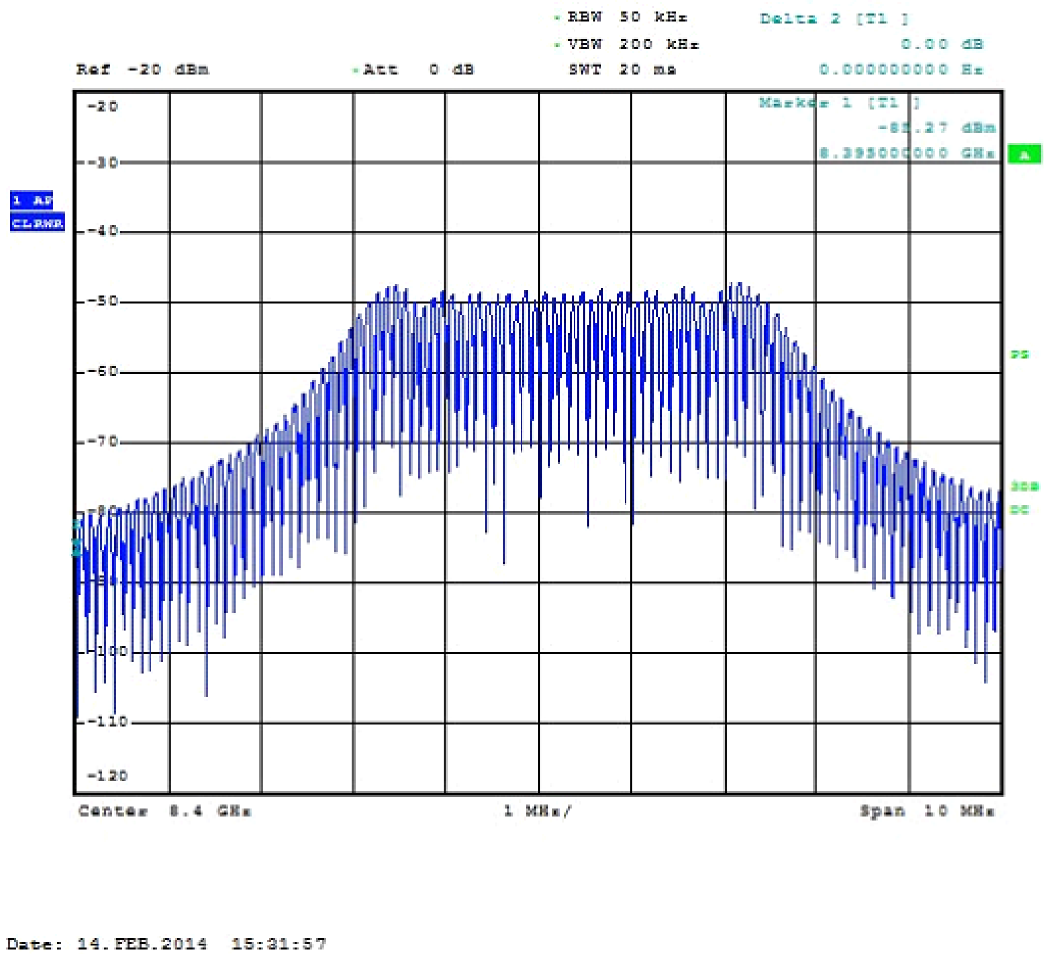
Equipment	Frequency Range	Field Strength
RPW Antenna 1	8.4 - 8.45 GHz	170 dBµV/m (316 V/m)
RPW Antenna 2		
RPW Antenna 3		
SWA-EAS	8.4 - 8.45 GHz	166 dBµV/m (200 V/m)
MAGIBS		
MAGOBS		
RPW-SCM		

The following modulation shall be applied during test: 18681

Frequency Modulation with High Modulation Index shall be applied as per the characteristics given below:

Ramp Function, f = 100 kHz, Amplitude, 500 mV peak to peak, FM - DC coupled, 10MHz/volt

18647



4.10.3.15 *Radiated susceptibility, magnetic field*

EIDA-3245//

EIDA R-326: *(deleted)*

4.10.3.16 *Magnetic emissions, dc and low frequency ac (f < 10÷100Hz)*

D: See EMC requirements in chapter 9. 3247

4.10.3.17 *ESD susceptibility, radiated*

EIDA-3249//

EIDA R-327: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in Annex A, paragraph A.15 of ECSS-E-ST-20-07C [NR-09].*

D: the requirement is implicitly specified by the values included in the test set-up in paragraph 5.4.12 of the same standard. 3250

4.10.3.18 *ESD susceptibility, conducted*

EIDA-3252//

EIDA R-328: *The PI and Prime Contractor shall ensure that each unit is not susceptible when submitted to discharges into the ground plane or structure/unit case of 10 kV, 15 mJ, rise time (10%-90%) <10ns, duration (half amplitude) 100ns, Test Duration > 3 minutes, with a repetition rate of 10 arcs/min.*

4.11 Instrument Handling Requirements

4.11.1 Transport Container

EIDA-3256//

> ***EIDA R-329:** The PI shall provide a transport container for each instrument unit, compatible with the instrument environment, cleanliness and handling requirements.*

4.11.2 Cleanliness

D: See chapter 9 and the "Product Assurance Requirements for Instruments" document [NR-25]. 3258

4.11.3 Physical Handling

EIDA-3260//

> ***EIDA R-330:** The PI shall define the handling requirements of each unit in the document "Instrument and Ground Support Equipment Packaging, Storing, Transport and Handling Procedures"*

D: This document is part of the Instrument End-Item Data Package 3261

4.11.4 Purging

D: See chapter 9 3263

4.11.5 GSE

EIDA-10328//

> *E**IDA R-840:** The PI shall ensure that the MGSE delivered together with their deliverable HW is compliant with [NR-36].*

EIDA-10329//

> ***EIDA R-841:** The PI shall ensure that the EGSE delivered together with their deliverable HW is compliant with [NR-37].*

4.12 Mission Environment Requirements

4.12.1 Radiation Environment

4.12.1.1 *Single Event Upset (SEU)*

D: A single event upset is a soft error consisting of bit-flips with no preference for 1 to 0 versus 0 to 1 transitions. The bit-flips can cause loss of a pointer, resulting in a micro processor stopping, or corruption of a data register which could cause a control parameter to be altered. 3274

D: The other important parameter with respect to SEU is the critical charge which is the lowest ionization-generated charge required to produce upset in the device. For normal incidence this is directly related to Linear Energy Transfer (LET) and LET spectra form part of the analysis method as defined in ECSS-E-ST-10-04 [NR05] and ECSS-E-10-12 [NR-06]. 3275

EIDA-3276//

> ***EIDA R-336:** The PI shall characterize for radiation tolerance before incorporation into the design those devices not currently available as RAD HARD.*

D: The ESA Project Office will support the PI in such cases. 3277

EIDA-3266//

> ***EIDA R-331:** The PI shall ensure that the instrument withstand the environment defined in the Solar Orbiter Environmental Specification [NR-23], predicted for the worst case extended mission duration with no detriment on its performances*

D: The Solar Orbiter Environmental Specification [NR-23] provides mission-integrated data for solar energetic particles at the 90% and 95% confidence intervals. This is a statistical risk analysis and therefore does not include the worst case of a single large solar particle event when below 0.3AU. 3267

EIDA-3268//

EIDA R-332: *The PI shall ensure that electronic equipment design is based on components and sensors which have been proven to withstand the expected radiation environment.*

EIDA-3269//

EIDA R-333: *The PI shall comply with the relevant requirements, as defined in The ECSS-E-10-12C [NR-06].*

EIDA-3270//

EIDA R-334: *The PI shall be responsible for the optimization of the local shielding inside each unit for those components sensitive to Total Ionisation Dose (TID) effects, assuming a uniform, spherical radiation shielding provided by the spacecraft of 1 mm equivalent Al.*

D: the 1 mm equivalent Al shielding is applicable for internally mounted units 3271

D: Detector damage and damage to some classes of electronic components are due to “displacement damage”. The parameter used to quantify the effect and characterize the environment is non-ionizing energy loss (NIEL), rather than the ionizing dose. 3272

D: [IR-21] provides the preliminary radiation analysis for the Solar Orbiter Spacecraft 10330

with the project specific environment and with a detailed model of the spacecraft structure and individual equipment mass and volume. accommodation as provided by the

Mechanical Engineering team.

4.12.2 Micrometeorite Environment

EIDA-3279//

EIDA R-339: *The PI shall ensure that the instrument withstands the micro-meteorite environment defined in the Solar Orbiter Environmental Specification [NR-23].*

5 MISSION OPERATIONS

D: This chapter describes synthetically the following elements and aspects related to the Solar Orbiter 3281
mission: ground segment, mission operations, mission products, system operation testing & simulation and finally instrument documentation.

5.1 *Ground Segment*

D: The Solar Orbiter Ground Segment will provide all the capabilities for the monitoring and for the 3284
control of the spacecraft and payload during all mission phases, as well as for the reception, archiving and distribution of payload instrument data. The Ground Segment will consist of the Operational Ground Segment and the Science Ground Segment.

D: This chapter specifies the mission operation requirements, applicable to the PIs. 3282

5.1.1 Operational Ground Segment

D: The Operational Ground Segment will include: 3286

1. A Ground Station and Communication Network performing telemetry, telecommand and 3287
tracking operations within the X-band frequencies. The ground station used throughout all mission phases will be the ESA Malargüe deep space station, complemented by the ESA New Norcia and Cebreros 35m stations during near-Earth mission phases and other critical mission phases.

2. The Solar Orbiter Mission Operations Centre (SMOC) , which will consist of: 3288

    a. The Solar Orbiter Mission Control System (SMCS) to support with both hardware 3289
    and software, the data processing tasks essential for controlling the mission, as well as spacecraft performance evaluation and on-board software validation and maintenance.

    b. The Solar Orbiter Data Disposition System (SDDS), supporting the acquisition 3290
    and interim storage of raw scientific data to be accessible together with raw non-science and auxiliary data at remote locations.

    c. The Solar Orbiter Mission Planning System (SMPS), supporting command 3291
    request handling and the planning and scheduling of spacecraft and payload operations and generation of the Mission Timeline (MTL).

    d. The Flight Dynamics System (FDS), supporting all activities related to attitude and 3292
    orbit determination and prediction, preparation of slew and orbit manoeuvres-including reception and validation of manoeuvre requests-, calibration of the AOCS subsystem, ground station coverage prediction , spacecraft dynamics evaluation and other navigation activities.

    e. The System Simulator, a software simulator of the ground stations and space 3293
    segment, to support procedure validation, operator training and the simulation campaign before each major event of the mission.

D: The SMOC located at ESOC (Darmstadt, Germany) will be responsible for the operation and 3294
control of the spacecraft during all mission phases, described in paragraph 5.2.2.

D: In case of a catastrophic event at the SMOC, preventing spacecraft control over periods beyond 3295
the maximum survival capabilities of the Solar Orbiter spacecraft, a Back-Up Control Centre (BUCC) will be available in another location, currently baselined to be the Cebreros ground station. This centre will include all basic ground segment equipment to ensure the spacecraft safety until the nominal control centre returns operational.

5.1.2 Science Ground Segment

D: The Solar Orbiter Science Ground Segment (SSGS) will consist of: 3297

1. A Solar Orbiter Science Operations Centre (SSOC), responsible for scientific mission 3298
planning and experiment command request preparation for consolidated submission to the SMOC.

2. Pipeline processing of science telemetry in support of the PI teams and preparation of the 3299
ingestion of the scientific data products into the Solar Orbiter Archive.

3300

D: The science operations will be conducted from the SSOC in close collaboration with the PI teams and the SMOC. The SSGS will be responsible for the coordination, planning and execution of science operations and for data archiving, which includes establishing the Solar Orbiter Archive.

EIDA-3301//

> ***EIDA R-354:*** *The PI shall make available the necessary resources to support the science operations conducted from the SSOC.*

D: The SDDS will process the input telemetry stream from the SMOC into the various data levels described below. 3302

D: The telemetry stream from the SMOC will be processed into telemetry files by the SSOC (Level 0b). The telemetry files will consist of time-ordered telemetry packets organized by instrument and grouped into either science or housekeeping data. 3303

D: The telemetry files will be processed into scientific data units (Level 1b) by each PI. These data units will be still uncalibrated but the files will be in an established scientific format (e.g. FITS, CDF, etc.). 3304

D: The data in Level 1b format will be calibrated by each PI into the calibration level needed for scientific analysis (Level 2). 3305

D: The Level 3 processing will create higher-level data, derived data or combined data from several instruments. 3306

EIDA-3307//

> ***EIDA R-697:*** *The PI shall be responsible for Level 1b, Level 2 and Level 3 processing.*

EIDA-3308//

> ***EIDA R-355:*** *The PI shall deliver the Level 1b, Level 2, and Level 3 data to the Solar Orbiter Archive.*

EIDA-3309//

> ***EIDA R-356:*** *The PI shall ensure that Level 1b and the Level 2 processing SW comply with the requirements specified in [NR-15], "Software".*

EIDA-3310//

> ***EIDA R-698:*** *The PI shall identify a single point of contact for instrument planning activities and for data deliveries to the Solar Orbiter Archive.*

D: The PI shall support the design and implementation of the SSOC-PI interface which will be governed by the 'PIs to SOC interactions document'. 13321

EIDA-3311//

> ***EIDA R-359:*** *The PI shall deliver to the SSOC and maintain the software implementing the data processing pipelines to Level 1b and Level 2.*

D: A subset of Level 1b data will be generated and used at the SSOC for planning purposes. The software shall be provided to the SSOC by the PI teams. 13322

EIDA-3312//

> ***EIDA R-360:*** *The PI shall make available the necessary resources to support the installation and the maintenance of any relevant software at the SSOC.*

D: The PI-supplied software running at SSOC shall be maintained by the PI-team throughout the operational phase of the mission. 13323

EIDA-3314//

> ***EIDA R-361:*** *The PI shall provide inputs, for the instrument modelling at the SSOC.*

5.2 Mission Operations

5.2.1 Basic Principals

5.2.1.1 *General*

D: Operations for both spacecraft and scientific payload will only be conducted in strict compliance with validated event sequences and procedures documented in the Flight Operations Plan (FOP). This will encompass all operations (i.e. special operations and contingency operations as well as routine operations during the different mission operation phases). 3318

D: The SMOC will switch-off any instrument which is deemed to be interfering with or endangering the mission objectives, using agreed and validated contingency procedures. 3319

D: Science TM packets will not be processed at the SMOC. All information relevant to the health and safety of the payload and in general required for engineering activities on the instrument (monitoring and control, troubleshooting, software maintenance, etc.) will be contained in non-science TM packets. 3320

EIDA-3321//

> ***EIDA R-362:*** *The PI shall ensure that the instrument non-science TM packets follow the requirements specified in the Solar Orbiter Operation Requirements Document [NR-27].*

EIDA-3322//

> ***EIDA R-363:*** *Removed*

5.2.1.2 *Off-Line Operations*

D: Due to the one-way propagation delay of up to 16 minutes the spacecraft will be mainly controlled via off-line operations. After the initial spacecraft commissioning, all telecommands required to carry out the mission will normally be loaded in advance on the Mission Timeline for later execution. All telemetry generated on-board will be stored for later retrieval by ground. 3324

D: Telemetry evaluation will be mainly off-line with limited possibility of quasi real-time intervention in selected critical phases and in major contingency cases. 3325

D: In order to support the off-line operations approach required for a deep-space mission, several autonomous capabilities will be provided by the spacecraft. 3326

D: On-board Control Procedures (OBCP) will allow autonomously execution of complex procedures, including decision loops which ground cannot support due to propagation delay. On-board Control Procedures will be modifiable in flight. 3327

EIDA-3328//

> ***EIDA R-364:*** *The PI shall ensure that the use of OBCPs complies with the requirements specified in the Solar Orbiter Operation Requirements Document [NR-27] Section 3.17.*

EIDA-3329//

> ***EIDA R-726:*** *The PI shall ensure that detection and autonomous recovery from any single failure will include reconfiguration to a safe back-up mode in case the detected failure is not recoverable.*

EIDA-3330//

> ***EIDA R-365:*** *The PI shall ensure that the use of instrument autonomy complies with the requirements specified in the Solar Orbiter Operation Requirements Document [NR-27] Section 2.2 and the referenced documents.*

D: The spacecraft will be able to continue nominal operations (and generation of mission products) without ground contact during the longest solar conjunction period plus five days. In case of a non-recoverable failure, the spacecraft will be able to survive for the longest solar conjunction period plus five days. 3331

D: Anomalies will only be detected by the SMOC with a delay, corresponding at least to the light travel time, but typically rather of the order of one day in the case of daily passes, and two to four 3332 days in the case of cruise when 3 passes per week are planned. Reaction to on-board failures from the SMOC within these typical reaction times will require unambiguous identification of the failure in telemetry, and the related contingency procedures being contained in the instrument user manual (and translated in the FOP).

EIDA-3333//

> ***EIDA R-366:*** *The PI shall comply with the relevant requirements specified in the Solar Orbiter Operation Requirements Document [NR-27] on Spacecraft Control (Section 2.1) and referenced documents therein.*

EIDA-3334//

> ***EIDA R-367:*** *The PI shall identify unambiguously in the non-science TM packets the type of potential instrument failures / anomalies.*

EIDA-3335//

> ***EIDA R-368:*** *Removed.*

EIDA-3336//

> ***EIDA R-369:*** *The PI shall support the investigation and resolution of Instrument-related anomalies in-flight.*

D: This may include provision of technical consultancy and presence of PI team technical experts at the SMOC if required. 3337

5.2.1.3 *Ground Contact*

D: The contacts between the SMOC and the spacecraft will not be continuous and will be primarily used for pre-programming of autonomous operations functions on the spacecraft and for data collection for subsequent off-line status assessment. The ground contact frequency will vary in general between once per day and three times per week, depending on the mission phase, excluding solar conjunction periods. 3339

D: During the Cruise Phase (CP) the spacecraft activity will be low and dedicated to the generation and downlink of science by the “in-situ” instruments. In this phase passes will be taken 3 times per week for health checks, upload of spacecraft and instruments commands and telemetry recovery. Periodic (typically twice per year) pre-programmed check-out of the remote sensing instruments will be carried out. Daily passes are planned during the passive check outs. Presently foreseen duration of the passive check out will be about 7 days. 3340

Platform operations will be limited to routine maintenance activities such as transponder and data handling operations, reaction wheel off-loadings, etc. 3341

D: The period around a planetary swing-by will be dedicated to navigation operations. In such period the frequency of the ground station passes will vary from 3 per week to one per day. Such period usually will start two months before the event and finish about one month after. 3342

D: In Nominal Mission Phase (NMP) and Extended Mission Phase (EMP) the remote sensing payload will be activated and ground station passes frequency will increase to one pass per day, to allow the downlink of a higher data volume. 3343

5.2.1.4 *In Flight Thermal Control and Characterization*

EIDA-3345//

> ***EIDA R-370:*** *The PI shall comply with the in-flight thermal control requirements, specified in the Solar Orbiter Operation Requirements Document [NR-27] section 2.3.7.*

D: In order to more accurately predict the thermal behaviour of the spacecraft during the CP , the NMP and the EMP phases , thermal characterization campaigns will be performed both during LEOP and at the beginning of the NMP, with the aim to define the operational thermal envelope of the spacecraft. 3346

D: No real-time thermal analysis will be performed in any phase of the mission. While in the CP the above thermal characterization approach is deemed sufficient, in the NMP and EMP a stable baseline 3347 plan will be required since short term mission redefinitions based on updated thermal constraints will not be affordable. One possible exception, is the recovery from onboard thermal contingencies, e.g. failure of a heater circuit, resulting in an unforeseen thermal environment, where by “unforeseen” it is meant as unforeseen in the contingency recovery operations.

D: The entire operations planning for the NMP and EMP will be produced on the basis of a robust, conservative but realistic set of spacecraft operations constraints that will ensure safe thermal operations during the observation windows. 3348

5.2.1.5 *Solar Conjunction Operations*

D: The nominal RF link to/from the spacecraft will be likely degraded when the Sun-Earth-Spacecraft angle is lower than 5 degrees. 3350

D: Degradation of the signal also will affect tracking measurements. For this reason the mission will be designed such that critical navigation activities (e.g. manoeuvres, planet swing-bys) will not take place within 5 degrees angular separation from the Sun as seen from Earth. 3351

D: Solar conjunctions are periods when the Sun-Earth-Spacecraft angle is less than 3 degrees. 3352

D: The spacecraft will be able to operate autonomously during solar conjunctions even though communication with Earth may not be possible. 3353

5.2.1.6 *Reporting*

D: The SMOC will regularly report on the mission and spacecraft status with a frequency depending on the criticality of the mission operation; namely: 3355

a. During LEOP operations reports will be issued daily. 3356

b. For critical event operations report will be issued ad-hoc. 3357

c. During routine phases operations reports will be issued weekly to monthly depending on the level of activity. 3358

Contents and distribution lists of these reports will be agreed with the Mission Manager. 3359

D: The SMOC will report anomalies within one working day from their detection to the Mission Manager, to the Flight Operations Director and to the Prime Contractor. In case of anomalies affecting the payload, SMOC will report such anomalies to the Project Scientist, to the SSOC and to the affected PI. 3360

EIDA-3361//

EIDA R-371: *The PI shall issue instrument operations reports after each in-flight phase.*

5.2.2 Mission Phases

D: The definition and the mission phases and the PI related support is summarized in the following table (Table 5.2-1): 3363

3364

Mission Phase	Operations Support
Launch and Early Orbit Phase (LEOP) **LEOP definition:** The LEOP extends from the removal of the umbilical, through to the separation of the Spacecraft from the launcher upper stage until completion of the launch trajectory error correction and acquisition of nominal communication through the HGA.	• The Mission Control Team covers 24 hours daily operations in two shifts of about 12 hours each. • The LEOP operations will be carried out from the Main Control Room (MCR), supported by the ESTRACK Control Centre (ECC), the Flight Dynamics Room (FDR), the Software Support Room (SSR) and the Project Support Room (PSR). • Launch support will start 8 hrs before launch and includes a final readiness test with the stations. After spacecraft separation from the launch vehicle, a series of configuration activities will be performed automatically by the spacecraft. The post-launch spacecraft operations will start immediately following Acquisition of Signal (AOS), when the control centre takes over control of the

Mission Phase	Operations Support
	spacecraft and completes the initial configuration activities. • Execution of a Trajectory Correction Manoeuvre (TCM) is planned during LEOP in order to cancel any possible orbit injection error by the launcher. • Ground station network is assumed to be New Norcia and Cebreros. • On site support from Project and Industry teams. • Duration: about 7 days.
Near Earth Commissioning Phase (NECP) **NECP definition:** The NECP extends from end of LEOP until the end of the initial check out of the Spacecraft including its Payload.	• Any remaining subsystem initialisation/switch on • Activation and functional checkout of the spacecraft and payload; in particular, all RF links will be tested during this phase, and both sets of instruments will be commissioned. • The control centre operations will be carried out from the Dedicated Control Room (DCR) with the support of the PSR. • The Malargüe ground station will be used over the full visibility. • The Flight Control Team (FCT) will reduce the support to 1 shift. • Flight Dynamics will provide off-line support. • On-site support by Project, Prime Contractor and PI Teams for selected operations. • Duration: about 3 months.
Cruise Phase (CP) **CP definition:** The CP starts at the end of the NECP and ends with the gravity assist manoeuvre that leaves the Spacecraft in the operational orbit with the target perihelion altitude. The In-Situ instruments are operational during CP. For the Remote-Sensing instruments payload check-out windows are scheduled every 6 months during the CP.	• Monitoring and maintenance activities of the spacecraft platform will be performed off-line. The size of the FCT is reduced with respect to LEOP and NECP. • Reduced science operations and calibration are performed with the “in-situ” instruments offline through the normal mission planning cycle on a best effort basis in order not to drive spacecraft resources. • Above 1.2 AU the baseline is to put spacecraft in hibernation mode with instruments and non-critical units, including the SSMM, switched off. • Periodic (typically twice per year) pre-programmed check-out of the remote sensing instruments are planned. • Malargüe is used 3 times a week for a pass duration sufficient to provide 8 hours of science dump. • The support for the planetary swing-bys will typically start two months before the swing-by and finish 1 month after, and will mainly consist in trajectory correction manoeuvres and required spacecraft configuration changes. Additional support from the 35 m antennae in New Norcia and Cebreros is required for Orbit Determination purposes (both conventional and delta-DOR tracking activities). • Operations during this period will be conducted from the DCR. • This phase starts after end of NECP and finishes at the end of VGA2.
Nominal Mission Phase (NMP) **NMP definition:** The NMP is the	• This phase is supported by a FCT with increased size. • Full science operations are performed with the

Mission Phase	Operations Support
nominal time period during which mission products are generated and returned from the operational orbit. The NMP starts at the end of the CP with the gravity assist manoeuvre that leaves the Spacecraft in the operational orbit and ends at VGAM-4 (VGAM-5 for the March 2017 launch opportunity). The NMP contains 8 orbits in the case of the January 2017 baseline scenario, and 8 orbits in the case of the 2018 backup scenario. The baseline NMP is expected to end 85 months after launch.	entire payload complement offline through the normal mission planning cycle. • Malargüe is used daily for a pass duration sufficient to provide 8 hours of science data downlink. • The support for the planetary swing-bys will be the same as for the cruise phase (see above). • Operations are conducted from the DCR.
Extended Mission Phase (EMP) **EMP definition:** The Extended Mission Phase, if approved, will start after NMP and continue until VGAM-6. This represents an extended mission duration of 6 to 8 solar orbits, depending on the actual launch date and will result in an increase in the inclination of the Spacecraft orbit with respect to the solar equator.	• As for NMP

10409

Table 5.2-1: Mission phases and the PI related support.

5.2.3 Payload Operations Support

D: The payload operations will be governed by the rules and guidelines established and periodically discussed by the Science Working Team (SWT). The preparation, coordination and execution of science operations will vary depending on the phases of the mission. 3384

5.2.3.1 *Near Earth Commissioning Phase Operations*

D: Payload operations during NECP are conducted in a near-real time manner to support the critical post-launch initial activation and checkout activities and to take advantage of the relatively short distance to Earth. 3386

D: During NECP, all instrument operations will be executed at the SMOC using a detailed phase timeline and related procedures established before the start of the phase. Timelines and procedures will be defined by the SWT and the PI teams, produced by the FCT, reviewed and agreed by the PIs. After validation via the system simulator, they will be included in the Flight Operations Plan. 3387

D: During NECP it will be possible for the PI teams to submit change requests to procedures and/or timelines until very close to the execution time. The deadline for the submission will depend on the type and amount of changes. These requests will be discussed with the FCT in daily operations review meetings under the supervision of the Project Scientist and the Spacecraft Operations Manager. 3388

D: A PI Support Area (PISA) will be provided at the SMOC to accommodate PI provided EGSE to be used during NECP when critical payload operations will be conducted which might require near-real time interaction between the FCT and the PI team for decision making. 3389

D: The PISA will enable data access and commanding capabilities, as well as communication with remote locations. At the PISA an interface with the SDDS will be available to support both the telemetry delivery services to the experiment EGSE and special command requests from PIs to the SMOC. 3390

EIDA-3391//

> ***EIDA R-372:*** *The PI shall make available the necessary resources during NECP at the SMOC to monitor the operations execution in near-real time and to support GO/NOGO decisions at predefined steps in the procedures. The PI shall make available the necessary resources for the installation of instrument EGSE equipment at SMOC required to support this, such installation to occur at L-6 months.*

EIDA-3392//

> ***EIDA R-727:*** *The PI shall submit change requests to the SMOC for approval, in case of deviations from foreseen procedures and activities.*

5.2.3.2 *Cruise Phase Operations*

D: During CP only the In-Situ set of instruments will be operated continuously, subject to spacecraft resources, whilst the Remote Sensing instruments will not be observing, except for periodic non-interactive check-out periods (one week twice per year approximately). Instruments may need to be switched off, subject to spacecraft resources. 3394

D: The SSOC will be responsible for planning all science payload operations, while the SMOC will remain responsible for the overall mission planning and mission operations. Engineering activities with the instruments (e.g. on-board software maintenance, troubleshooting, etc.) will be conducted by SMOC directly with the PI Team, in dedicated slots agreed with SSOC. 3395

D: For typically three to four weeks around planet swing-bys payload operations will be supported on a best effort and non-interference basis, giving priority to the critical spacecraft navigation activities. 3396

EIDA-3397//

> ***EIDA R-373:*** *The PI shall submit operations requests to the SSOC.*

D: The SSOC will coordinate and prepare the necessary science plans in order to deliver to SMOC the list of needed payload operations requests. The SMOC will process and merge the operations requests into a timeline to be uplinked to the spacecraft. 3398

D: During CP all activities will be carried out off-line, according to the planning and deadlines established in the mission planning concept. The final instrument checkout timeline generated at the SMOC will be checked against the mission rules and constraints and the available spacecraft environmental resources, iterated if necessary with the SSOC/PI and finally implemented in the mission timeline to be uplinked to the spacecraft. 3399

5.2.3.3 *Nominal & Extended Mission Phase Operations*

D: In the Nominal Mission Phase all instruments on board the spacecraft will perform scientific measurements. 3401

D: The SSOC will be responsible for planning all payload operations, while the SMOC will remain responsible for the overall mission planning and mission operations. 3402

D: The SSOC will be responsible for submitting consolidated payload operations requests to the SMOC at the level of command sequences. The SMOC will convert the submitted operations requests into commands and will ensure timely uplink to the spacecraft for execution. The interface between SMOC and SSOC will include a list of command sequences authorized for scheduling by the SSOC. 3403

D: During NMP and EMP all activities will be carried out off-line according to the planning periods and deadlines established in the mission planning concept. The inputs from the SSOC will be checked by the FCT at the SMOC against the mission rules and constraints and the available spacecraft and environmental resources, iterated if necessary with the SSOC/PI and finally implemented in the mission timeline to be uplinked to the spacecraft. 3404

5.2.3.4 *Payload On-Board Software Maintenance*

EIDA-3406//

> ***EIDA R-375:*** *The PI shall comply with the requirements specified in the Solar Orbiter Operation Requirements Document [NR-27] for Onboard Processors and Software (Section 2.3.2); Memory Management Service (Section 3.7) and referenced documents therein.*

EIDA-3407//

> ***EIDA R-376:*** *The PI shall maintain the instrument on-board software throughout the mission.*

D: The SMOC will provide the facilities and services required to safely uplink to the instrument the required software modifications, as developed by the PI team and delivered through an agreed interface and format. 3408

EIDA-3409//

> ***EIDA R-378:*** *Removed*

EIDA-3410//

> ***EIDA R-379:*** *The PI shall submit SW modifications including memory maintenance requests in form of text files.*

D: Such requests include Memory Patch Requests, Memory Dump Requests and Memory Check Request. As part of the request, the PI team will indicate a time window where the memory maintenance request has to be executed and any other relevant constraints. 3411

D: The SMOC will be responsible for converting the text files input into Memory Maintenance commands. 3412

D: The SMOC will be responsible for scheduling and executing the maintenance activity. Instrument pre- and post-maintenance operations are executed as specified in the instrument User Manual, normally from the Mission Timeline, unless requested otherwise by the PI. When the instrument is ready to receive the maintenance commands, the execution of the corresponding TC file is started and the on-board system issues the maintenance commands to the instrument. 3413

EIDA-3414//

> ***EIDA R-380:*** *The PI shall be responsible for the verification of correct loading of the instrument software updates, since science telemetry processing will not be performed at the SMOC.*

D: If requested by the PI, telemetry generated by the maintenance commands (dump / check) can be compared by the SMOC against the contents expected by the PI. These telemetry packets will also be available to the PI via the DDS. 3415

D: Changes affecting the functioning of the instrument will be implemented only with explicit approval of both the ESA Mission Manager and the ESA Spacecraft Operations Manager (SOM). In addition, before the implementation of software changes, any effects related to the SMOC ground software will be determined and, if required, modifications shall be initiated by the SOM. 3416

D: The SMOC will support system-level operational validation of instrument software updates upon PI request, provided that a representative instrument model is mounted on the Engineering Test Bed (ETB). 3417

5.2.3.5 *Mission Planning*

D: The payload operations will be governed by the rules and guidelines established and periodically discussed by the SWT. While in the LEOP, NECP and for special engineering activities like contingency recovery, anomaly troubleshooting and on-board software maintenance operations will be executed following dedicated procedures and timelines defined in the FOP, for all other mission phases, the preparation, coordination and execution of instrument operations will be carried out via an automated cyclic mission planning and execution approach. 3419

EIDA-3420//

> ***EIDA R-381:*** *The PI shall support the preparation of the Solar Orbiter Mission Planning, including exchange of files between the SSOC and SMOC in line with the requirements set out in the SGS-OGS ICD [NR-TBD)."*

D: SGS-OGS ICD is not yet available. 3421

D: The Mission Planning approach for all the routine science operations phases will be built on the experience of previous missions including Mars Express, Venus Express, Rosetta and BepiColombo. 3422

EIDA-3423//

> ***EIDA R-382:*** *The PI shall provide inputs to the SSOC for the requested science operations for integration in the mission planning products.*

D: The SSOC will pass a consolidated request to the SMOC which will check the requests against mission, environmental and resource constraints. 3424

D: The planning concept is traditionally based on a cyclic process during which operations are iteratively refined in stages and the required level of checking at each stage is performed. The planning concept will allow to pre-plan instrument and spacecraft operations evolving from coarse to more detailed planning while being able to freeze spacecraft resources, like pointing, as early as possible, to give SMOC enough time to evaluate the requests at plan level and resolve conflicts if needed. 3425

D: During NMP and EMP events like eclipses, occultations, Earth distance, etc. will play a major role in establishing the constraints scenario against which the payload operations plan will have to be checked. This means that the SMPS will utilize information coming from the FDS in the form of a skeleton timeline defining the evolution of the S/C orbit and attitude with the epoch. 3426

D: The set of constraints applicable to the payload operations during NMP and EMP implies that a baseline science plan will have to be established long before the SSOC submits the final science operations requests to the SMOC. 3427

D: The mission planning scenario during CP, NMP and EMP will be divided into different levels: 3428

1. **long term planning** will fix the trajectory and the ground station schedule. This process typically will take place once for each cruise phase revolution and for each NMP / EMP revolution after the 2nd Venus fly-by covering the the full revolution. As part of this cycle, payload operations exclusion windows and on-board resources envelopes for payload operations will be defined by the SMOC. The output of this cycle will be a frozen trajectory, a coarse plan of operations and a frozen ground station schedule for the defined long-term planning period. 3429

2. **medium term planning** will fix the usage of spacecraft resources. This process typically will take place once for each cruise mission phase revolution covering the full revolution and every month (or other more adequate for science planning time span of the same order) during the NMP / EMP (after the 2nd Venus fly-by) around the Sun covering one month (or the selected time period). The SOC will aggregate inputs from all planning sources and it will provide a consolidated resource-consumption representative operations request, which is imported by the MOC in a single plan and undergoes resource and constraints checks. Conflicts are solved by replanning. The output of this phase will be a frozen on-board resource usage profile and a refined conflict-free operations plan. 3430

3. **short term planning** will generate detailed schedules of commands for the spacecraft and for the ground stations. This process will take place typically every week covering one week. The SOC will provide detailed operations requests which are imported by the MOC in a single plan, and will undergo final detailed resource and constraints checks. In case of conflicts in this phase, the conflicting operations requests will be rejected from the plan. Re-planning will not be supported. In case of contingency, it will be possible to modify an existing instrument operation after expiration of the normal deadline up to 3 working days before execution. In this cycle, detailed pass instructions will be also prepared for the on-console personnel. 3431

4. A set of routine mission operational rules and constraints will be identified by the FCT based on the spacecraft and payload user manuals as laid down by the manufacturer/instrument teams. 3432

These rules and constraints will drive the checks and modelling used during the planning process to validate a particular plan of operations.

5.3 Mission Products

D: Mission products will be made available to the SSOC and to the PIs in parallel, and will include all 3434
spacecraft and instrument raw telemetry data plus auxiliary data as defined in this section.

5.3.1 Telemetry Processing at SMOC

5.3.1.1 *Generic*

D: All telemetry packets received at the SMOC will be stored as raw data and made available to all 3437
mission users. Upon retrieval of raw data by ~~to~~ external users, additional information such as quality data and packet timing will be provided to enable the users to time correlate the data with UTC.

D: Decompression of data compressed by the instrument itself is not supported by the SMOC. These 3438
packets will be delivered as received by the on-board data handling system.

D: Non-science telemetry packets will be further processed by the SMOC in near real time for 3439
spacecraft control and monitoring purposes. In particular telemetry parameters will be extracted from packets. It will be possible to calibrate, display and check them against predefined limits. A subset of telemetry packets will be systematically processed for command verification, performance assessment, trouble shooting and on-board software maintenance as required.

D: The SMOC will not perform any processing of science telemetry packets beyond archiving, neither 3440
for calibration nor for instrument monitoring purposes. For this reason, it is essential that any information required at the SMOC for health and safety monitoring is included in the instrument non-science telemetry.

5.3.1.2 *Auxiliary Data*

D: Auxiliary data are non-telemetry data required to support mission planning and science data 3442
analysis. They will be stored and made available to external users in the same way as telemetry data, and will be correlated with UTC. It is foreseen to typically include:

a. Spacecraft ephemeris with respect to Sun, Earth and planet (swing-by). 3443

b. Spacecraft attitude prediction/reconstitution. 3444

c. Event files. 3445

d. Command history data. 3446

e. Time correlation history (OBT/UTC). 3447

f. Mission planning information. 3448

D: Auxiliary data will be provided in a format and within coordinate systems jointly defined between 3449
ESA and the PIs through the relevant SWT.

5.3.2 Data Disposition System

D: The SDDS is the part of the SMOC system that provides access to the mission telemetry and 3451
auxiliary data described above.

D: The SDDS will allow the authorized user to: 3452

a. Request a catalogue of available TM packets (per APID and time range of generation and/or 3453
reception on ground).

b. Request a set of TM packets per APID and time range (only for those APIDs for which he is 3454
authorised to submit request).

c. Request a specific file in the set of available auxiliary information files 3455

d. Specify off-line to the SMOC that selected auxiliary information files are automatically 3456
transmitted to the user's institute when a new version becomes available in the archive.

3457

D: The SDDS is a temporary repository of fresh telemetry and auxiliary information, which must be requested as soon as possible by the relevant user and transferred to the user's private archive. In order to avoid unnecessary overload of the SDDS, the users will be discouraged from using the SDDS as a remote archive, thereby requesting repetitively the same data more than once. To this aim data transfer quotas per user will be introduced and possibly a limit of availability of past data will be defined (typically the last 2 weeks of data will be retrievable at any time). This interface shall be governed by the Data Disposition Interface Document (DDID).

5.3.2.1 *Long Term Raw Data Archiving*

D: Raw telemetry and auxiliary data will be kept by the SMOC throughout all post launch mission phases on the Long Term Archive (LTA). This archive will be accessible remotely via the SDDS throughout the mission, up to 3 to 6 months after end of the EMP. The SMOC will ensure completeness and integrity of the LTA during its active lifetime. 3459

D: There will be no delivery of data on Raw Data Media during or after the mission. 3460

D: Processed scientific and auxiliary data will be archived by the SSGS according to the Solar Orbiter Archive Plan. 3461

5.3.2.2 *Delivery Formats*

D: Each data delivery request to the SDDS will result in a transfer of a block of data containing three main areas: 3463

1. An acknowledgment, including request details and status. 3464
2. A catalogue entry giving identification details of the requested data actually supplied (e.g. experiment, date, time). 3465
3. The requested data itself. 3466

5.3.2.3 *Command Request Handling*

D: In addition to the data access capability, the SDDS will allow for transfer of consolidated command requests to the SMOC as inputs to the mission planning system. The SMOC will support approval, authentication and authorisation of command requests. After validation the SMOC will incorporate the command requests into the mission planning system, which generates the final command schedule for uplink to the spacecraft. This interface will be governed by the Planning ICD. 3468

D: This interface allows direct PI->MOC command input. This is the expected commanding interface during NECP and instrument contingencies. It is not the nominal mission-planning interface. 13325

5.4 Testing, Training and Simulation

5.4.1 General

D: The ground system test and validation activities will begin around 2 years before launch. Activities will be mostly performed as part of the Ground Segment-Satellite Interface Tests (GSIT) and System Operations Validation (SOV) programme, and will include tests involving the payload as described in the following sections. 3471

5.4.2 System Validation Tests

D: Main objective of the System Validation Tests (SVTs) is: 3473

- the verification of end-to end communication links between spacecraft and SMOC, 3474
- the verification of databases needed in support of spacecraft operations, 3475
- the development and verification of Flight Procedures and Contingency Procedures for all spacecraft subsystems and instruments. 3476

The SVTs are performed with the actual satellite linked to the SMOC via a communications network for TM, TC and voice connections. 3477

EIDA-3478//

> ***EIDA R-383:*** *The PI shall make available the necessary resources to support the satellite interface tests outlined below through preparation of related inputs, review of test plans and procedures, and if required, through actual participation in the tests themselves.*

D: The Project will provide on-line access to the Solar Orbiter Flight Model for closed loop TM/TC testing (System Validation Test) with the ground segment and the flight control software. 3479

The SVTs will comprise: 3480

a. Spacecraft commanding from the SMOC 3481

b. Telemetry flow between satellite and SMOC. Real time non-science TM data processing in the SMOC in parallel to the (simulated) science TM processing in the Instrument Stations. 3482

D: A series of SVTs will be performed with the satellite, starting at around L-18 months. Typically SVT0, SVT1 and SVT2 slots will be scheduled and executed in this period. SVT0 will extend over a longer time period and mainly acquire satellite telemetry to verify databases and to perform some basic commanding; SVT1 emphasises “software” validation activities which include all mission control software facilities and databases. SVT2 is intended for re-validation of outstanding software facilities as well as for exercising and validating FOP sequences with the actual spacecraft. 3483

EIDA-3484//

> ***EIDA R-384:*** *The PI shall provide instrument test procedure inputs for the relevant part of the SVTs.*

EIDA-3485//

> ***EIDA R-385:*** *The PI shall review and approve instrument procedures defined by the SMOC for the relevant part of the SVTs.*

EIDA-3486//

> ***EIDA R-386:*** *The PI shall make available the necessary resources for real-time support at test site and/or at the SMOC during SVT execution.*

EIDA-3487//

> ***EIDA R-387:*** *The PI shall support the evaluation of the relevant part of the SVT results.*

EIDA-3488//

> ***EIDA R-388:*** *The PI shall support instrument anomaly investigation and resolution for the relevant part of the SVTs.*

5.4.3 System Operations Validation Test (SOVT)

D: The System Operations Validation Test (SOVT) programme will execute a series of end-to-end operational scenarios to verify readiness of the ground segment as a whole to support the mission. As such, a number of standard and mission unique test are executed. It should be noted that some of the test involving the end-to-end science operations systems will be differed to the post launch phases. Details about the overall system testing activities will be defined in the Ground Segment System Test Plan. 3490

5.4.4 Data Disposition System (DDS) Interface Tests

D: At around L-10 months the DDS interface to the remote PIs locations and SSGS will be tested to demonstrate compatibility in terms of physical/logical connectivity and application interfaces (file request/transfer mechanism, command request capability). This test may be performed applying an operational scenario with multiple users, and may include measurements of the turnaround times. 3492

D: Note that the DDS interfaces will have to be tested both in remote configuration and with the payload support systems installed at the SMOC in the configuration required for critical operations. 3493

EIDA-3494//

> ***EIDA R-389:*** *The PI shall make available the necessary resources to support the procedure definition, the procedure approval, the test execution, the results analysis and the anomaly investigation/resolution for the Data Disposition System Interface Test (DDSIT).*

5.4.5 SMOC/SGS End-to-End Test

D: The objective of the SMOC-/SGS Interface test is to verify the interface functions and procedures required to generate a consolidated operation request schedule, ready for subsequent up-link to the spacecraft. Furthermore, all operational interfaces defined in the mission planning ICD and in the Science Operations Implementation Agreement (SOIA) will be exercised. 3496

EIDA-3497//

> ***EIDA R-390:*** *The PI shall make available the necessary resources to support the procedure definition, the procedure approval, the results analysis and the anomaly investigation/resolution for the SMOC-SSGS End-to-End Test.*

5.4.6 Pre-Launch Operations

D: Pre-launch operations support will start approximately 6 months before the launch. During this period the SMOC will perform its final simulation programme including the validation of the Flight Operations Plan (FOP) and the mission control system. PIs team specialist participation will be required for the simulations related to the first instrument switch-on and other critical operations (e.g. NECP simulations). 3499

EIDA-3500//

> ***EIDA R-391:*** *The PI shall make available the necessary resources to support the procedure definition, the procedure approval, the test executions, the results analysis and the anomaly investigation/resolution for the first instrument switch-on Simulation campaign.*

5.5 Instrument Documentation and Data Inputs

5.5.1 Documentation

D: The payload will be operated and controlled in-flight according to the requirements defined in a set of documents used to prepare the FOP, which governs all flight operations. 3503

EIDA-3507//

> ***EIDA R-392:*** *The PI shall ensure that the list of contents for the instrument user manual complies with the Solar Orbiter Instrument User Manual DRD [NR-39].*

D: ESA will propose a common, coherent List of Content for the instrument User Manual based on the tailoring of the User Manual definition in ECSS-E-70. 3508

EIDA-3509//

> ***EIDA R-393:*** *The PI shall review and approve the FOP for the aspects/sections relevant to instrument operations.*

5.5.2 Instrument Database

D: A single, Project-wide spacecraft TM/TC database will be specified, using the structure and detailed definition of the SCOS-2000 MIB (Mission Information Base) compliant to SCOS-2000 Database ICD, EGOS-MCS-S2K-ICD-0001. This will ensure compatibility of the spacecraft database required by the multi-mission control system which is part of the SMOC infrastructure. 3511

D: The SMOC operations team shall be formally part of the review and approval process for all change requests produced on the MIB during the pre-launch population and maintenance phase. 3512

D: The SMOC will contribute to the population work pre-launch with direct inputs in areas agreed with the Project, such as payload TM/TC, displays, etc. 3513

D: Responsibility for database maintenance will be transferred to the SMOC at the Flight Acceptance Review. 3514

EIDA-3515//

> ***EIDA R-394:*** *The PI shall establish, maintain, validate and deliver an Instrument Data Base (IDB) to the ESA Solar Orbiter Project Office.*

D: The IDB will become part of the Mission Information Base (MIB). 3516

EIDA-9455//

> ***EIDA R-830:*** *The PI shall use the MIB format for the SCOS database as specified in NR34 (Solar Orbiter Spacecraft SRDB Payload ICD) and NR35 (Solar Orbiter Spacecraft SRDB Naming Convention and Population Rules)*

EIDA-3518//

> ***EIDA R-395:*** *The PI shall ensure that the IDB contain a complete definition of telemetry and telecommand data required for the detailed design of the flight control software, for the design of the software simulator and for setting up the operational telemetry and telecommand data files and operations procedures.*

EIDA-3519//

> ***EIDA R-396:*** *The PI shall ensure that the IDB comply to the detailed format, population rules and conventions defined & documented by the Prime Contractor*

D: Data to be provided as input to the SRDB (the list is not exhaustive): 3521

For TM: Mnemonic, description, addressing, coding, calibration, validity conditions, monitoring limits. 3522

For TC: Mnemonic, description, addressing, coding, calibration, execution conditions, execution checking. 3523

Model (e.g. EQM, FM), SW version (where applicable) and TM/TC ICD document reference 3524

Change log defining changes in data above from previous version (inserts, deletions and updates) 3525

6 VERIFICATION REQUIREMENTS

D: This chapter addresses the following aspects of the instrument verification: definitions, concept, analyses, acceptance and qualification test programmes, models and test philosophy, responsibilities. 3527

6.1 *Definitions*

D: Acceptance Verification: Verification intended to demonstrate that hardware is acceptable for flight. 3529

D: Acoustics/Random Vibration: an environment induced by high-intensity acoustic noise associated with various segments of the flight profile: it manifests itself throughout the instrument in the form of directly transmitted acoustic excitation and as structure-borne random vibration excitation. 3530

D: Electromagnetic Compatibility (EMC): The prevailing condition when various electronic devices are performing their functions according to design in a common electromagnetic environment. 3531

D: Electromagnetic Interference (EMI): Electromagnetic energy which interrupts, obstructs, or otherwise degrades or limits the effective performance of electrical equipment. 3532

D: Electromagnetic Susceptibility: Undesired response by a component, instrument or system to conducted or radiated electromagnetic emissions. 3533

D: Environmental Tests: Tests conducted on the flight or flight configured hardware to assure that the flight hardware will perform satisfactorily in one or more of its flight environments. To this class of test belong: Acoustic, Thermal Vacuum and EMC tests. 3534

D: Functional / Performance Tests: Testing at unit or instrument level in accordance with defined operational procedures to determine that the functionalities and performances are within the specified requirements before / after environmental tests. 3535

D: Incoming / Receiving Inspection: Inspection and / or functional tests to declare that the item is ready for integration on the spacecraft. 3536

D: Modal Survey Test: A series of mechanical investigations to determine the natural frequencies and associated modes of a structure. 3537

D: Performance Verification: Determination by test, analysis, or a combination of the two intended to demonstrate that the complete instrument or instrument unit can operate in line with the specified performance requirements. 3538

D: Protoflight Verification: Combination of qualification and acceptance on the flight hardware. A protoflight item is designated in advance to serve both as qualification and flight model and has to be designed for such purpose. The protoflight model is subject to tests at qualification levels but with flight acceptance duration. 3539

D: Qualification Programme: Determination by test, analysis, or a combination of the two intended to demonstrate that the item functions within performance specifications under simulated conditions more severe than those expected from ground handling, launch and orbital operations without exceeding design safety margins or introducing unrealistic modes of failure. 3540

D: Thermal Balance Test: A test conducted to verify the adequacy of the Thermal Model, the adequacy of the thermal design, and the capability of the thermal control system to maintain thermal conditions within established mission limits. 3541

D: Thermal Cycling Test: A test to demonstrate the ability of the instrument to fulfil functional and performance requirements after repeated thermal cycling over a specified temperature range. 3542

D: Thermal Vacuum Test: A test to demonstrate the validity of the instrument design to meet its functional and performance requirements under vacuum and in a specified thermal environment. 3543

D: Shock Tests: A test conducted to verify the soundness of the design under the transport, spacecraft and launcher induced shocks. 3544

D: Sinus Vibration Test: A test to demonstrate that the instrument can withstand the mechanical environment of the low frequency (less than 100 Hz) sinusoidal and transient vibrations. 3545

3546

D: Static Loads: The maximum combination (longitudinal and lateral) of static loads which acts on an instrument during the various segments of the flight profile. It consists of steady state accelerations (e.g. due to engine constant thrust or lateral wind loads) and quasi-static loads which are structure borne loads generated by the launch vehicle in the low frequency (less than 100 Hz) range (e.g. engine cut-off loads or wind gusts).

D: Test: Verification method (e.g. functional test, environmental tests), achieved when requirements have to be verified by measuring product performances, functions, interfaces under various simulated environments. 3547

D: Analysis: Verification method (e.g. structural, thermal analyses), achieved by performing theoretical or empirical evaluation by accepted techniques. 3548

D: Inspection: Verification method achieved by visual determination of physical characteristics (such as construction features, hardware conformance to document drawing or workmanship requirements). 3549

D: Review-of-design: Verification method achieved by validation of records or by evidence of validated design documents or when approved design reports, technical descriptions, engineering drawings unambiguously show the requirement is met. 3550

6.1.1 Documentation

EIDA-3552//

> ***EIDA R-410:*** *The PI shall provide for each test defined in the Instrument Assembly, Integration and Test Plan, a test specification describing, as a minimum, the relevant test configuration, test setup, test levels & tolerances, test facility, test goals, success criteria.*

EIDA-3553//

> ***EIDA R-411:*** *The PI shall provide a step-by-step procedure for each test defined in the Instrument Assembly, Integration and Test Plan.*

EIDA-3554//

> ***EIDA R-412:*** *The PI shall provide a test report containing the objectives, a description of test setup, a result summary vis a vis test predictions and the as-run procedure for each test defined in the Instrument Assembly, Integration and Test Plan.*

EIDA-3555//

> ***EIDA R-413:*** *The PI shall seek agreement with ESA before the start of any unit level test campaign.*

6.2 *Verification Concept and Methods*

D: The main instrument verification objectives are as follows: 3557

· to qualify the design; 3558

· to ensure that the is free from workmanship defects and acceptable for use in its spacecraft environment; 3559

· to verify that the instrument is able to fulfil mission requirements; 3560

EIDA-3561//

> ***EIDA R-414:*** *The PI shall apply one or more of the verification methods defined below to meet the above instrument verification objectives*

D: Verification by test is the preferred method. 3562

6.3 *Analyses and Mathematical Models*

D: A number of analyses are required to ensure the design soundness of the instrument. The list below is not exhaustive. Specific extra analyses may be requested to the PIs on a case by case basis. 3564

EIDA-3565//

EIDA R-415: *The PI shall perform for each instrument unit a structural analysis (stress and strength) and deliver the related reports which shall include at least:*

· A description of the configuration analyzed with reference to relevant MICDs 3566

· A description of the mathematical finite element model and/or of the assumptions taken to verify the structure 3567

· A description of all possible loading cases and an identification of the design driving load cases or load combinations 3568

· A description of the most loaded elements listed with relevant stresses, and the loading cases that generated them 3569

· A list of the materials and structural components with characteristics data sheets (including long-life effects under space environment) 3570

· A set of tables showing, for each structural element, the maximum value on each type of stress or combination of them with the allowable value, and the load case that determines it, together with its margin of safety. 3571

D: Further details on the content of the "Stress and Strength Analysis" document can be found in Annex K of ECSS-E-ST-32C [NR-11] 3572

EIDA-3573//

EIDA R-416: *The PI shall provide a Structural Mathematical Model (SMM) for each unit*

D: The Solar Orbiter Prime Requirement Specification for Structural FEM Models (Solar Orbiter - Mechanical FEM Requirement Specification SOL.S.ASTR.RS.00011 Issue 02, 30.09.2011) [IR-08], provides relevant guidelines 3574

D: The SMM will be used to calculate the mechanical characteristics and performances of each instrument unit. 3575

EIDA-3576//

EIDA R-417*: The PI shall ensure that the SMM is detailed enough to predict the dynamic loads to size the structure elements, and the interface loads in particular, with sufficient accuracy.*

EIDA-3577//

EIDA R-418*: The PI shall ensure that the SMM is able to reproduce the low frequency modes with an upper limit to the frequency range to be defined on a case-by-case basis.*

EIDA-3578//

EIDA R-419*: The PI shall ensure that the SMM fulfils the requirements of the Design Verification Requirements, when compared to test results.*

EIDA-3579//

EIDA R-420*: The PI shall ensure that a finite element model is accompanied by a clear description of the model itself and of the assumption made in the model, particularly concerning the boundary conditions at the spacecraft interfaces (i.e. hard mounted I/F).*

D: For mechanisms, two or more models (stowed, deployed; general position), may be required. 3580

EIDA-3581//

EIDA R-421*: The PI shall ensure that all mathematical models are maintained in current configuration.*

D: additional details for the compilation of the Structural Mathematical Model can be found in Annex I of ECSS-E-ST-32C [NR-11]. 3582

EIDA-3583//

EIDA R-422*: The PI shall perform a structural dynamic analysis and include at least:*

· A description of the configuration analyzed with reference to interface controlled drawings 3584

· A description of the mathematical finite element model and/or of the assumptions/reductions introduced in the analysis 3585

· A description of the checks performed on the model to verify its quality (e.g. rigid body modes, residual forces) 3586

· A list of eigen-frequencies with relevant mode type and associated modal effective 3587

D: additional details for the execution of the dynamic analysis can be found in Annex J of ECSS-E-ST-32C [NR-11] 3588

EIDA-3589//

EIDA R-423*: The PI shall deliver a 3D CAD Model for each unit, in support of the accommodation of instruments in the spacecraft and related structural design .*

EIDA-3590//

EIDA R-424*: The PI shall compile a 3D CAD model for each unit, in accordance with the check list described in Annex A6*

D: additional details for the compilation of the 3D CAD Model can be found in Annex A of ECSS-E-ST-32C [NR-11] 3591

EIDA-3592//

EIDA R-425: *The PI shall perform for each mechanism a functional analysis compliant with the requirements defined in ECSS-E-ST-33-01C, including at least include:*

· A detailed description of the mechanisms, with particular reference to its discrete components (bearings, actuators, switches) and to its operational/safety features 3593

· A detailed description of the operating modes with reference to ground and orbital activations 3594

· A definition of operating loads in various configurations with a clear definition of analysis assumptions. In particular, the functional analysis shall including the effects of the worst environmental conditions that could produce distortions or changes in clearance between movable parts (e.g. thermal gradient through bearings) 3595

· A Failure Modes, Effects and Criticality Analysis (FMECA) defining the failure modes and the functional margins of safety against each of them 3596

· A performance description of the control system that the mechanisms form a part of. 3597

6.3.1 Thermal Analysis

EIDA-3599//

EIDA R-426: *The PI shall perform a thermal analysis of each instrument unit.*

D: The objectives of the thermal analysis are as follows: 3600

· Verify that internal parts and materials are below their maximum allowed temperatures during flight conditions and acceptance/qualification testing; 3601

· Verify the ability of the unit thermal design to maintain the instrument specified internal temperatures and internal heat flow pattern that ensure performance requirements; 3602

· Verify the compliance with the spacecraft interface temperature ranges and interface heat flows specified in Annex A3. 3603

6.3.1.1 *Thermal Design Cases*

EIDA-3605//

EIDA R-427: *The PI shall perform thermal analyses with relevant parameters (e.g. power modes, dissipation profiles, external environmental fluxes, material properties, etc.) which lead* *to the worst case(s) combination and verify that the design is compliant with such worst case(s).*

EIDA-3606//

EIDA R-428: *The PI shall define and analyze the worst thermal sizing cases. In addition as a minimum the thermal cases given in the table below (Table 6.3-1) shall be analysed.*

D: This list is not exhaustive, since for example the thermal design of the internal units might require more cases to prove its soundness. 3607

3608

Case type	Analysis Type	Properties	Dissipations	Possible environments to be taken into account
Flight Hot Op.	steady-state	EOL	max (EOL)	min. sun distance, 0 to 3.5 degrees half-cone angle depointing; open and closed doors.
Flight Hot Op.	Transient	EOL	max (EOL)	min. sun distance up to 6.5 degrees half-cone angle depointing for 50 seconds; open doors
Flight manoeuvres (hot case)	steady-state, or transient	EOL	max (EOL)	sun in any direction at ≥ 0.95 AU and/or Venus and/or Earth environment, if relevant
Flight manoeuvres (cold case)	steady-state or transient	BOL	max (BOL)	sun in any direction, maximum solar distance depending on operational mode (i.e op and non-op); open and closed doors
Flight Cold Op.	steady-state or transient	BOL	min (BOL)	max. operational sun distance; 0 to 3.5 degrees, half-cone angle depointing; open and closed doors.
Flight Cold Non-Op.	steady-state or transient	BOL	min *	max. sun distance (≤ 1.47 AU), 0 to 3.5 degrees, half-cone angle depointing; open and closed doors.
Acceptance Test	steady-state	BOL	min/max (BOL)	min/max sun distance T_{URP} and T_R including acceptance margin **
Qualification Test	steady-state	BOL	min/max (BOL)	min/max sun distance T_{URP} and T_R including qualification margin **

Table 6.3-1: Thermal Design Cases. 3663

D: * during non-operating phases, heating power inside the unit might be necessary 3664

D: ** acceptance and qualification margins are specified in paragraph 4.6.2 3665

D: the sun angular radius has to be taken into account in the thermal analysis 3666

EIDA-3667//

EIDA R-757: *The PI shall perform transient analysis for the cold cases, to demonstrate the correct sizing of the instrument heaters (operational and survival ones) and compliance with heater power requirements given in Annex 3.2.*

6.3.1.2 *Thermal Mathematical Models*

EIDA-3669//

EIDA R-429: *The PI shall perform for each instrument unit a thermal analysis using an instrument Detailed Thermal Mathematical Model (DTMM) and an instrument Detailed Geometrical Mathematical Model (DGMM).*

EIDA-3670//

EIDA R-430: *The PI shall derive from the DTMM and DGMM and deliver an instrument Reduced Thermal Mathematical Model (RTMM) and an instrument Reduced Geometrical Model (RGMM) for coupled thermal analysis with the spacecraft.*

EIDA-3671//

EIDA R-431: *The PI shall ensure that the RTMM and RGMM comply with [NR-24], Payload Reduced Thermal Model Specification*

EIDA-3672//

EIDA R-432: *The PI shall ensure, in order to exchange of TMMs between PIs and ESA/Prime, that the RTMMs are in ESATAN-TMS/Thermal (formerly called ESATAN) format and the RGMMs are in ESATAN-TMS/Radiative format (formerly called ESARAD).*

D: For unit detailed thermal analysis, the following codes are recommended: 3673

· Thermal network solver: ESATAN-TMS/Thermal (formerly called ESATAN) Version Release R2 or higher; 3674

· Radiation coupling computation& Geometrical Model: ESATAN-TMS/Radiative (formerly called ESARAD) Version Release R2 or higher. 3675

EIDA-3676//

EIDA R-758: *The PI shall provide a RTMM / RGMM representative of the updated DTMM / DGMM after correlation with the results of the instrument thermal balance test.*

6.4 Testing

6.4.1 General

6.4.1.1 *General Test Approach*

EIDA-3680//

EIDA R-433: *The PI shall ensure that the instrument Flight Model is exposed to acceptance-level tests only, unless the PI selects a PFM model philosophy approach. In that case the PFM model shall be subject to tests at qualification levels but with flight acceptance duration.*

6.4.1.2 *Test Sequences and Programmes*

EIDA-3682//

EIDA R-434: *The PI shall specify and detail in the Assembly, Integration and Test Plan the qualification and acceptance test programmes the Instrument HW will undergo*

D: No specific environmental test sequence is required, but the test programme should be arranged in a way to best disclose problems and failures associated with the characteristics of the hardware and the mission objectives. 3683

D: It is strongly recommended that the vibration/acoustic test precede the thermal vacuum test unless there is an overriding reason to reverse that sequence. 3684

EIDA-3685//

EIDA R-435: *The PI shall demonstrate and justify via the defined qualification test programme that the HW will function within performance specifications under simulated conditions more severe than those expected from ground handling, launch and orbital operations.*

EIDA-3686//

> ***EIDA R-436:*** *The PI shall incorporate the following tests as part of the qualification programme.*

D: The actual tests and sequence of tests can be agreed on a case by case basis between the Solar Orbiter Project Office and the PI, based on a formal RFD/RFW. 3687

- Visual Inspection 3688
- Dimensions Verification 3689
- Physical Properties 3690
- Functional Test 3691
- Shock test 3692
- Sine Vibration test 3693
- Functional Test 3694
- Random Vibration test 3695
- Functional Test 3696
- Acoustic Noise test 3697
- Functional Test 3698
- Thermal Vacuum/ Thermal Balance test 3699
- Mechanism(s) lifetime testing. 3700
- Functional Test 3701
- Bonding test 3702
- Isolation test 3703
- Grounding test and conductivity test of space exposed surfaces 3704
- EMC Conducted Emission / Susceptibility test 3705
- EMC Radiated Emission / Susceptibility test 3706
- ESD susceptibility tests 3707
- DC Magnetic Properties test 3708
- Functional Test 3710
- Visual Inspection 3711

EIDA-3712//

> ***EIDA R-437:*** *The PI shall demonstrate and justify via the defined acceptance test programme that the hardware is acceptable for flight.*

EIDA-3713//

> ***EIDA R-438:*** *The PI shall incorporate the following tests as part of the acceptance programme:*
>
> - *Bonding test*
> - *Isolation test*
> - *Grounding test and conductivity test of space exposed surfaces*
> - *EMC Conducted Emission / Susceptibility test*
> - *EMC Radiated Emission / Susceptibility test*
> - *DC Magnetic Properties test*

3714

D: The actual tests and sequence of tests can be agreed on a case by case basis between the Solar Orbiter Project Office and the PI, based on a formal RFD/RFW.

- Visual Inspection 3715
- Dimensions Verification 3716
- Physical Properties 3717
- Functional Test 3718
- Sine Vibration test 3719
- Functional Test test 3720
- Random Vibration test 3721
- Functional Test test 3722
- Acoustic Noise test 3723
- Functional Test 3724
- Thermal Vacuum/ Thermal Balance test 3725
- Functional Test 3726
- Functional Test 3734
- Visual Inspection 3735

EIDA-3736//

EIDA R-439: *The PI shall ensure that modified / repaired / refurbished units (e.g. disassembled from the S/C after the system environmental testing and refurbished / repaired and then supposed to be re-integrated) undergo a set of test to verify the integrity and quality of the modified / repaired / refurbished units*

D: As a guideline the following sequence of tests is recommended: 3737

- Grounding / Bonding / Isolation
- EMC Conducted Emission / Susceptibility
- DC Magnetic Properties
- Functional Test 3738
- Random Vibration - 1 axis 3739
- Functional Test 3740
- Thermal Vacuum (2 cycles) 3741
- Functional Test 3742
- Visual Inspection 3746

6.4.1.3 *Test Level Tolerances*

EIDA-3748//

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

Electromagnetic Compatibility

- *Voltage Amplitude:* *± 5% of the peak value*
- *Current Amplitude:* *± 5% of the peak value*
- *RF Amplitudes:* *± 2 dB*
- *Frequency:* *± 2%*
- *Distance:* *± 5% of specified distance or ± 5 cm, whichever is greater*

Magnetic Properties

- *Mapping distance measurement: ± 1 cm*
- *Displacement of assembly Centre of Gravity (CoG) from rotation axis: ± 5 cm*
- *Vertical displacement of single probe centre line from CoG assembly: ± 5 cm*
- *Mapping turntable angular displacement: ± 3 degrees*
- *Magnetic field strength: ± 0.2 nT (tbc)*
- *Repeatability of magnetic measurements (short term): ± 5% or ± 0.2 nT (tbc), whichever is greater*
- *De-magnetizing and magnetizing field level: ± 5% of nominal*

Temperature 3749

- Tmax: 0 to +3°C, 3750
- Tmin: 0 to -3°C 3751
- Within the temperature range: -55°C ÷ +150°C 3752

Environmental heat fluxes 3753

- infrared fluxes: +/- 3% (from the SC) 3754

NOTE: The percentage figures in the following table (Table 6.4-1) reflects a Sun distance of 1AU. Solar Orbiter specific figures will be provided at a later date. 3755

3756

Solar intensity distribution in reference plane	±4 %	
Solar intensity distribution in reference volume	±6 %	
Solar intensity stability	±1 %	
Solar intensity stability (absolute)	±3 %	
Type	Wavelength (Angstrom)	Percent of total energy
Far Ultraviolet	1 to 2000	0.008
Near Ultraviolet	2000 to 3800	6.995
Visible	3800 to 7000	39.88 ±TBD%
Near Infrared	7000 to 10000	22.59
Infrared	10000 to 20000	24.02
Far Infrared	20000 to 100000	6.45

10411

Table 6.4-1: Environmental heat fluxes at a Sun distance of 1 AU.

Pressure: 3801

- Equal or above 0.1 mbar 10% 3802
- Below 0.1 mbar 50% 3803

Relative humidity: ± 5% 3804

Sinusoidal vibration: 3805

- Acceleration, amplitude ± 10% 3806
- Frequency above 50 Hz ± 2% 3807

Random vibration: 3808

- Power spectrum density (50 Hz or narrower) 3809

3810

20 to 500 Hz ± 1.5 dB

500 to 2000 Hz ± 3.0 dB 3811

· Overall g-rms ± 1.5 dB 3812

Static force: ± 5.0% 3813

Acoustic: ± 1 dB 3814

Mass Properties 3829

· Weight: ± 1 % 3830

· Centre of Gravity: ± 5 mm 3831

· Moments of Inertia: ± 10% 3832

6.4.2 Test Requirements at Instrument leveL

6.4.2.1 *Full Performance Test*

EIDA-3835//

> ***EIDA R-441:*** *The PI shall include all tests (e.g functional or performance, interface, etc) performed during the instrument-level FM AIV-program, in the Assembly, Integration and Verification Plan.*

EIDA-3836//

> ***EIDA R-442:*** *The PI shall define and perform an instrument Full Functional and Performance Test (FFPT), demonstrating that the hardware and software meet their performance requirements within allowed tolerances.*

D: The PI is in charge of structuring or decomposing this test as adequate for the instrument. 3837

EIDA-3838//

> ***EIDA R-443:*** *The PI shall demonstrate and document that the FFPT, is carried out in the representative environmental conditions and fulfil at least the following:*

· Verification of the proper operations of all nominal and redundant circuitry. 3840

· Instrument performances are satisfactory in all operational modes. 3841

· When provided with appropriate stimuli, instrument performances are satisfactory and outputs are within allowed limits. 3842

6.4.2.2 *Short and Abbreviated Functional Tests*

EIDA-3844//

> ***EIDA R-444:*** *The PI shall establish a Short Functional Test (SFT)*

D: The SFT is also used at spacecraft level testing - see below. 11459

EIDA-3845//

> ***EIDA R-445:*** *The PI shall ensure that as a minimum the SFTs:*

· focus on verification of instrument overall integrity and functionality 3846

· be completed within, typically one hour. 3847

D: The SFT is normally a subset of the FFT, and can be designed for the instrument-level AIV-flow as quick necessary and sufficient diagnostic tool after any mayor testing activity. The SFT should test both the nominal and redundant branches. 3848

D: The SFT may also be used in cases where FFT is unwarranted or impracticable. 3849

6.4.3 Instrument Functional Test at SC Level

EIDA-3851//

> ***EIDA R-721:*** *The PI shall define and carry out instrument Short Functional Tests (SFT) and instrument Full Functional Tests (FFT);*

D: SFTs will be basically diagnostic tests after major SC test steps. They will serve for verifying the 3853
command and telemetry paths during overall spacecraft functional tests. They should typically last no more than 1 hour.

D: Full instrument functional tests (FFT) are foreseen at least once at the start of the spacecraft-level 3854
environmental test campaign, and another one before the launch campaign. They shall serve to demonstrate full functioning of all elements of an instrument and all instrument operational modes, as far as compatible with operations in ambient conditions. However, instrument performance characteristics will, in general, not be (re-)verified during the spacecraft AIT campaign. They should typically last no more than 8 hours.

D: The initial FFT will serve as a baseline against which the results of all later FFTs can be readily 3852
compared.

EIDA-3855//

> ***EIDA R-446:*** *The PI shall provide the instrument databases and procedures for all tests to be performed at spacecraft level at least 6 months before delivery of the relevant instrument model to the Prime Contractor.*

D: The instrument FFTs, SFTs will be conducted in normal cleanroom conditions, as foreseen during 3856
the spacecraft AIV-program. They will not rely on any specific constraints on the spacecraft (such as spacecraft orientation, temperature, access by personnel, or stimuli (open loop).

D: potential constraints on what can be done within these tests might depend on the SC AIT 3857
sequence. Ideally the tests should not be dependent on any particular orientation of the spacecraft and should not require any breaking of electrical or mechanical connections (i.e. be non-invasive) and should not require use of any optical or mechanical I-EGSE.

6.4.4 EMC Test Requirements

EIDA-3859//

> ***EIDA R-447:*** *The Prime Contractor shall prepare a system-level Control and Verification based on tailoring of ECSS-E-ST-20-07C [NR-09].*

EIDA-3860//

> ***EIDA R-448:*** *The Prime Contractor shall prepare Control and Verification Report based on tailoring of ECSS-E-ST-20-07C [NR-09].*

EIDA-3861//

> ***EIDA R-449:*** *The Prime Contractor shall establish a verification matrix showing all combinations of individual equipment/subsystems under test in order to verify overall intra-system compatibility.*

EIDA-3862//

> ***EIDA R-453:*** *The Prime Contractor shall demonstrate safety margins at system level. If done by test, the spacecraft suite of equipment and subsystems shall be operated in a manner simulating actual operations.*

EIDA-3863//

> ***EIDA R-454:*** *The Prime Contractor shall use time domain methods for safety margin demonstration of a time domain circuit. (includes EEDs)*

EIDA-3864//

EIDA R-458: *The Prime Contractor shall verify by test bonding of discharge elements, thermal blankets, or metallic items removed from structure and requiring a bond for static potential equalisation.*

EIDA-3865//

EIDA R-459: *The Prime Contractor shall verify by test immunity to electrostatic discharge for equipment under Prime Contractor responsibility.*

D: *Since ESD testing can cause failure of the test article, verification will be performed on representative qualification models.*

6.4.4.1 *General Set-Up Requirements*

D: The following general EMC testing requirements both at instrument and unit-level apply. 3868

EIDA-3869//

EIDA R-460: *The PI shall ensure that the tests shall be performed in an ambient electromagnetic environment which is at least 6 dB below the performance levels required in chapter 4.*

D: Included in the ambient level are also emissions from test equipment, including unit-testers (EGSE) with its harness. 3870

EIDA-3871//

EIDA R-461: *Removed.*

EIDA-3872//

EIDA R-462: *Removed.*

EIDA-3874//

EIDA R-463: *The PI shall ensure that, in the cases where real electrical/electronic loads cannot be used, these loads are simulated by dummy loads with similar characteristics.*

EIDA-3875//

EIDA R-464: *The PI shall not take the interface wires to ground if not done in the actual/final installation in the spacecraft.*

EIDA-3876//

EIDA R-465: *The PI shall ensure that the power sources used for the tests have well defined impedance below 10 MHz.*

EIDA-3877//

EIDA R-466: *The PI shall ensure that the test harnesses are flight representative.*

EIDA-3878//

EIDA R-467: *The PI shall ensure that the grounding of interfaces is in accordance with flight installation.*

EIDA-3879//

EIDA R-468: *The PI shall ensure that bonding of units, unit tester, etc to the ground plane are verified by a bonding test.*

EIDA-3880//

EIDA R-469: *The PI shall ensure that the unit bonds are similar to that specified for the actual installation.*

EIDA-3881//

EIDA R-470: *The PI shall ensure that all equipment used for emission and susceptibility tests are calibrated.*

EIDA-3882//

EIDA R-471: *The PI shall ensure that passive equipment, such as antennas, current probes etc. have calibration curves from the manufacturer.*

6.4.4.2 *Conducted emissions on power lines, differential mode, frequency domain*

EIDA-3884//

EIDA R-472: *The PI shall abide by paragraph 5.4.2 of ECSS-E-ST-20-07C [NR-09].*

6.4.4.3 *Conducted emissions on power and signal lines, common mode, frequency domain*

EIDA-3886//

EIDA R-473: *The PI shall abide by paragraph 5.4.3 of ECSS-E-ST-20-07C, [NR-09]*

6.4.4.4 *Conducted emissions on power lines, differential mode, time domain*

EIDA-3888//

EIDA R-474: *The PI shall measure current ripple and spikes according to the test set-up in fig. 5-8 of ECSS-E-ST-20-07C, [NR-09] with current probe and oscilloscope with the required bandwidth.*

EIDA-3889//

EIDA R-475: *The PI shall measure voltage ripple/spike on the primary power bus inputs of the units according to the test set-up in fig. 5-8 ECSS-E-ST-20-07C, [NR-09] where a differential voltage probe (instead of a current probe) is connected to the power lines wires and the data recorder is an oscilloscope.*

6.4.4.5 *Conducted emissions on power lines, common mode, time domain*

EIDA-3891//

EIDA R-476: *The PI shall measure the current ripple and spikes according to the test set-up in fig. 5-9 of ECSS-E-ST-20-07C, [NR-09]*

6.4.4.6 *Conducted emissions on power lines, inrush current*

EIDA-3893//

EIDA R-477: *The PI shall abide by paragraph 5.4.4 of ECSS-E-ST-20-07C, [NR-09].*

6.4.4.7 *Conducted emissions on antenna ports*

EIDA-3895//

EIDA R-478: *The PI shall abide by MIL-STD 461F, CE106*

6.4.4.8 *Conducted susceptibility on power lines, differential mode, frequency domain*

EIDA-3897//

EIDA R-479: *The PI shall abide by paragraph 5.4.7 of ECSS-E-ST-20-07C, [NR-09]*

EIDA-3898//

EIDA R-480: *The PI shall use, above 50 kHz, the test set-up and the calibration set-up shown in the figures below (Figure 6.4-1 and Figure 6.4-2).*

3899

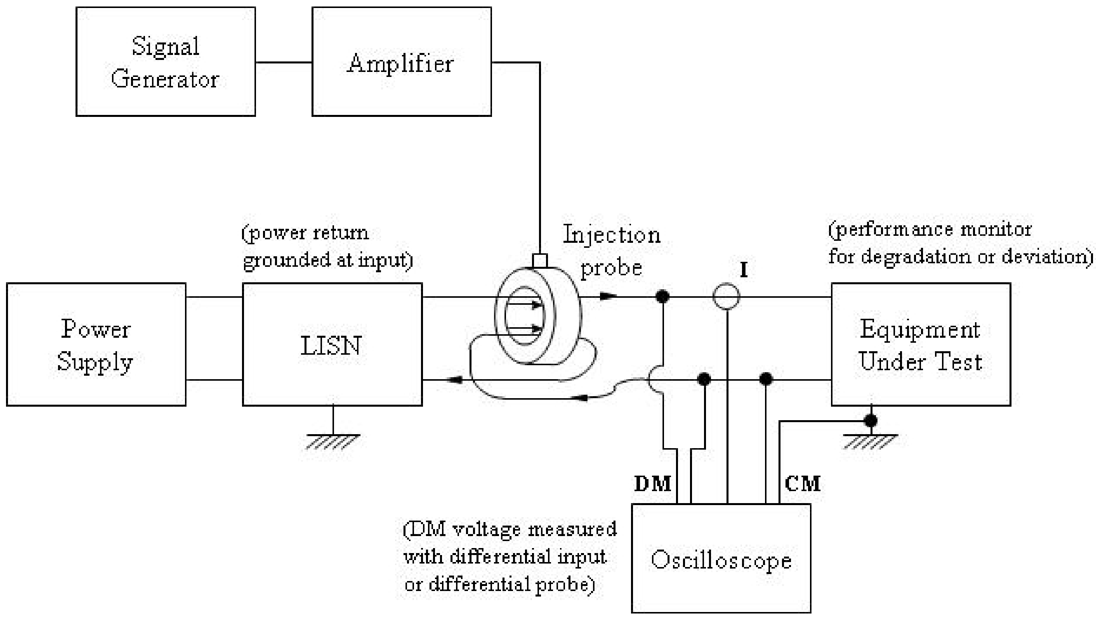


Figure 6.4-1: Conducted Susceptibility on power lines, differential mode, frequency domain. 3900

3901

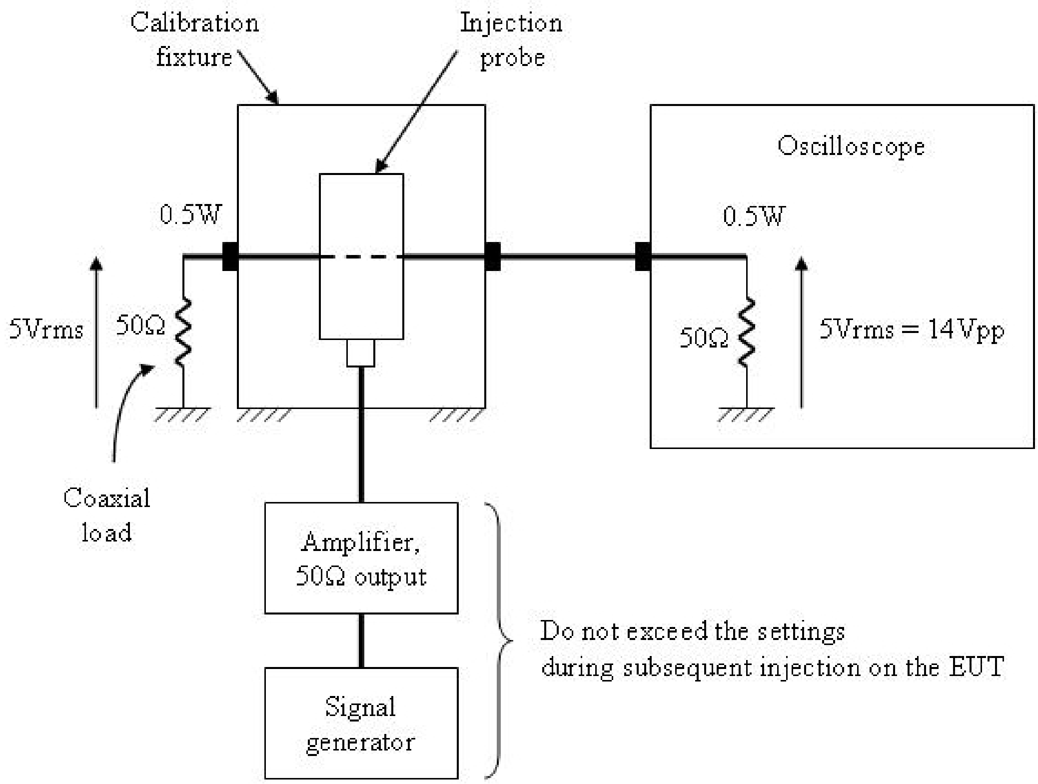


Figure 6.4-2: Conducted Susceptibility on power lines, differential mode, frequency domain, calibration set-up. 3902

6.4.4.9 *Conducted susceptibility on power lines, common mode, frequency domain*

EIDA-3904//

EIDA R-481: *The PI shall abide by paragraph 5.4.8 of ECSS-E-ST-20-07C, [NR-09]*

6.4.4.10 *Conducted susceptibility on power lines, differential mode, transient*

EIDA-3906//

EIDA R-482: *The PI shall abide by paragraph 5.4.9 of ECSS-E-ST-20-07C, [NR-09]*

6.4.4.11 *Conducted susceptibility on signal lines, common mode*

6.4.4.12 *Radiated emissions, electric field*

EIDA-3910//

EIDA R-484: *The PI shall abide by paragraph 5.4.6 of ECSS-E-ST-20-07C, [NR-09] for frequencies above 30MHz.*

D: Dealing with the low frequency measurements, a number of precautions are needed to be reproducible. It is necessary to avoid all parasitic resonances of the test set-up, so that measurements are reproducible and the radiated emission of canonical objects can be measured according to prediction. 3912

D: Recommended test configurations and test precautions are presented in ECSS-E-HB-20-07A Chapter 7.3. 3911

6.4.4.13 *Radiated emissions, ac magnetic field (f >10÷100Hz up to 1MHz)*

D: This activity has to be carefully defined. For frequencies up to ~10 kHz a search coil magnetometer should be used; for higher frequencies an air coil should be used. The test set-up and method have to be defined. 3920

6.4.4.14 *Radiated susceptibility, electric field*

EIDA-3922//

EIDA R-486: *The PI shall abide by paragraph 5.4.11 of ECSS-E-ST-20-07C, [NR-09]*

6.4.4.15 *Radiated susceptibility, magnetic field*

EIDA-3924//

EIDA R-487: *(deleted)*

6.4.4.16 *Magnetic emissions, dc and low frequency ac (f <10÷100Hz)*

D: This activity has to be carefully defined. For dc magnetic tests and ac up to f <10÷100Hz a fluxgate magnetometer should be used. The test set-up and method have to be defined. 3926

6.4.4.17 *ESD susceptibility*

EIDA-3928//

EIDA R-488: *The PI shall carry out testing for susceptibility against electrostatic discharge (ESD) at least once during an instrument development program on a model which is fully representative for the purpose of the test. Due to the risk of latent defects, FMs or PFMs shall not undergo ESD testing.*

6.4.4.18 *ESD susceptibility, radiated*

EIDA-3930//

EIDA R-489: *The PI shall abide by paragraph 5.4.12 of ECSS-E-ST-20-07C, [NR-09]*

6.4.4.19 *ESD susceptibility, conducted*

EIDA-3932//

EIDA R-490: *The PI shall follow the set-up as shown in to the figure below (Figure 6.4-3).*

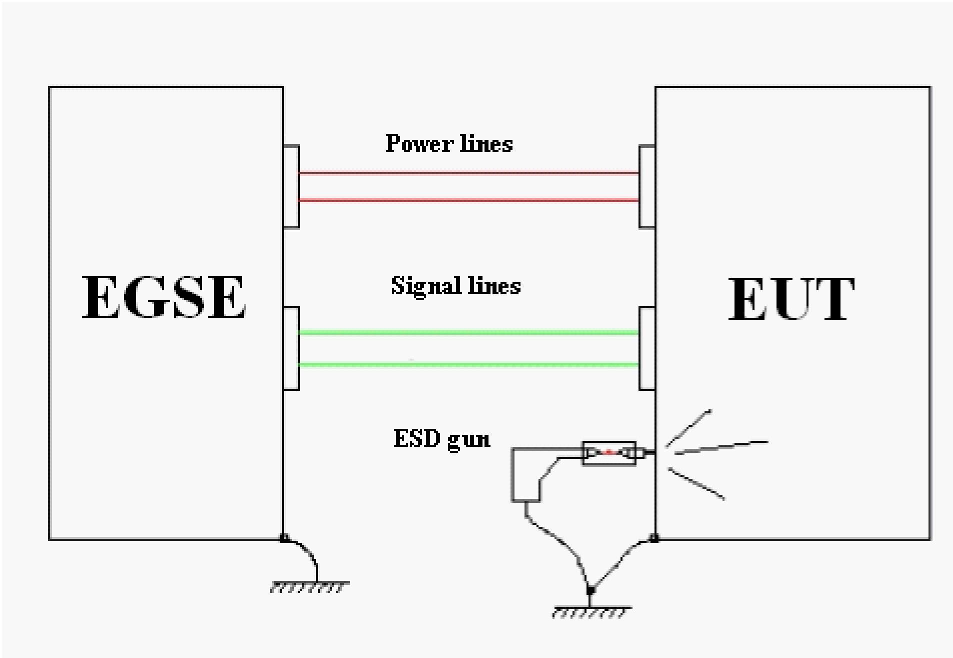
 3933

Figure 6.4-3: Conducted ESD test set-up. 3934

6.4.4.20 *EMC Test Categories*

D: The development tests should be performed at an early stage of the programme to evaluate the design approach, indicate critical areas where design improvement is required and assure design compliance with EMC requirement and support analytical methods or generate essential design data. 3936

D: The qualification tests and sequence are described in paragraph 6.4.1.2 3937

D: The acceptance tests and sequence are described in paragraph 6.4.1.2 3938

6.4.5 Structural Test Requirements

6.4.5.1 *Structural Test Setup*

EIDA-3941//

> ***EIDA R-491:*** *The PI shall ensure that the instrument units are tested in launch configuration.*

D: launch configuration refers to units status / mode at launch from an electrical, SW, mechanisms, thermal point of view. Actual units orientation wrt the SC is not relevant. 3942

EIDA-3943//

> ***EIDA R-492:*** *The PI shall ensure that test adaptors and / or non flight items are removed before test.*

EIDA-3944//

> ***EIDA R-493:*** *The PI shall provide any special test adapter required for the test.*

EIDA-3945//

> ***EIDA R-494:*** *The PI shall vibrate the instrument in hard mounted configuration through the designated S/C interface points.*

EIDA-3946//

> ***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.*

EIDA-3947//

EIDA R-496: *The PI shall ensure that any amplification from the fixture do not contribute more than 1% to the g-rms value during the random test.*

6.4.5.2 *Sine Vibration Test Levels*

EIDA-3949//

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 (Table 6.4-2) at unit / structure interface.*

9462

Axis	Frequency (Hz)	Qualification	Acceptance
Out of plane	5-20	15 mm	9.9 mm
	20-100	24 g	16 g
In plane	5-20	9.9 mm	6.6 mm
	20-100	16 g	10.7 g
		2 Oct/min	4 Oct/min

3981

Table 6.4-2: Qualification and Acceptance Levels for Sine Vibration Tests.

EIDA-3982//

EIDA R-809: *The PI shall ensure that the units listed in the table below are designed to withstand without degradation the sinusoidal environment as defined in table (Table 6.4-3) below at unit / structure interface.*

9494

Axis /Unit	Frequency (Hz)	Qualification	Acceptance
SWA-PAS/HIS/EAS RPW-SCM (all axis)	5-20	15.5 mm	12.4 mm
	20-100	25 g	20 g
		2 Oct/min	4 Oct/min

4004

Table 6.4-3: Qualification and Acceptance Levels for Sine Vibration Tests.

EIDA-4005//

EIDA R-810: *The PI shall ensure that the units listed in the table below are designed to withstand without degradation the sinusoidal environment as defined in table (Table 6.4-4) below at unit / structure interface.*

9515

Axis/ Unit	Frequency (Hz)	Qualification Level	Acceptance Level
MAGOBS/ IBS (all axis)	5-20	43.5 mm	31.1 mm
	20-100	70 g	50 g
		2 Oct/ min	4 Oct/min

4027

Table 6.4-4: Qualification and Acceptance Levels for Sine Vibration Tests for MAG.

EIDA-4028//

EIDA R-811: *The PI shall ensure that the SolO-Hi SIM assembly (i.e. including the mounting bracket) is designed to withstand without degradation the sinusoidal environment as defined in table below (Table 6.4-5) at unit / structure interface.*

9536

Axis	Frequency (Hz)	Qualification	Acceptance
Out of plane	5-20	6.2 mm	5.0 mm
	20-100	10 g	8 g
In plane	5-20	21.7 mm	15.5 mm
	20-100	35 g	25 g

Axis	Frequency (Hz)	Qualification	Acceptance
		2 Oct/min	4 Oct/min

Table 6.4-5: Qualification and Acceptance Levels for Sine Vibration Tests for SOLOHI SIM at the mounting bracket base. 4060

EIDA-9406//

EIDA R-823: *The PI of PHI and STIX shall ensure that the HREWs and windows are designed to withstand without degradation the sinusoidal environment as defined in the table below (Table 6.4-6) at the unit- structure interface.* 9407

Axis	Frequency (Hz)	Qualification	Acceptance
In Any Direction	5 - 22.5	+/- 12.4 mm	8mm
	22.5 - 100	25 g	17g

Table 6.4-6: Qualification and Acceptance Levels for Sine Vibration Tests for PHI HREWs and STIX windows. 10412

EIDA-4062//

EIDA R-498: *Removed*

6.4.5.3 Random Vibration level Tests

EIDA-4063//

EIDA R-499: *The PI shall ensure that each unit is designed to withstand without degradation the random environment as defined in Table 6.4-7 and Table 6.4-8 below at unit/structure interface.*

D: For the STIX window the requirement in Table 6.4-8 the levels apply at the feedthrough mounting interface at the heatshield support panel and are intended to be used in conjunction with the FEM model of the feedthrough 17607

D: Instruments covered by the generic Table 6.4-7 include EPD, SPICE and METIS. The remainder are covered by the tables that are shown after this one. 18766

9255

Axis / unit mass	Frequency (Hz)	Qualification g2/Hz	Acceptance
Perpendicular to mounting plane Mass < 0.5 kg (1 axis)	20-100	+12dB/Oct	Qualification/2 (PSD)
	100-250	1	
	250-500	1.5	
	500-2000	-8dB/Oct	
		g-rms = 30.9	
Perpendicular to mounting plane 0.5 kg <Mass < 3 kg (1 axis)	20-100	+12dB/Oct	Qualification/2 (PSD)
	100-500	1	
	500-2000	-8dB/Oct	
		g-rms = 26.3	
Perpendicular to mounting plane 3 kg <Mass < 10 kg (1 axis)	20-80	+3dB/Oct	Qualification/2 (PSD)
	80-500	0.5	
	500-2000	-6dB/Oct	

Axis / unit mass	Frequency (Hz)	Qualification g2/Hz	Acceptance
		g-rms = 20.4	
Perpendicular to mounting plane Mass > 10 kg (1 axis)	20-80	+3dB/Oct	Qualification/2 (PSD)
	80-500	0.3	
	500-2000	-6dB/Oct	
		g-rms = 15.8	
Parallel to mounting plane All Unit Masses	20-80	+4 dB/Oct	Qualification/2 (PSD)
	80-1000	0.1	
	1000-2000	-3dB/Oct	
		g-rms = 12.8	

Table 6.4-7: General Qualification and Acceptance Levels for Random Vibration Tests. 8958

. 18931

Unit	Axis	Freq (Hz)	Qualification g2/Hz	Acceptance g2/Hz
STIX Filters (upper & lower)	S/C Y-axis & Z-axis (in-plane)	20-100	+4 dB/Oct	+4 dB/Oct
		100-300	0.4	0.2
		300-330	+32 dB/Oct	+32 dB/Oct
		330-500	1.1	0.55
		500-2000	-15 dB/Oct	-15 dB/Oct
			g-rms = 21.04	**g-rms = 14.88**
	S/C X-axis (out-of-plane)	20-120	+18 dB/Oct	+18 dB/Oct
		120-180	5.0	5.0
		180-225	-24.75 dB/Oct	-24.75 dB/Oct
		225-550	0.8	0.8
		550-2000	-15 dB/Oct	-15 dB/Oct
			g-rms = 29.24	**g-rms = 20.67**

17515

14702

Unit	Axis	Frequency Hz	Qualification g2/Hz	Acceptance
PHI HEW	S/C X-axis (out-of-plane)	20-135	+16.71 dB/Oct	Qualification/2 (PSD) Qual./1.41 g-rms
		135 - 200	3	
		200 - 320	-11.48dB/Oct	
		320	0.5	
		330 - 400	1.5	
		400 - 2000	-13.12dB/Oct	
			grms=26.6	
	S/C Y-axis & Z-axis (in-plane)	20 - 100	+23.6 dB/Oct	Qualification/2 (PSD)
		100 - 250	9.0	
		250 - 300	-56.16 dB/Oct	
		300 - 500	0.3	

		500 - 2000	-20 dB/Oct	
			grms = 41	
Unit	**Axis**	**Frequency Hz**	**Qualification g2/Hz**	**Acceptance**
PHI FEW	S/C X-axis (out-of-plane)	20 - 120	+34.82dB/Oct	Qualification/2 (PSD)
		120 - 340	9.0	
		340 - 2000	-17.02dB/Oct	
			g-rms = 52.2	
	S/C Y-axis & Z-axis (in-plane)	20 - 120	+21.67 dB/Oct	Qualification/2 (PSD)
		120 - 250	12.0	
		250 - 400	-31.34 dB/Oct	
		400 - 900	-12.62 dB/Oct	
		900 - 2000	-8.68 dB/Oct	
			g-rms = 45.4	
Unit	**Axis**	**Frequency Hz**	**Qualification g2/Hz**	**Acceptance**
PHI E-box	S/C Y-axis (out-of-plane)	20	0.06	Qualification/2 PSD)
		100	0.5 (9.21dB/Oct)	
		250	0.5	
		300	0.0225 (-13.47dB/Oct)	Qual./1.41 for g-rms
		320	0.0225	
		410	0.5 (13.47dB/Oct)	
		500	0.5	
		2000	0.03 (-12.22dB/Oct)	
			g-rms = 19.11	
	S/C X-axis (in-plane)	20-100	+4 dB/Oct	Qualification/2 (PSD)
		100	0.1	
		450	0.1	
		550	0.04	Qual./1.41 for g-rms
		600	0.04	
		700	0.07	
		600-2000	-3dB/Oct	
			g-rms = 9.88	
	S/C Z-axis (in-plane)	20 - 100	+4dB/Oct	Qualification/2 (PSD)
		100	0.1	
		500	0.1	Qual./1.41 for g-rms
		500-2000	-3dB/Oct)	
			g-rms = 10.66	

14856

Table 6.4-8: General Qualification and Acceptance Levels for Random Vibration Tests for the PHI HEW/ FEW / E-Box and the STIX windows.

EIDA-4176//

EIDA R-812: *The PI shall ensure that the units listed in the tables below (Table 6.4-9, Table 6.4-10 and Table 6.4-11) are designed to withstand without degradation the random environment as defined in the table below at unit/structure interface.* 16338

Unit /Axis	Frequency Hz	Qualification g2/Hz	Acceptance
SWA-PAS S/C X-axis (in plane)	20-100	+12dB/Oct	Qualification/2 (PSD) Qual./1.41 for g-rms
	100	1.5	
	170	1.5	
	220	0.1 (-31.62 dB/Oct)	
	250	0.1	
	320	1 (+28.08 dB/Oct)	
	650	0.03 (-14.9 dB/Oct)	
	850	0.03	
	2000	-6dB/Oct	
		g-rms = 16.97	
SWA-PAS S/C Y-axis (in-plane)	20-100	+12 dB/Oct	Qualification/2 (PSD) Qual./1.41 for g-rms
	100	1.5	
	300	1.5	
	650	0.03 (-15dB/Oct)	
	850	0.03	
	2000	-6dB/Oct	
		g-rms = 21.4	
SWA-PAS S/C Z-axis (out-of-plane)	20-100	+12dB/Oct	Qualification/2 (PSD) Qual./1.41 for g-rms
	100	1.5	
	240	1.5	
	320	0.1 (-28.34 dB/Oct)	
	350	0.1	
	410	0.3 (+20.9 dB/Oct)	
	650	0.03 (-15.04 dB/Oct)	
	850	0.03	
	2000	-6 dB/Oct	
		g-rms = 18.44	

16336

Table 6.4-9: Qualification and Acceptance Levels for Random Vibration Tests for SWA-PAS.

9567

Axis/ Unit	Frequency (Hz)	Qualification g2/Hz	Acceptance
RPW-SCM (all axes)	20 - 100	+12 dB/oct	Qualification /2 (PSD)
	100 - 300	1.5	
	300 - 650	- 15 dB/oct	
	650 - 850	0.03	
	850 - 2000	-6 dB / oct	
		g-rms = 21.4	

16337

Table 6.4-10: Qualification and Acceptance Levels for Random Vibration Tests for RPW-SCM.

12956

Axis	Frequency (Hz)	Qualification g2/Hz	Acceptance
	20-80	+12 dB/Oct	
	80-150	0.6	

Axis	Frequency (Hz)	Qualification g2/Hz	Acceptance
SWA- EAS unit X-axis (in-plane)	200-445	0.2	Qualification/2 (PSD)
	650--850	0.03	
	850-2000	-6 dB/Oct	
		g-rms = 12.5	
SWA-EAS unit Y-axis (in-plane) unit Z-axis (out-of-plane)	20-80	+12 dB/Oct	Qualification /2 (PSD)
	80-150	1.5	
	200-350	0.15	
	350-2000	-15 dB/Oct	
		g-rms = 13.9	

12955

Table 6.4-11: Qualification and Acceptance Levels for Random Vibration Tests for SWA-EAS.

EIDA-10063//

EIDA R-833: *The PI shall ensure that the units listed in the tables below are designed to withstand, without degradation, the random environment as defined in the table below (Table 6.4-12 and Table 6.4-13)) at unit/structure interface.*

10064

Axis/ Unit	Frequency (Hz)	Qualification g2/Hz	Acceptance
SWA-HIS S/C X-axis (in-plane)	20-50	+18 dB/Oct.	Qualification/2 (PSD) Qualification /1.41 (g-rms)
	50-115	0.60	
	115-120	-28.7 dB/Oct.	
	120-150	0.40	
	150-155	+37.2 dB/Oct.	
	155-300	0. 60	
	300-2000	-12 dB/Oct.	
		g-rms = 14.4	

10146

Table 6.4-12: Qualification and Acceptance Levels for Random Vibration Tests for SWA-HIS: X Axis Test on the Spacecraft.

10149

Axis / Unit	Frequency (Hz)	Qualification g2/Hz	Acceptance
SWA- HIS S/C Y axis (in-plane) S/C Z axis (out-of-plane)	20 - 50	+18 dB/Oct.	Qualification/2 (PSD) Qualification /1.41 (g-rms)
	50 -80	1.50	
	80 - 100	-14.8 dB/Oct.	
	100 -300	0.50	
	300 - 2000	-12 dB/Oct.	
		g-rms = 14.96	

10185

Table 6.4-13: Qualification and Acceptance Levels for Random Vibration Tests for SWA-HIS: Y and Z Axis Test on the Spacecraft.

EIDA-4214//

EIDA R-813: *The PI shall ensure that the units listed in the tables below are designed to withstand without degradation the random environment as defined in the tables below (Table 6.4-14 and Table 6.4-15) at unit/structure interface.*

16711

Unit/Axis	Freq (Hz)	Qualification g2/Hz	Acceptance
MAG IBS & OBS S/C X-axis (in-plane)	20	0.0020	Qualification/2 (PSD) Qualification /1.41 (g-rms)
	70	0.3	
	400	0.3	
	2000	0.004	
		g-rms = 13.06	

Table 6.4-14: Qualification and Acceptance Levels for Random Vibration Tests for MAG: X Axis Test on the Spacecraft. 16708

16797

Unit/Axis	Freq (Hz)	Qualification g2/Hz	Acceptance
MAG IBS & OBS S/C Y-axis (in-plane) S/C Z-axis (out-of-plane)	20	0.0070	Qualification/2 (PSD) Qualification /1.41 (g-rms)
	80	1.75	
	200	1.75	
	225	1	
	400	1	
	2000	0.01388	
		g-rms = 25.9	

Table 6.4-15: Qualification and Acceptance Levels for Random Vibration Tests for MAG: Y and Z Axis Test on the Spacecraft. 10413

EIDA-4241//

EIDA R-814: *The PI shall ensure that the SolOHI SIM unit and the SolOHI SPS unit are designed to withstand without degradation the random environment as defined in the tables below (Table 6.4-16 and Table 6.4-17) at unit/structure interface.*

16615

Unit/Axis	Frequency Hz	Qualification g2/Hz	Acceptance g2/Hz
SolOHI-SIM S/C Y-axis (out-of-plane)	20-105	+3dB/Oct	Qualification/2 (PSD) Qual./1.41 for g-rms
	105	0.4	
	180	0.4	
	190	0.11 (-70.63 dB/Oct)	
	258	0.11	
	268	0.25 (+56.4 dB/Oct)	
	575	0.25	
	2000	-6dB/Oct	
		g-rms = 15.57	
SolOHI-SIM S/C X-axis & Z-axis (in-plane)	20-80	+3dB/Oct	Qualification/2 (PSD) Qual./1.41 for g-rms
	80	0.6	
	103	0.6	
	113	0.225 (-31.9 dB/Oct)	
	816.5	0.225	
	2000	-6 dB/Oct	
		g-rms = 17.53	

Table 6.4-16: Qualification and Acceptance Levels for Random Vibration Tests for SOLOHI SIM at the mounting bracket base. 4288

11553

Axes/ Unit	Frequency (Hz)	Qualification g2/Hz	Acceptance
SolOHI SPS	20 -100	+3 dB/ Oct	Qualification / 2

Axes/ Unit	Frequency (Hz)	Qualification g2/Hz	Acceptance
S/C X-axis & Z-axis (in-plane)	100 - 240	0.2	(PSD)
	240 - 260	-26.07	
	260 - 500	0.1	Qualification / 1.41 (g-rms)
	500 - 2000	-3 dB/ Oct	
		g-rms = 10.11	

11594

SolOHI SPS S/C Y-axis (out-of-plane)	20 - 105	+ 3 dB/Oct	Qualification / 2 (PSD)
	105 - 180	0.4	
	180 - 190	-70.63 dB/Oct	
	190 - 258	0.1125	
	258 - 268	+77.64 dB/ Oct	Qualification / 1.41 (g - rms)
	268 - 500	0.3	
	500 - 2000	-6 dB/ Oct	
		g-rms = 15.63	

11506

Table 6.4-17: Qualification and Acceptance Levels for Random Vibration Tests for SOLOHI SPS at the mounting base.

EIDA-16859//

EIDA R-869: *The PI shall ensure that the SPICE SOU is designed to withstand without degradation the random environment as defined in Table 6.4-18 at unit/structure interface.*

16862

Unit/Axis	Freq(Hz)	PSD (g2/Hz)	dB	Oct	dB/Oct	Area	Grms
SPICE SOU S/C Z-axis (out-of-plane)	20	0.0754	*	*	*	*	*
	80	0.3000	6.00	2.00	3.00	11.27	3.36
	290	0.3000	0.00	1.86	0.00	74.27	8.62
	330	0.1000	-4.77	0.19	-25.59	81.46	9.03
	880	0.1000	0.00	1.42	0.00	136.46	11.68
	2000	0.0189	-7.23	1.18	-6.10	185.27	13.61
		g-rms	**13.6**				
SPICE S/C X-axis (in-plane) S/C Y-axis (in-plane)	20	0.0158	*	*	*	*	*
	80	0.1000	8.01	2.00	4.01	3.30	1.82
	160	0.1000	0.00	1.00	0.00	11.30	3.36
	200	0.0700	-1.55	0.32	-4.81	14.64	3.83
	350	0.0700	0.00	0.81	0.00	25.14	5.01
	390	0.1000	1.55	0.16	9.92	28.51	5.34
	1000	0.1000	0.00	1.36	0.00	89.51	9.46
	2000	0.0501	-3.00	1.00	-3.00	158.91	12.61
		g-rms	**12.6**				

16858

Table 6.4-18: Qualification and Acceptance Levels for Random Vibration Tests for SPICE SOU at unit/structure interface.

EIDA-16861//

EIDA R-870: *The PI shall ensure that the EUI OBS is designed to withstand without degradation the random environment as defined in Table 6.4-19 below at unit/structure interface.*

17224

Unit/Axis	Frequency Hz	Qualification g2/Hz	Acceptance
EUI OBS S/C X-axis (in-plane)	20	0.0158	Qualification/2 (PSD) Qual./1.41 for g-rms
	80	0.1 (4dB/Oct)	
	150	0.1	
	170	0.004 (-77.4 dB/Oct)	
	210	0.004	
	235	0.1 (+86.1 dB/Oct)	
	300	0.1	
	400	0.055 (-6.3dB/Oct)	
	1000	0.055	
	2000	0.0276 (-3dB/Oct)	
		g-rms = 9.86	
EUI OBS S/C Y-axis (out-of-plane)	20	0.01	Qualification/2 (PSD) Qual./1.41 for g-rms
	80	0.16 (+6 dB/Oct)	
	300	0.16	
	350	0.035 (-29.7dB/Oct)	
	390	0.035	
	410	0.07 (41.7dB/Oct)	
	750	0.07	
	2000	0.019 (-4dB/Oct)	
		g-rms = 10.66	
EUI OBS S/C Z-axis (in-plane)	20	0.0158	Qualification/2 (PSD) Qual./1.41 for g-rms
	80	0.1 (4dB/Oct)	
	200	0.1	
	208	0.04	
	232	0.04	
	240	0.1 (81.4dB/Oct)	
	300	0.1	
	400	0.055 (-6.3 dB/Oct)	
	1000	0.055	
	2000	0.0276 (-3 dB/Oct)	
		g-rms = 10.09	

16856

Table 6.4-19: Qualification and Acceptance Levels for Random Vibration Tests for EUI OBS at unit/structure interface.

EIDA-4290//

EIDA R-500*: The PI shall apply the random qualification level for the duration of 2 minutes*

EIDA-4291//

EIDA R-501*: The PI shall apply the random acceptance level for the duration of 1 minute*

6.4.5.4 Acoustic Test levels

EIDA-4292//

> ***EIDA R-732:*** *The PI shall ensure that each unit is designed to withstand without degradation the acoustic environment as defined in the table below (Table 6.4-20).*

D: Values are presently TBC 4293

9675

Frequency (Hz)	Flight/ Limit Acceptance (dB)	Qualification SPL (dB)	Test Tolerance (dB)
31.5	130.1	133.1	-1/+3
63.0	131.4	134.4	-1/+3
125.0	136.0	139.0	-1/+3
250.0	134.8	137.8	-1/+3
500.0	132.6	135.6	-1/+3
1000.0	126.2	129.2	-1/+3
2000.0	121.4	124.4	-1/+3
4000.0	116.9	119.9	-1/+3
8000.0	112.4	115.4	-1/+3
OASPL	140.7	143.7	-1/+3

D: Note: Sound Pressure Reference Level = 2×10^{-5} Pa. 9751

D: Acceptance test level duration is 1 minute.

D: Qualification test level duration is 2 minutes.

Table 6.4-20: Acoustic Test Levels. 4371

6.4.5.5 *Shock Test Levels*

EIDA-4373//

> ***EIDA R-502***: *The PI shall ensure that each unit is designed and qualified to withstand without degradation the shock levels specified in the Figure 6.4-4 and Table 6.4-21, applicable independently to each axis at unit / structure interface.*

9752

Shock Level 1 - Lower	**1000g**		
Frequency	100 Hz	1400 Hz	10 kHz
Shock response spectrum (Q=10) at unit interface	36g	1000g	1000g

Shock Level 2 - Higher	**1,500g**		
Frequency	100 Hz	1500 Hz	10 kHz
Shock response spectrum (Q=10) at unit interface	54g	1500g	1500g

15859

15861

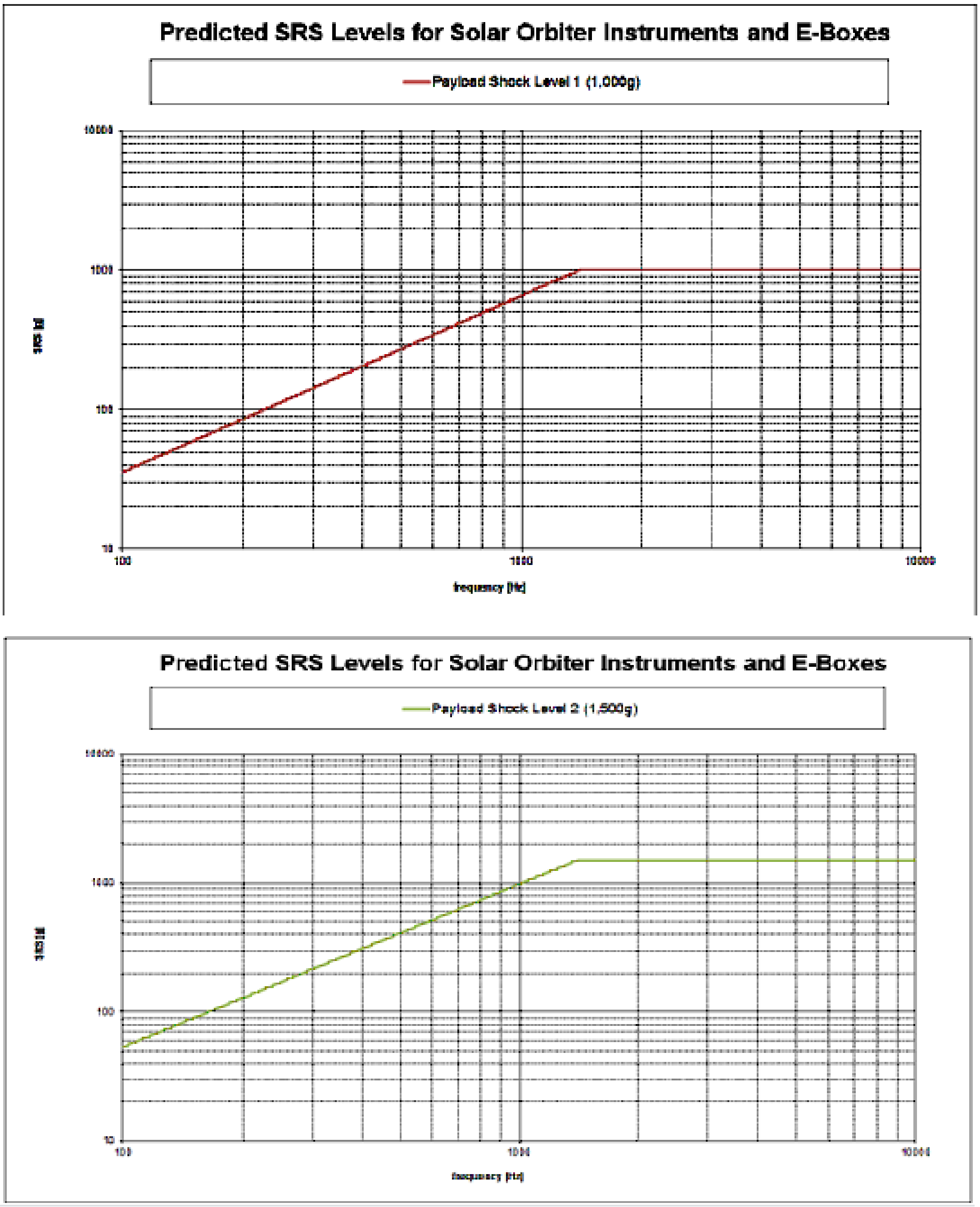


Figure 6.4-4: Shock Environment. 15856

Shock Level 1 - Lower :		16040
PHI OU	1000g	
METIS MOU		
EUI OBS		
STIX Imager		
STIX DEM		
SPICE OU		
SOLOHI		
EPD-SIS		
SWA-EAS		
SWA-HIS		

Shock Level 1 - Lower :	
SWA-PAS	
SWA-DPU	
RPW-ANT	
RPW-SCM	
MAG IBS/OBS	
Shock Level 2 - Higher :	
PHI EU	1500g
METIS MPPU	
EUI CEB	
SPICE SEB	
MAG ELB	
RPW MEB	
EPD ICU	
EPD EPT-HET1	
EPD EPT-HET2	
EPD STEP	

Table 6.4-21: Shock Environment Levels (Lower & Higher. 16039

EIDA-4386//

***EIDA R-503**: The PI shall carry out shock testing at least once during an instrument development program on a model which is fully representative for the purpose of the test*

D: Due to the risk of latent defects, FMs or PFMs will not undergo shock testing. 4387

D: Component level shock testing may be considered for shock sensitive items to retire risk early prior to higher level testing. 4388

6.4.5.6 *Thermo-elastic loads*

(N/A) 4390

6.4.5.7 *Pressurized Items Test Requirements*

EIDA-4392//

***EIDA R-505:** The PI shall abide by the guidelines and requirements define in ECSS-E-ST-32C [NR-11].*

6.4.6 Mechanism Test Requirements

6.4.6.1 *General*

EIDA-4395//

***EIDA R-506**: The PI shall ensure that the test(s) to verify that the instrument mechanisms fulfil the requirements for use as space hardware are defined in a test plan and agreed by the Agency.*

D: The aim of testing can be either, development, qualification or acceptance. 4396

D: The test(s) will also verify the predicted deployment kinematics do not exceeded the allocated volume. 4397

EIDA-4398//

***EIDA R-507**: The PI shall ensure that tests are performed to check mechanisms performance in both launch and operational configurations.*

6.4.6.2 *Development tests*

EIDA-4400//

EIDA R-508: *The PI shall carry out development test(s) on bread-board models to test specific aspects agreed by the Agency.*

EIDA-4401//

EIDA R-509: *The PI shall carry out the following mechanisms verification tests on development model mechanisms during the definition phase, except in the case(s) where the Agency agrees that the test data from a previous space application can be used instead:*

- functional performance tests in ground ambient environment. 4402
- vibration and thermal tests. 4403
- tribological lifetime test on life critical components. 4404

6.4.6.3 *Qualification tests*

EIDA-4406//

EIDA R-510: *The PI shall ensure that mechanisms qualification test(s) are performed in a representative sequence and in a representative environment, agreed by the Agency.*

EIDA-4407//

EIDA R-511: *The PI shall select the mechanisms qualification test (s) from a list of 9 typical mechanisms tests (structural, thermal, functional, electrical, lifetime, etc.) as defined in ECSS-E-ST-33-01C chapter 4.8.3.3 [NR-14]*

6.4.6.4 *Acceptance tests*

EIDA-4409//

EIDA R-512: *The PI shall ensure that new builds of qualified designs are acceptance tested to verify that the flight hardware is free from manufacturing defects.*

EIDA-4410//

EIDA R-513: *The PI shall select the mechanisms acceptance tests type, sequence, criteria, levels, etc. from the typical mechanisms tests listed in ECSS-E-ST-33-01C (chapter 4.8.3.3 and 4.8.3.3.) [NR-14].*

6.4.6.5 *Mechanism Lifetime Tests*

EIDA-4412//

EIDA R-514: *The PI shall demonstrate the lifetime of a mechanism by test in the appropriate environment, using the sum of the predicted nominal ground test cycles and the in-orbit operation cycles.*

EIDA-4413//

EIDA R-515: *The PI shall ensure that the number of predicted cycles for the test demonstration are multiplied by the following factors:*

Type/Number of Predicted Cycles 4414

Ground Testing x4 4415

number of on-ground test cycles 4416

(the minimum number to be used is 10) 4417

In-orbit predicted cycles: 4418

- 1 to 10 actuations x10 4419
- 11 to 1,000 actuations x4 4420

4421

- 1001 to 100,000 actuations x2
- > 100,000 actuations x1.25 4422

D: As actuation, a full output cycle or full revolution of the mechanism is defined. 4423

EIDA-4424//

> ***EIDA R-516****: The PI shall ensure that an accumulation of actuations multiplied by their individual factors are used in order to determine the lifetime to be demonstrated by test.*

6.4.7 Thermal Test Requirements

6.4.7.1 *Thermal Design Verification*

EIDA-4427//

> ***EIDA R-517:*** *The PI shall verify the thermal design and functionalities of each unit by a dedicated thermal vacuum tests and by thermal balance tests.*

In particular: 4428

- thermal balance (TB) test(s) at STM level and at FM level 4429

· thermal vacuum (TV) cycling test at FM level 4430

EIDA-4431//

> ***EIDA R-518:*** *The PI shall carry out for internal electronic units only TV test(s).*

EIDA-4432//

> ***EIDA R-519:*** *The PI shall carry out for external electronic units both TV test(s) and TB test(s)*

EIDA-4433//

> ***EIDA R-520:*** *The PI shall ensure that the equipment is tested in a thermal vacuum environment, having a pressure of 0.0013 Pa (10-5 Torr) or less.*

6.4.7.2 *Thermal Balance Test*

D: The objectives of the thermal balance test will be to: 4435

- Provide data for the verification of the thermal mathematical model 4436
- Demonstrate the ability of the unit thermal control to maintain temperatures inside the specified limits 4437
- Verify the performance of the thermal control hardware 4438
- Verify that the unit performs correctly under vacuum and thermal conditions expected to be encountered during the mission 4439
- Provide data about sensitivity of the unit thermal design with respect to parameter changes (e.g. heat dissipation, pointing 4440

EIDA-4441//

> ***EIDA R-521:*** *The PI shall perform the TB test(s) using adequate test instrumentation and test set-up (e.g. number and position of temperature sensors, heaters) to provide accurate data (e.g. temperatures, voltages, unit dissipations)*

EIDA-4442//

> ***EIDA R-522:*** *The PI shall ensure that the TB test(s) conditions are clearly defined and reproducible, so that accurate and reliable input for thermal model correlation can be provided*

EIDA-4443//

> ***EIDA R-523:*** *The PI shall ensure that the TB test(s) consist of at least a hot and a cold steady-state phase and several transient phases that simulate boundary conditions experienced during the mission, including actual Sun exposure (when applicable)*

EIDA-4444//

EIDA R-524: *The PI shall ensure that the TB test(s) conditions encompass, as far as possible, the worst thermal conditions expected throughout all mission phases (including simulation of radiative and conductive external interfaces).*

D: provision of feedthroughs to relevant PI teams for the simulation of the feedthrough environment during instrument TB test is planned by ESA. 4445

EIDA-4446//

EIDA R-525: *The PI shall ensure that the test item is a fully thermally representative configuration. In particular the thermal hardware shall be flight representative as far as any critical interface.*

EIDA-4447//

EIDA R-526*: The PI shall assume that each steady state phase is reached when the temperatures of the unit does not vary by more than 1 C/ 3 hour.*

6.4.7.3 *Thermal Vacuum Cycling Test*

D: The purpose of the thermal vacuum cycling test is to demonstrate the ability of the unit design (qualification level) and the flight unit (acceptance level) to perform in a thermal vacuum environment that simulates the worst conditions in-orbit including adequate margins. 4449

EIDA-4450//

EIDA R-527: *The PI shall ensure apply the acceptance and qualification margins, specified in para 4.6.2.*

6.4.7.4 *Test Methods for Thermal Vacuum Cycling Test*

EIDA-4452//

EIDA R-528: *The PI shall ensure that the equipment shall be mounted in a vacuum chamber in a thermally controlled environment as shown in the figure below (Figure 6.4-5).*

EIDA-4453//

EIDA R-529: *The PI shall ensure that the test item experiences actual temperatures equal to or beyond the minimum and maximum qualification/acceptance temperatures.*

EIDA-4454//

EIDA R-530: *The PI shall apply to the* ***non-optical and optical units internally mounted*** *the following test methods and requirements, as appropriate:*

· equipment bolted to a mounting panel, using the correct bolts and bolt torques as specified in the MICD . 4455

· mounting panel black-painted (except for the mounting contact area) 4456

D: the following guidelines are given for its dimensions : 4457

· length and breadth approximately equal at least to twice the nominal base dimensions of the equipment. 4458

· Mounting panel(s) temperature-controlled to a fixed temperature in order to achieve the acceptance / qualification temperature level on the URP temperature 4459

· shroud(s) providing the specified radiative environment (Annex A3) modified by the acceptance/qualification margins. 4460

EIDA-4461//

EIDA R-532: *Removed*

EIDA-4462//

EIDA R-533: *The PI shall ensure that the radiative environment provided by the Heat Shield Feed-Through (and modified by the Acceptance/qualification margins) shall be simulated during the test.*

EIDA-4463//

EIDA R-534: *The PI shall apply to the* ***units externally mounted*** *the following:*

· equipment bolted to a mounting panel, using the correct bolts, bolt torques and insulation H/W as specified in the MICD. 4464

· Temperature-controlled mounting device able to maintain the URP temperature values. 4465

· Unit baseplate radiatively insulated from the mounting device. 4466

· panel(s) temperature-controlled to a fixed temperature in order to achieve the acceptance / qualification temperature level on the URP temperature 4467

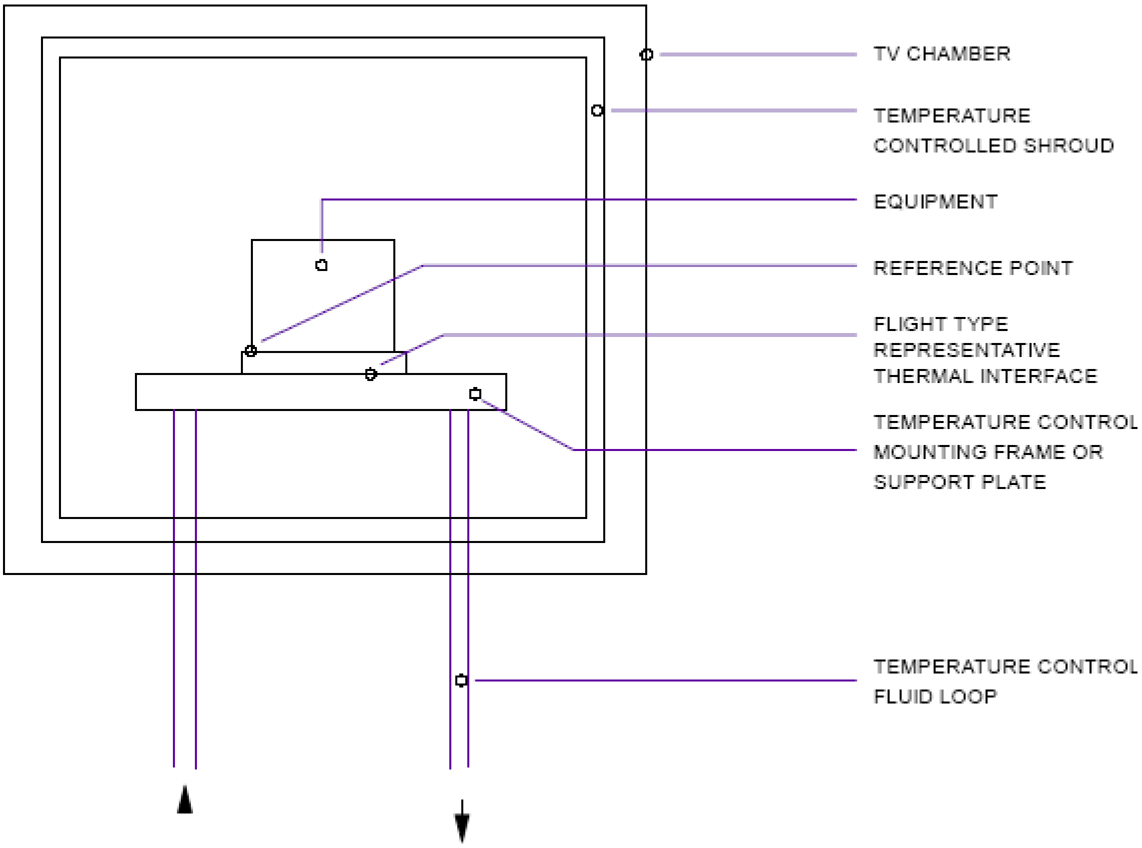
· shroud(s) providing the specified radiative environment (Annex 3) modified by the acceptance/qualification margins. 4468

EIDA-4469//

EIDA R-535: *The PI shall test the optical units applying representative sun flux as in orbit conditions.*

D: Applied solar fluxes will not be modified for acceptance or qualification testing 10337

4470



4471

Figure 6.4-5: Unit Thermal Vacuum Cycling Test set-up.

EIDA-4472//

EIDA R-536: *The PI shall thermal vacuum cycle test each unit in line with the following sequence, shown in the figure below (Figure 6.4-6).*

D: The Temperature cycle begins with the initial functional test with the chamber at ambient temperature. The pressure in increased to 0.013 Pa. The temperature is increased first, for better outgassing, up to the high non-operating level (TNO-MAX). After a dwell time tE, the temperature is decreased to the hot start-up level (TSU-MAX), then the instrument switched ON and thereafter the temperature stabilized at the high operating temperature (TOP-MAX) during a time tE. After the time tE, the functional test is performed. 4473

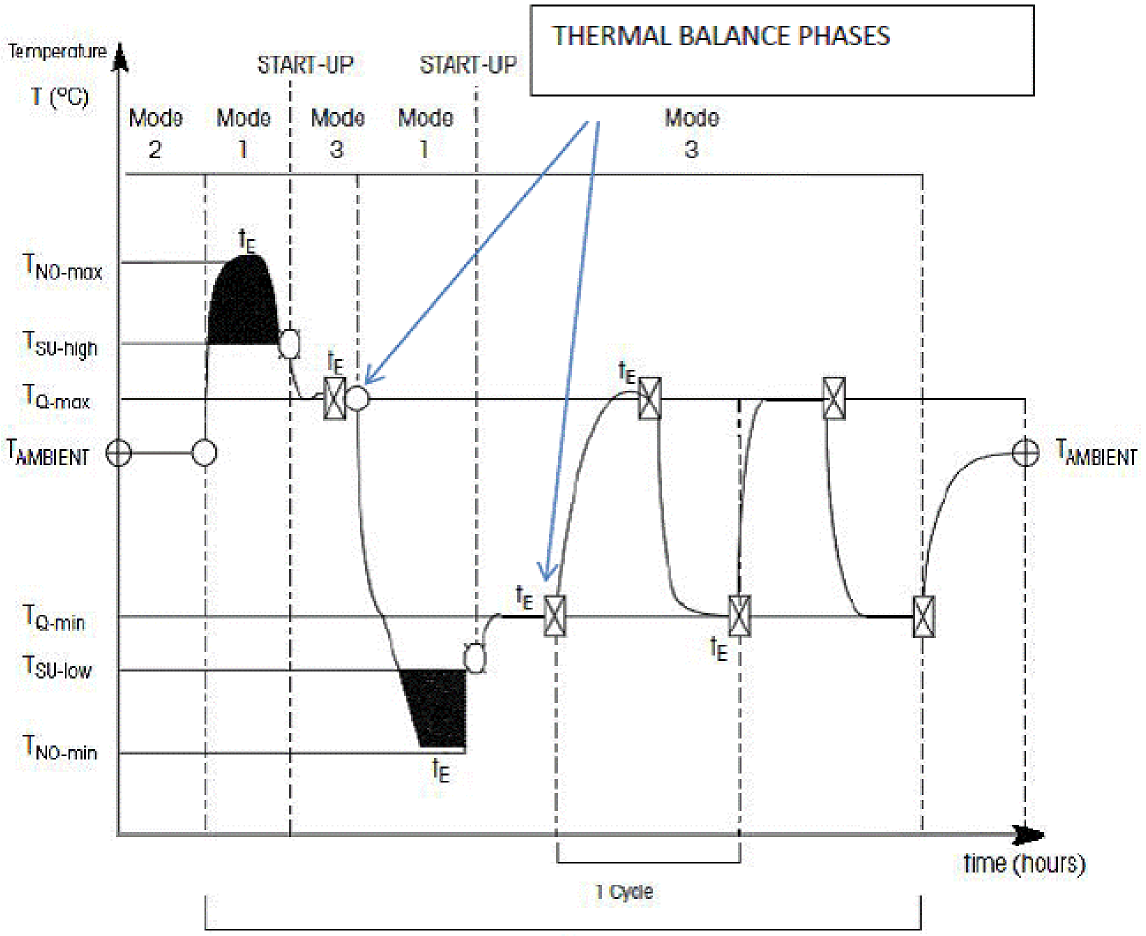
D: after the functional test, the hot thermal balance phase is performed where the all the conditions are maintained stable to reach the required TB temperature stabilization (the PI can choose if it is preferable to lower the boundary conditions to flight values or leave them at acceptance or qualification level). 4474

D: The equipment is switched off and the temperature is decreased and stabilized at the low non-operating minimum temperature (TNO-MIN) during the time tE. The temperature is increased to the cold start-up to switch the equipment ON. After stabilization at the low operating level (TOP-MIN), after a time tE, the functional test is performed. This constitutes one complete cycle. 4475

D: after the functional test, the cold thermal balance phase is performed where the all the conditions are maintained stable to reach the required TBT temperature stabilization (the PI can choose if it is preferable to increase the boundary conditions to flight values or leave them at acceptance or qualification level). 4476

D: Then at the high operating level after a time tE, the functional test is repeated, followed by a low operating level with a functional test after the time tE. This is the second cycle (without the hot and cold start-up and non-operating levels). The second cycle is repeated for the number of cycles required. The number of cycles, the temperature levels and rate of change and the dwell time are specified in the table below. 4478

11640



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Picture>

Figure 6.4-6: Unit Thermal Vacuum Cycling and Thermal Balance Combined Test Sequence. 4479

4480

D: see below for NOMENCLATURE for Figure 6.4-6 above

4481

Symbol	Description
T	Test item temperature
$T_{AMBIENT}$	Ambient temperature
T_{NO-max}	Maximum non-operating temperature (highest design temperature for the equipment to survive not powered)
T_{NO-min}	Minimum non-operating temperature (lowest design temperature for the equipment to survive not powered)
$T_{SU-high}$	Maximum start-up temperature (highest design temperature of the equipment, at which the equipment can be switched on)
T_{SU-low}	Minimum start-up temperature (lowest design temperature of the equipment, at which the equipment can be switched on)
T_{Q-max}	Maximum qualification temperature (highest design temperature at which the equipment demonstrates full design ability)
T_{Q-min}	Minimum qualification temperature (the lowest design temperature at which the equipment demonstrates full design ability)
P	Pressure
MODE 1	Functionally inert (test item not energized). Normally applicable to the non-operating condition.
MODE 2	Partially functioning. Conditions as detailed in applicable design specifications, but normally applicable to conditions during launch.
MODE 3	Fully functioning (test item fully energized and fully stimulated). Normally applicable to conditions during orbit.
⊕	Initial and final "functional and performance test"
⊠	Intermediate reduced functional and performance test
t_E	Dwell time
	Switch-on (Start-up)
○	Switch-off

EIDA-4482//

EIDA R-537: *The PI shall apply the values specified in the table below (Table 6.4-22):* 10877

Temperatures	For Qualification test the qualification temperatures shall be used. For acceptance test the acceptance temperatures shall be used.
Temperature rate of change	dT/dt = 1 ... 5 deg C/min
Dwell time	$t_E \geq 2$ h
Stabilisation Criterion	$\Delta T/dt \leq 1$ deg C/ h
Number of cycles	n = 8 for qualification n = 4 for acceptance n = 4 for recertification

Table 6.4-22: Test Parameters Values for Thermal Vacuum Test. 4485

6.5 HW Inspections

EIDA-4487//

EIDA R-538: *The PI shall ensure that the HW inspection, performed at the beginning and end of acceptance and qualification testing include as a minimum:*

- Completeness of hardware 4488

- Identification of hardware 4489
- Connectors 4490
- Grounding Points 4491
- Attachment Surfaces 4492
- Thermal Surfaces (any visible changes) 4493
- Inspection of transport conditions 4494
- Inspection for damage 4495
- Inspection of Interfaces 4496
- Visual inspection for contamination assessment 4497
- Completeness of documentation 4498

EIDA-4499//

EIDA R-539: *The PI shall measure the mass, and measure or calculate the CoG and the Moment of Inertia of each unit*

6.6 *Final Acceptance*

D: The acceptance process will demonstrate that the Instrument has been fully verified in terms of: 4501

- scientific performances (including calibration and characterization) 4502
- behaviour versus environmental conditions (including EMC) 4503
- all functional interfaces 4504

D: The ESA Solar Orbiter Project Office will provide specific guidelines and procedures detailing the objectives, the responsibilities, the process, the procedures, the deliverables related to the instrument final acceptance 4505

6.7 *System Level AIT*

6.7.1 Model Philosophy

6.7.1.1 *Satellite Model and Test Philosophy*

D: The presently foreseen satellite model philosophy consisting of: 4509

- STM: Structural Thermal Model; 4510
- ETB: Electrical Test Bench 4511
- PFM: Proto Flight Model 4512

D: The following preliminary test programme is for information only 4513

9763

Test	STM	ETB	PFM
Physical Properties	(+)		(+)
Static Load	(+)		
Fit-check Elements	(+)		(+)
Fit-check Launcher	(+)		(+)
Deployment + Separation Shock	(+)		(+)
Launcher Separation Shock	(+)		(+)
Low Level Sine	(+)		(+)
Sine Vibration	(+)		(+)
Acoustic Noise	(+)		(+)
Modal Survey	(+)		(+)
Mechanisms	(+)		(+)

Test	STM	ETB	PFM
Alignment	(+)		(+)
Pressure / leak	(+)		(+)
Thermal Balance	(+)		(+)
Thermal Vacuum Cycling	(+)		(+)
Electrical Interfaces		(+)	(+)
HW/SW Compatibility		(+)	(+)
Conducted EMC		(+)	(+)
Radiated EMC			(+)
RF compatibility			(+)
Ground Segment Compatibility			(+)

Table 6.7-1: Preliminary test programme for STM, ETB and PFM. 10433

6.7.1.2 *Instrument Model and Test Philosophy*

EIDA-4537//

EIDA R-540: *The PI shall follow the following instrument Model Philosophy*

- STM: Structural Thermal Model; 4538
- EM: Engineering Model 4539
- FM: Flight Model 4540

D: In support of instrument qualification (before delivery of FM to the spacecraft) the PI should manufacture and test a Qualification Model of the instrument. The Qualification Model can be used as temporary substitution of other deliverable models, if compliance to the relevant built-standards can be demonstrated. 4541

EIDA-4542//

EIDA R-541: *The PI shall propose, justify and seek agreement with the ESA Solar Orbiter Project Office in case he/she does not intend to follow the baselined instrument model philosophy (e.g Proto-Flight model philosophy)*

EIDA-4543//

EIDA R-542: *The PI shall propose, justify and seek agreement for an alternative qualification and acceptance test programme, in case he/she does not intend to follow the baselined qualification and acceptance test programme and model philosophy.*

EIDA-4544//

EIDA R-543: *The PI shall ensure that the instrument STM units, including the STIX and PHI "filters", have the following build standard:*

- structure flight representative, including, where applicable, alignment cubes with flight representative mountings and locations. 4545
- mechanisms flight dummies (with the exception of deployment actuators that have a shock characteristic, which should be flight representative) 4546
- thermal control hardware flight representative 4547
- representative for mass, CoG, first eigen-frequency, interface mounting pattern, internal power dissipation. 4548
- representative for key thermo-optical interfaces / properties, to be agreed with ESA. 4549
- harness flight representative for mass, shape, with flight representative connectors 4550

4551

· all connectors at correct locations, allowing representative harness connection and routing between instrument units and allowing, as minimum, the powering of the unit(s) heaters and temperature sensors (*)

D: departure from the above specified STM harness built standard will be agreed between ESA and the Prime Contractor and with the relevant PI teams on a case by case basis and documented in the respective EID-B 4552

D: (*) Thermocouples are also allowed to come out of the STM units as flying leads without going through connectors. 10893

EIDA-4553//

> ***EIDA R-544:*** *The PI shall ensure that the instrument EM units have the following minimum build standard:*

· electronics flight standard except for parts quality 4554

· commercial parts have to be of same technology, same supplier as FM parts 4555

· mechanisms flight representative for electrical actuators 4556

· structure flight representative for mounting and shape 4557

· electrically representative as needed for conducted EMC tests (emissions and susceptibility). 4558

· software flight standard as needed for all command/ control/ data interactions with the spacecraft. 4559

· harness flight representative 4560

D: In order to save cost the EM hardware contents may be reduced by reducing redundancy 4561

D: cold redundant units may be deleted if no automatic switch-over function is involved 4562

D: multiple redundancy of hot redundant units or modules may be reduced by electrical dummies (to e.g. dual redundancy) if EM objectives for interference and crosstalk tests are not compromised. 4563

D: possible use of a simulator for some of the EM verification purposes is to be agreed with ESA. 4564

D: Use of EQM if sufficiently representative electrically and functionally. 4565

D: The EM units will remain at the Prime Contractor's and/or ESA premises following delivery. 4566

D: In support of achieving instrument qualification the PI may manufacture and test a Qualification Model of the instrument. 4567

EIDA-4569//

> ***EIDA R-545:*** *The PI shall ensure that the instrument FS units have full flight standard verified by formal acceptance tests.*

D: The Flight Spares (FS) objectives are to facilitate replacement of failed or damaged equipment at integration and launch site without, or with minimal impact on the overall schedule. 4570

EIDA-4571//

> ***EIDA R-546:*** *The PI shall ensure that in case of identified need to exchange the instrument FM, the FS are available at the site of spacecraft integration or the launch site after not more than 4 weeks.*

D: In order to save cost the FS units: 4572

· may be derived from refurbished qualification units if full flight worthiness can be demonstrated 4573

· may be reduced to repair kits if pre-determined turnaround time is ensured. This approach has to be agreed with the ESA project office on a case by case basis. 4574

6.7.1.3 *Spares Philosophy*

EIDA-4576//

> ***EIDA R-547:*** *The PI shall propose a spares philosophy, to be agreed with the ESA Project Office.*

7 PRODUCT ASSURANCE REQUIREMENTS

D: Cleanliness requirements are specified in chapter 9. 4579

D: The product assurance requirements for the instruments and the related Normative Reference documents [NRs] are now specified in the self-standing “Product Assurance Requirements for Instruments” document, [NR-25] 4578

EIDA-11641//

> ***EIDA R-848:*** *The PI shall not use Prohibited and Restricted Materials*
>
> *as defined and listed in ECSS-Q-70-71 [NR-40]. The following materials are additionally classed as restricted for this programme. Proposed use of these materials shall be subject to review and approval by Prime and ESA via RFD/RFA/RFW and in every case shall be quantified and justified:*

- Silicone-Based Adhesives and Primers 11642
- Silicone-Based Paints or Coatings and Primers 11643
- Coatings, Primers or Paints containing Silanes and Siloxanes 11644
- Velcro use shall be limited, particularly near sensitive surfaces. 11645

8 MANAGEMENT REQUIREMENTS

8.1 *Introduction*

D: This chapter defines the agreements and requirements between ESA and the Principal 4582
Investigators (PIs) related to project management, organizations, programmatic and deliverable aspects.

8.2 *Organization and Responsibilities*

8.2.1 ESA Solar Orbiter Project office Responsibilities

D: The management of the Solar Orbiter mission will be under the responsibility of the ESA Solar 4585
Orbiter Project Manager located at ESTEC, Noordwijk, The Netherlands.

D: The ESA Solar Orbiter Project Manager will have full responsibility for all aspects of the 4586
development, launch and initial operations of the mission.

D: If, in the interest of the overall programme, significant technical and/or programmatic changes to 4587
an experiment are necessary, then ESA will be responsible for the definition of the required change to be implemented by the Principal Investigator (PI).

D: The ESA Solar Orbiter Project Manager will be directly supported in the execution of the 4588
programme by the engineering, administrative and project control staff of the ESA Solar Orbiter Project Office located at ESTEC.

D: The Solar Orbiter Instruments are will be managed by Payload Solar Orbiter System Manager and 4589
his team of engineers under the overall responsibility of the ESA Solar Orbiter Project Manager.

D: The Solar Orbiter Payload System Manager and his team of engineers will deal with the day to day 4590
Instrument activities and follow up on a regular basis the progress to ensure that they meet the Solar Orbiter programme objectives.

D: The Payload Solar Orbiter System Manager and his team of engineers will have in particular the 4591
following responsibilities:

· Support the PI team in solving technical and programmatic issues. 4592

· Accommodation of the payload into the spacecraft in line with the technical and programmatic 4593
requirements defined in the Experiment Interface Document (Part A and Part Bs).

· Assess and disposition engineering change requests (ECRs). 4594

· Oversee acceptance tests of the Instrument deliverable items as part of the delivery 4595
procedure to the Industrial consortium

· Supervise and coordinate with the PI the support and inputs required for the spacecraft 4596
system test activities, the launch campaign and the operations in flight

· Coordinate with the PI and the industrial Prime Contractor all deliverables needed by either 4597
the PI or the Prime Contractor in relation to the accommodation of the instruments in the spacecraft

D: The ESA Solar Orbiter Project Office will fulfil its function until the completion of the spacecraft in- 4598
flight commissioning phase.

D: An ESA Solar Orbiter Mission Manager will be responsible for the conduct of the mission from the 4599
end of the commissioning phase until the end of the mission.

8.2.2 ESA Solar Orbiter Project Scientist Responsibilities

D: The ESA Project Scientist is responsible for ensuring that the scientific objectives of the mission 4601
are achieved through the verification of the instrument performance and for the science operation planning. As such she/he is the formal interface for all scientific matters.

D: The ESA Project Scientist will organize regular Science Working Team (SWT) meetings in support 4602
of the above objectives.

D: The ESA Project Scientist will monitor the state of the implementation and readiness of the 4603
instrument operations and of the scientific data processing infrastructure.

D: After the in-orbit Near-Earth Commissioning Phase (NECP), the Project Scientist will be 4604
specifically responsible for:

- Coordinating the scientific operations according to the policy and guidelines established by 4605
the SWT
- Supporting the short term planning of payload operations in conjunction with relevant PIs 4606
including resolution of conflicting payload operations requests and contingency support
- Coordinating the creation of the scientific products, their archiving and distribution to the 4607
scientific community

8.2.3 Principal Investigator Responsibilities

8.2.3.1 *General Requirements*

EIDA-4611//

> ***EIDA R-548:*** *The PI shall ensure that the complete Instrument is developed and implemented within the mission and schedule constraints of the approved Solar Orbiter Programme.*

EIDA-4612//

> ***EIDA R-549:*** *The PI shall be responsible for the overall instrument management and for his/her team organisation.*

EIDA-4613//

> ***EIDA R-550:*** *The PI shall be fully responsible for the instrument programme.*

EIDA-4614//

> ***EIDA R-551:*** *The PI shall retain at all times full authority within the PI team over all aspects related to the procurement and the execution of the programme.*

EIDA-4615//

> ***EIDA R-552:*** *The PI shall make commitments and make decisions on behalf of all other participants in the instrument programme.*

8.2.3.2 *Instrument Management Requirements*

EIDA-4617//

> ***EIDA R-553:*** *There shall be a single PI for each instrument.*

EIDA-4618//

> ***EIDA R-554:*** *The PI shall be the ultimate managerial and decision making authority interfacing with the ESA Solar Orbiter Project Office.*

EIDA-4619//

> ***EIDA R-555:*** *The PI shall appoint an instrument manager for the running of the day to day activities of the instrument team.*

EIDA-4620//

> ***EIDA R-556:*** *The PI shall ensure that instrument team include, as a minimum, personnel responsible for the following tasks:*

- Project Management 4621
- Project Control 4622
- Schedule Control 4623
- Documentation and Configuration Control 4624
- System Engineering 4625
- Assembly Integration Test and Verification 4626

- Product Assurance 4627

EIDA-4628//

> ***EIDA R-557:*** *The PI shall make available the necessary resources in support, as a minimum, to the relevant instrument system level integration, tests and anomaly investigations of his / her HW, SW and related GSE at the ESA premises, at the Prime Contractor premises and at the launch site.*

D: Examples of GSE needed after integration with the spacecraft: purging equipment prior to integration; HV supply for ion pump, special monitoring equipments, if needed, (e.g mass spectrometers , etc) 4629

EIDA-4630//

> ***EIDA R-558:*** *The PI shall provide the necessary training, if necessary, for the correct use of his/ her deliverable HW, SW and GSE to the ESA and to the Prime Contractor relevant staff.*

EIDA-4631//

> ***EIDA R-560:*** *The PI team, during the relevant instrument system level activities, shall be integrated with the ESA Solar Orbiter Project Office team and work under its technical management*

EIDA-4632//

> ***EIDA R-561:*** *The PI shall make available the necessary resources to support the technical Working Groups, chaired by ESA.*

EIDA-4633//

> ***EIDA R-562:*** *The PI shall create and maintain an instrument EID Part B, up to a time agreed with the ESA Solar Orbiter Project Office.*

EIDA-4634//

> ***EIDA R-563:*** *The PI shall ensure compliance with all ITAR regulations in a timely manner.*

EIDA-4635//

> ***EIDA R-564:*** *The PI shall report to the ESA Solar Orbiter Project Office any surveillance requirements arising from ITAR regulations.*

EIDA-4636//

> ***EIDA R-565:*** *The PI shall bear any costs associated with such surveillance requirements.*

EIDA-4637//

> ***EIDA R-566:*** *The PI shall participate to Science Working Team meetings as called by the ESA Project Scientist.*

D: Expected specific contributions will be agreed between the ESA SO Project Scientist and the PI on a case by case basis 4638

EIDA-4639//

> ***EIDA R-568:*** *The PI shall be responsible for the fulfilment of the instrument scientific requirements towards the Science Working Team.*

EIDA-4640//

> ***EIDA R-569:*** *The PI shall submit a Science Performance Report as a minimum at every project review.*

EIDA-4641//

> ***EIDA R-570:*** *The PI shall produce, implement and maintain under configuration control a Management Plan covering the proposed investigation for the entire duration of the mission and shall include as a minimum the following:*

· The contribution of each institution and the responsibilities of each participant including HW & SW deliverables and related dates. 4642

· A complete PI team directory and organigramme containing the names of all partners: PI, CO-I's, Instrument Development Manager, and all key personnel; their roles and responsibilities.. 4643

· The qualifications and experience of the PI team members 4644

· A Product Tree (PT) to identify and break down the instrument into its components, both hardware software and GSE and identify the related responsibilities 4645

· A Work Breakdown Structure (WBS), based on the PT, with its Work Packages which shall define and describe the scope of the work including the instrument development models and support functions necessary to produce all the HW, SW, GSE and documentation to be red. 4646

EIDA-4647//

> ***EIDA R-571:*** *The PI shall develop, as part of his Management Plan, a Risk Management Plan.*

D: For each identified major risk, the following information are expected to be specified: 4648

- The name of the custodian for control of the risk 4649
- An explanatory description 4650
- Reasons for its criticality 4651
- Importance of their consequences (classification and severity) 4652
- Magnitudes of consequences (e.g. schedule and/or cost impacts) 4653
- Probability of their occurrence 4654
- The preferred solution, with reasons 4655
- Alternative solutions and contingencies 4656
- Current status 4657

EIDA-4658//

> ***EIDA R-572:*** *The PI shall comply with the scientific data policy of the Agency as defined in the Science Management Plan [NR-26]*

EIDA-4659//

> ***EIDA R-573:*** *The PI shall provide the inputs for the definition and implementation of the science operations planning, and data handling and archiving concepts;*

EIDA-4660//

> ***EIDA R-574:*** *The PI shall make available necessary resources for the definition and the implementation of the Solar Orbiter ESA scientific data archive.*

EIDA-4661//

> ***EIDA R-575:*** *The PI shall support the definition of the instrument interfaces to the spacecraft in coordination with the ESA Solar Orbiter Project Office and the Industrial Prime contractor.*

EIDA-4662//

> ***EIDA R-576:*** *The PI shall participate in the technical working groups and the control boards as requested by the ESA Solar Orbiter Project Office.*

8.2.3.3 *Science Management Requirements*

EIDA-4664//

> ***EIDA R-577:*** *The PI shall demonstrate compliance to the relevant Solar Orbiter scientific requirements, described in the Solar Orbiter Science Requirements Document [IR-02], by preparing a Compliance Matrix to the Instrument Performance Requirements Document.*

EIDA-4665//

> ***EIDA R-578:*** *The PI shall be responsible for the definition and the execution of the FM instrument calibration plan before delivery and in space.*

EIDA-4666//

> ***EIDA R-579:*** *The PI shall identify and detail any on-ground FM instrument calibration activity after delivery and before launch.*
>
> ***D:*** *It is presently assumed by ESA that there are no calibration activities needed after FM instrument delivery to the Prime Contractor*

D: Calibration activities after FM instrument delivery to the Prime Contractor will only be considered when scientifically justified. The PI will seek agreement with the ESA Solar Orbiter Project Office. 4667

EIDA-4668//

> ***EIDA R-580:*** *The PI shall participate to the definition and consolidation of the overall Solar Orbiter science operations*

EIDA-4669//

> ***EIDA R-581:*** *The PI shall provide support to the Science Operation Centre, including the activities related to the integration of the instrument Software into the Science Operation Centre (SOC).*

EIDA-4670//

> ***EIDA R-582:*** *The PI shall exploit the scientific results of the mission and assure their diffusion.*

EIDA-4671//

> ***EIDA R-583:*** *The PI shall provide the scientific data (raw data, calibrated data, and higher level data), including relevant calibration products, to the Solar Orbiter archive*

D: The PI shall agree the format of the scientific data with the SOC for applications by the general science community. 4672

8.2.3.4 *Hardware and Software Requirements*

EIDA-4674//

> ***EIDA R-584:*** *The PI shall specify in the EID-B the functional requirements, characteristics and constraints of any ground-support equipment (i.e. MGSE, EGSE, OGSE, etc.) necessary for instrument testing at spacecraft system level.*

EIDA-4675//

> ***EIDA R-586:*** *The PI shall be responsible for the design, development, procurement, manufacturing, testing, qualification, calibration and delivery of the instrument models, GSE and related documentation to the ESA Solar Orbiter Project Office, in accordance with the standards, technical and programmatic requirements defined in the Experiment Interface Document, Part A and Part B.*

D: The harnesses interconnecting the instrument sensors mounted on the boom from a TBD interface, which for example could be a pigtail connector from the sensor, to an interface panel on the spacecraft will be procured by the Prime Contractor on the basis of technical specifications provided by the relevant instrument teams. Case by case electrical interface detail will be agreed with the relevant PI teams and documented in the respective EID-Bs: annex 5 provides the expected format for the boom-mounted instruments harness technical specifications. Values in annex 5 are for information only and in case of conflict with the respective EID-Bs the latter will take precedence. 4676

D: text under EIDA R-586 refers to EID-Bs for harness info. Electrical interfaces are thoroughly documented in EICDs (applicable document in EIDBs) 18685

EIDA-4677//

EIDA R-587: *The PI shall monitor and control the evolution of the design at subsystem and unit level to ensure compatibility with the system design and specifications.*

D: This includes resolving interface problems between all instrument elements. 4678

EIDA-4679//

EIDA R-588: *The PI shall identify and document all the critical instrument technologies and components.*

EIDA-4680//

EIDA R-589: *The PI shall ensure and provide evidence that all the identified instrument critical technologies and components reach as a minimum the Technology Readiness Level (TRL) 5 by the Instrument Preliminary Design Review*

D: TRL 5 calls for Component and/or Breadboard Validation in a Relevant Environment. 4681

EIDA-4682//

EIDA R-590: *The PI shall identify, include in the schedule and execute all necessary pre-developments of the instrument critical technologies and components with the aim of reaching their qualification in line with the overall development schedule and with the instrument model philosophy.*

EIDA-4683//

EIDA R-591: *The PI shall detail the overall instrument Qualification Plan, including the identified critical Components and Technologies, in the instrument Design, Development and Verification (DDV) Plan.*

EIDA-4684//

EIDA R-592: *The PI shall provide the necessary equipment and SW to process the instrument data in accordance with the standards, technical and programmatic requirements defined in the Experiment Interface Document- Part A and Part B*

EIDA-4685//

EIDA R-593: *The PI shall be responsible for the development, procurement, manufacturing, testing and delivery of all instrument software and related documentation to the ESA Solar Orbiter Project Office necessary for the control, monitoring, testing, operation, data reduction and analysis of the instrument at instrument and spacecraft system level, in accordance with the standards, the technical and programmatic requirements and guidelines, defined in the Experiment Interface Document- Part A and Part B.*

EIDA-4686//

EIDA R-594: *The PI shall maintain under configuration control and update all the software and the related documentation for the duration of the mission including a post operations (archiving) phase.*

EIDA-4687//

EIDA R-595: *The PI shall establish, maintain and deliver the Instrument Data Base (IDB) for AIT and Instrument Operation*

D: The IDB will become part of the Mission Information Base 4689

EIDA-4690//

EIDA R-596: *Removed*

EIDA-4691//

EIDA R-597: *The PI shall make available the necessary resources for supporting joint tests and integration activities of the instrument software after relevant model delivery.*

8.2.3.5 *Operations Requirements*

EIDA-4693//

EIDA R-598: *The PI shall make available the necessary resources to support all in-orbit mission phases at the MOC/SOC, including the commissioning phase, supporting for example resolution of anomalies and malfunctions of the instrument*

D: The PI will agree with the ESA Solar Orbiter Project Office the defined level of support for all in-orbit mission phases at the MOC/SOC. 4694

EIDA-4695//

EIDA R-599: *The PI shall make available the necessary resources to support ~~for~~ the preparation and the implementation of the mission and science operations up to the end of the mission including:*

- Delivery of a instrument user manual 4696
- Delivery of inputs to the data-base 4697
- Delivery of inputs to the Flight Operations Plan 4698

8.2.3.6 *Data Processing and Dissemination Requirements*

EIDA-4700//

EIDA R-600: *The PI shall support the implementation of data processing, analysis and reporting according to plans established in collaboration with the SOC.*

EIDA-4701//

EIDA R-601: *The PI shall provide the data analysis facilities (hardware and software) and the manpower for achieving the Solar Orbiter Science mission programme until end of mission.*

EIDA-4702//

EIDA R-602: *The PI shall deliver preliminary instrument calibrated data according to plans established in collaboration and agreed with the SWT.*

EIDA-4703//

EIDA R-603: *The PI shall participate to and provide instrument calibrated data for scientific SO workshops, as agreed with the SO SWT.*

EIDA-4704//

EIDA R-604: *The PI shall provide due acknowledgement to ESA in all published material related to the SO mission.*

EIDA-4705//

EIDA R-605: *The PI shall deliver [back] final data products to the SOC for further dissemination and archiving.*

8.2.3.7 *Financial Responsibilities*

D: The instrument financial status will be guaranteed by the relevant national Funding Agency of the Lead Nation. The relevant Funding Agency will be considered responsible vis-à-vis ESA for all what concerns financial matters related to the selected investigations. The Funding Agency of the Lead Nation will be responsible for the funding arrangements of the complete instrument. The Funding Agency of the Lead Nation It will ensure that adequate funding is available at the required time for all aspects of the instrument and its support. A funding margin should be provided, not only to cater for experiment evolution, but also to finance changes deemed necessary by the ESA Solar Orbiter Project Office. 4707

D: Co-I teams are required via their national funding agencies to seek agreement with the Lead Funding Agency, which will retain full responsibility for the instrument development. The Funding Agency of the Lead Nation will be the sole contact with ESA with respect to the Letter of Commitment 4708

8.2.3.8 *Public Relations Requirements*

EIDA-4710//

> ***EIDA R-606:*** *The PI shall make available the necessary resources to adequately support ESA science communications and public relations activities.*

EIDA-4711//

> ***EIDA R-607:*** *The PI shall provide data and scientific results to ESA in a timely manner and in a form suitable for public relations purposes.*

8.2.4 Science Working Team Responsibilities

D: The Solar Orbiter SWT will comply with the duties and responsibilities defined in the Solar Orbiter Science Management Plan [NR-26] 4713

D: The Solar Orbiter SWT will advise the ESA Solar Orbiter Project Office on all the scientific aspects related to the Solar Orbiter mission. 4714

D: The SWT will establish guidelines for the science operation and determine the long and short term planning. 4715

D: The PIs and his/her instrument technical managers will support the SWT. 4716

D: Participation of the experiment Co-Investigators, team members, inter-discipline scientists and Industry will be left to the decision of the Project Scientist in consultation with the ESA Solar Orbiter Project Office. 4717

8.2.5 Prime Contractor's Responsibilities

EIDA-4719//

> ***EIDA R-608:*** *The Prime Contractor shall update and maintain under configuration control the EID Part A and Part Bs, from a time in the Project lifecycle which will be agreed with the ESA Solar Orbiter Project Office.*

D: The time in the Project lifecycle when the Prime Contractor will update and maintain under configuration control the EID Part A and Part Bs will start after the signing of the EID Part A and Part Bs by the relevant parties. 4720

8.3 *Communications Requirements*

D: A smooth informal communication between the ESA team, the Prime Contractor team and the PI teams is essential to ensure an efficient exchange of information. 4722

EIDA-4724//

> ***EIDA R-609:*** *All formal communication concerning technical and programmatic agreements shall be made between each PI and the ESA Solar Orbiter Project Manager.*

D: They will be the single points of contact for the ultimate negotiation and resolution of programmatic and technical requirements and issues. 4725

EIDA-4726//

> ***EIDA R-610:*** *No other party, including the Prime Contractors and its subcontractors shall have formal authority, without written delegation from the ESA Solar Orbiter Project Manager.*

D: Formal communication is a communication with a registration number in the configuration control system, independently of the medium used to transfer it (mail, fax, e-mail). 4727

D: Working level communication concerning technical and programmatic aspects between each PI and ESA are delegated to the Solar Orbiter Payload System Manager and his team of engineers, in coordination with the Prime Contractor Payload Manager 4728

D: Each instrument project manager and the Solar Orbiter Payload System Manager will be the single "Point of Contact" for all working level programmatic and technical issues. Points of Contact detail are specified in chapter 2. 4729

EIDA-4730//

> ***EIDA R-611:*** *Any formal communication interchanged between PIs and PS or other ESA entity shall be copied to the ESA Solar Orbiter Project Manager.*

EIDA-4731//

> ***EIDA R-612:*** *The PI shall provide an interface to allow electronic transfer of data (documentation, progress reports including schedule information, changes, technical data, etc.) between the PI, the Prime Contractor and the ESA Solar Orbiter Project Office.*

EIDA-4732//

> ***EIDA R-613:*** *The Prime Contractor team and the PI teams shall insure that informal communications shall always be coordinated with the ESA team.*

8.4 *Project Phasing, Planning and Schedule Requirements*

D: The main spacecraft milestones are as follows: 4734

• Initiation of Phase B2/C/D	February 2011	4735
• System Requirements Review:	Q2 2011	4736
• Preliminary Design Review:	Q4 2011	4737
• Critical Design Review:	Q4 2013	4738
• Flight Model Acceptance Review:	March 2016	4739
• Launch	January 2017	4740

D: Sequence and durations of all mission phases after launch and up to completion of the Extended Mission Phase are described in chapter 5 4741

EIDA-4742//

> ***EIDA R-614:*** *The PI shall establish and maintain under configuration control an Instrument Schedule in Microsoft Project format covering in detail all the instrument programme activities identified in the Work Breakdown Structure.*

EIDA-4743//

> ***EIDA R-615:*** *The PI shall include in the Instrument Schedule as a minimum the following programme activities:*

- HW, SW and GSE delivery dates 4744
- Design, development, integration , testing and calibration of each Instrument models, and, where applicable, also of breadboards and/or of development models / subsystems 4745
- Qualification activities 4746
- Long lead items procurement 4747
- all ITAR related approval aspects 4748
- Activities on the critical path 4749
- Main instrument milestones (including , for example TRRs, PTRs) 4750
- Main instrument reviews 4751
- Main spacecraft milestones 4752
- System schedule Margin 4753

EIDA-4754//

> ***EIDA R-616:*** *The PI shall identify for each activity / task included in the Instrument schedule their interdependencies, durations, constraints, slack.*

EIDA-4755//

> ***EIDA R-617:*** *The PI shall notify the ESA Solar Orbiter Project Office of any change to the instrument Baseline Master Schedule that affect agreed instrument milestones within 5 working days*

EIDA-4756//

> ***EIDA R-618:*** *The PI shall seek approval with the ESA Solar Orbiter Project Office about (changes to) the instrument Baseline Master Schedule to ensure that it is in line with the S/C schedule*

EIDA-4757//

> ***EIDA R-619:*** *The PI shall submit the Instrument Schedule to the ESA Solar Orbiter Project Office, as a minimum, every three months, identifying all the major changes wrt the previous issue.*

EIDA-4758//

> ***EIDA R-620:*** *The PI shall identify additional milestones as required and shall agree them with the ESA Solar Orbiter Project Office.*

8.4.1 Progress Control and Reporting Requirements

EIDA-8847//

> ***EIDA R-621:*** *The PI shall submit 5 working days after the end of the month an instrument Monthly Progress Report. in which the current status of each activity is described and problem areas or potential problem areas are highlighted together with identification of proposed remedial action.*

EIDA-4761//

> ***EIDA R-622:*** *The PI shall address, as a minimum, the following topics in the instrument Monthly Progress Report:*

- Synthetic instrument HW and SW status and progress, covering, engineering design and interface aspects for each of the main technical disciplines (e.g mechanical / mechanisms, thermal, electrical, SW, optical, etc) 4762
- Synthetic instrument GSE (MGSE, EGSE, OGSE) status and progress 4763
- Status of design changes and open Engineering Change Requests (ECRs) vis a vis the EID-A and B, overall progress status 4764
- Design Development and Verification status, covering status of design definition and verification of interfaces, test and calibration, GSE, operations, 4765
- PA status, including NCR and RFW status, 4766
- Overall programmatic status, including procurement and long lead items activities. 4767
- Overall funding and contractual status 4768
- List of the main measurable milestones for the past three months and for the following six months, 4769
- Science Performance status, 4770
- Problem areas and corrective actions. 4771
- Resource budgets status (including as a minimum: mass, power, thermal, SW, pointing) highlighting changes wrt previous issue and anticipated future changes 4772
- Current status of each major activity 4773
- Major existing technical, programmatic, funding, and contractual issues together with the proposed remedial closure action plan 4774

- Urgent issues under the responsibility or to be addressed together with the ESA Solar Orbiter Project Office and/or with the Prime Contractor 4775

- Major technical, programmatic, funding, and contractual risks (potential issues) together with proposed remedial closure action plan 4776

- Open Action list 4778

- List of the currently agreed and under configuration control documents (Document Delivery List), making up the instrument configuration baseline, including as a minimum: MICDs, Mathematical models (RTMM, RGMM, CAD, FEM), EID-B 4777

D: The frequency of the instrument Progress Report may be increased, at the ESA Solar Orbiter Project Office request, during period judged critical. 4779

EIDA-4780//

> ***EIDA R-623:*** *The PI shall provide to the ESA Solar Orbiter Project Office a monthly schedule report as part of the Monthly Progress Report*

8.5 *Meetings, Teleconferences and Reviews Requirements*

EIDA-4782//

> ***EIDA R-624:*** *The PI shall organize progress Technical Interface Meeting (TIM) & Progress Meetings (PM) at his/her premises, at least every three months, among the relevant members of the ESA Solar Orbiter Project Team, the PI team and the Prime Contractor Team.*

D: Main objective of these meeting will be to ensure that the interfaces, the design integrity of the instrument and its elements, its compatibility with the spacecraft system and resources and the instrument programmatic are proceeding in a manner which does not jeopardize the overall programme. 4783

D: Detailed technical problems occurring on either side of the interface will be flagged during these MTI meetings and corrective actions, including their schedule impact, will be agreed and implemented 4784

D: ESA, in coordination with the Prime Contractor, will organise regular teleconferences with each PI team to enable technical interchange and status information exchange on a monthly basis. 4785

EIDA-4786//

> ***EIDA R-625:*** *The PI shall call for and organise, if considered necessary, ad-hoc meetings or telecons to address specific critical / urgent subjects among the relevant members of the ESA Solar Orbiter Project Team, the PI team and the Prime Contractor Team*

EIDA-4787//

> ***EIDA R-626:*** *The PI shall support with relevant members of his/her team ad-hoc meetings / telecons to address specific critical / urgent when requested by the ESA Solar Orbiter Project Office or the Prime Contractor.*

EIDA-4788//

> ***EIDA R-627:*** *The Prime Contractor shall take the minutes of the MTI meetings, of the monthly telecons and of the ad-hoc meetings / telecons*

D: Minutes of the meetings will be finalised and agreed by the end of meetings / telecons. 4789

EIDA-4790//

> ***EIDA R-628:*** *The PI shall agree with the ESA Solar Orbiter Project Office and make available the necessary level of resources to support the reviews at instrument, ground segment and mission level on a case by case basis.*

D: The following is an indicative list of presently foreseen reviews at instrument, ground segment and mission level 4791

a. Instrument Level 4792

4793

i. Instrument Preliminary Design Review, IPDR

ii. Instrument Critical Design Review, ICDR 4794

iii. Instrument Qualification Review, IQR 4795

iv. Instrument FM Acceptance Review, IFAR 4796

v. Other Reviews as required (e.g. Test Readiness Reviews (TRR), Pre-Environment Review (PER), Post-Test Review (PTR), etc) 4797

4798

b. Ground Segment Level 4799

i. Ground Segment Requirements Review 4800

ii. Ground Segment Design Review 4801

iii. Ground Segment Implementation Review 4802

iv. Ground Segment Readiness Review 4803

c. Mission Level 4804

i. System Requirements Review 4805

ii. Preliminary Design Review 4806

iii. Critical Design Review 4807

iv. Qualification Review 4808

v. Flight Acceptance Review 4809

vi. Flight Readiness Review 4810

vii. Mission Commissioning Results Review 4811

viii. Other Reviews as required 4812

D: The instrument reviews will take place according to the following planning, with all 10 instrument reviews completed by the specified dates: 4813

- January 2012 Instrument Preliminary Design Review (IPDR) 4814
- January 2013 Instrument Critical Design Review (ICDR) 4815
- February 2014 Instrument Qualification Review (IQR) 4816
- December 2014 Instrument Flight Acceptance Review (IFAR) 4817

D: Dates for specific instrument TRRs, PERs and PTRs will be agreed between PIs and ESA on a case by case basis 4818

D: The ESA Solar Orbiter Project Office will organise, and conduct the Instrument Level reviews. 4819

D: ESA will define the objectives, the success criteria, the content of the acceptance data package, the organisation, the review process and the schedule of each instrument level review in specific procedures, which will be distributed to the relevant parties at least 2 months before the relevant review kick-off 4820

D: The Instrument Level Review will typically be held before the Mission Level, so that the findings of the Instrument Level review can be taken into consideration as formal input. 4821

D: ESA, at its discretion, may identify other reviews and/or milestones. 4822

EIDA-4823//

> ***EIDA R-629:*** *The PI shall provide, for each Instrument Level review a specific set the documents, the Review Data Package, as defined in annex "A 9 Instrument hardware and software deliverable documentation".*

10910

D: A TBC tailored content of the STM EIDP is defined in Annex A11.

D: ESA will propose the tailoring of the content of the EIDP for the EM instrument models. 10911

EIDA-4824//

EIDA R-630: *The PI shall provide the relevant review data package 2 weeks before the review kick-off date to be agreed with the ESA Solar Orbiter Project Office.*

D: Note: in support of instrument qualification review (before delivery of FM to the spacecraft) the PI may manufacture and test a Qualification Model of the instrument. The Qualification Model can be used as temporary substitution of other deliverable models, if compliance to the relevant built-standards can be demonstrated. 4825

8.6 *Configuration Management Requirements*

D: The objectives of Configuration Management are to establish: 4827

- a **configuration identification** baseline system which defines through approved specifications, interface documents and associated data the requirements for the instrument, 4828
- a **configuration control** system which controls all the changes to the identified configuration of the instrument, 4829
- a **configuration accounting** system which documents all changes to the baseline configurations, maintains an accurate record of configuration change incorporation, and ensures conformity between the end item As Built Configuration (ABCL) and its appropriate design and qualification identification (CIDL including waivers). 4830

EIDA-4831//

EIDA R-631: *The PI shall establish a configuration control management system which shall ensure that all hardware, software, GSE and documentation are fully and unambiguously identified and their changes traceable at any time throughout the life cycle of the instrument.*

EIDA-4832//

EIDA R-632: *The PI shall ensure that configuration changes to his / her documents are introduced, only after consultation with the ESA Solar Orbiter Project Office, if such change impact on technical interface or programmatic agreement between them.*

EIDA-4833//

EIDA R-633: *The PI shall allow the ESA Solar Orbiter Project Office to conduct a configuration audit, if requested, at any time in the life cycle of the instrument in order to obtain the up-to-date status of the instrument configuration.*

EIDA-4834//

EIDA R-634: *The PI shall ensure that a suitable configuration management scheme is followed by contractors and suppliers for the items being provided to the instrument.*

EIDA-4835//

EIDA R-635: *The PI shall ensure compatibility between their own configuration management scheme and the one implemented by all other participants to their instrument programme.*

EIDA-4836//

EIDA R-636: *The PI shall be responsible for the management of the Configuration Control Board (CCB) at his level.*

EIDA-4837//

EIDA R-637: *The PI shall establish, for each model delivered to the ESA Solar Orbiter Project Office, an instrument configuration baseline~~s~~ with respect to requirements, design and verification documents.*

EIDA-4838//

EIDA R-638: *The PI shall include as a minimum in the instrument configuration baseline the following documents:*

- Solar Orbiter Science Requirements Document 4839
- Instrument Science Requirements 4840
- Instrument System Functional and Performance Specification 4841
- Instrument System Support Specification 4842
- Interface Control Documents, including the EID-A and the EID-B 4843
- Instrument Units Specifications 4844
- Normative References, called up in chapter 9 of the EID-A 4845
- Design Specification 4846
- Drawings 4847
- Manufacturing Procedures 4848
- Control and Inspection Procedures 4849
- Operating and Handling Procedures 4850
- Test specifications 4851
- Test Procedures 4852
- Design Development & Verification Plan 4853
- Assembly, Integration and Test Plan 4854
- Compliance, Traceability and Verification Matrix 4855

EIDA-4856//

EIDA R-639: *The PI shall prepare a Compliance, Traceability and Verification Matrix wrt the above mentioned Requirements Baseline documents.*

D: The Compliance, Traceability and Verification Matrix is used for the following reasons: 4857

· To state compliance to the identified set of requirements (e.g. scientific, functional, performance, instrument interface, subsystems requirements, etc) 4858

· To ensure forward and backward traceability of all requirements 4859

· to define the required verification method 4860

D: The Compliance, Traceability and Verification Matrix need not trace the Normative References requirements, called up in chapter 10 of the EID-A. Compliance statement to the Normative Reference documents will be sufficient. 4861

EIDA-4862//

EIDA R-640: *The PI shall present the instrument configuration baseline at each Instrument Level review, identifying any change introduced since the previous review.*

D: Instrument configuration baseline~~s~~ may also be reviewed, if requested by the ESA Solar Orbiter Project Office, other intermediate stages of the instrument life cycle. 4863

EIDA-4864//

EIDA R-641: *The PI shall explicitly identify in the "Compliance, Traceability and Verification Matrix to the Requirements Baseline those requirements that he/ she does not intend to comply with, if any.*

4865

D: Note: compliance statement to the Normative References, called up in the EID-A is not applicable to the Solar Orbiter NASA-funded instruments.

EIDA-4866//

> ***EIDA R-642:*** *The PI shall inform the ESA Solar Orbiter Project Office of any change of in his / her instrument configuration baseline impacting science performances, engineering interface requirements, allocated resources, schedule agreed milestones, verification and calibration requirements and plans, within 2 weeks from the change.*

EIDA-4867//

> ***EIDA R-643****: The PI shall identify and document, for each non-flight model delivered to the ESA Solar Orbiter Project Office, the differences, if any, wrt the (as designed) FM instrument configuration baseline.*

EIDA-4868//

> ***EIDA R-644:*** *Any change to the EID-B proposed by the PI shall be submitted via a change request (CR).*

D: The CR may be initiated at any time by either the PI or ESA in writing. 4869

EIDA-4870//

> ***EIDA R-645:*** *(deleted)*

EIDA-4872//

> ***EIDA R-646:*** *(deleted)*

EIDA-4873//

> ***EIDA R-647:*** *The PI shall submit for approval to the ESA Solar Orbiter Project Office and justify deviations to the requirements defined in EID-A by means of a Request for Waiver (RFW).*

D: RFW submission is necessary when the disposition of a major NCR is "use as is" or "repair", and there is a discrepancy with an Agency requirement, or when the PI wishes to deviate from an the EID-A requirement for whatever reason. A distinction between "waiver" and "deviation" need not to be performed. 4874

EIDA-4875//

> ***EIDA R-648:*** *The PI shall identify in the RFW the baseline and specification affected, provide an estimate of the impact on schedule, and logistics.*

EIDA-4876//

> ***EIDA R-649:*** *The PI shall identify uniquely and unambiguously each CR or RFW identified by an individual number by a suitable numbering system of his / her choice.*

EIDA-4877//

> ***EIDA R-650:*** *The PI shall keep the CRs and RFDs/RFWs under configuration control.*

EIDA-4878//

> ***EIDA R-651:*** *The PI (or any other initiating party) shall ensure that following its receipt, the CR / RFW / RFD is submitted to the Change Control Board (CCB) of the receiving part which shall process the request and take a decision on the change (CR / RFW disposition within 4 weeks).*

D: The Change Control Process constitutes of the following: 4879

CR from PI to ESA: 4880

1) Upon receipt of the CR ESA will carry out an investigation as to the consequences of the request, and together with an assessment initiate the change to the Prime Contractor, together with status information to the originating PI. 4881

4882

2) The Prime Contractor will assess the consequences by a Change Control Board (CCB) and (typically within 1 week) prepare an Engineering Change Proposal (ECP) addressing all aspects of possible implementation including cost and schedule. ESA shall assess the ECP and decide on the disposition of the change (approval / reject) and inform the Originator accordingly.

3) In order to shortcut possible iterations and to ensure an efficient process it is expected that early identification of potential changes and informal exchange is used between the PI, ESA and the Prime Contractor to the utmost possible extend. 4883

CR from Prime/ESA to PI: 4884

1) Following receipt/generation of an ECP and initial assessment ESA shall inform the PI about any changes affecting his instrument, and similarly the PI (respectively the Contractor responsible for instrument procurement) shall return his assessment using equivalent bodies (CCB) within 1-2 weeks. 4885

2) Again early exchange of information at working level between the three involved parties (PI, ESA and Prime, represented by his experiment interface engineers) should be used to anticipate the impact of arising changes. 4886

RFD/RFW 4887

1) Upon receipt of the RFD/RFW ESA will carry out an investigation as to the consequences of the 4888

request. If this inpact other parties their assessment will be required.

2) The affected parties will assess the consequences and prepare a report, part of the RFD/RFW assessment file, addressing all aspects of the possible implementation including cost and schedule and give a formal answer through a Change Control Board (CCB). ESA CCB will assess and decide on the

disposition of the RFD/RFW and inform the Originator accordingly.

3) In order to shortcut possible iterations and to ensure an efficient process it is expected that early

identification of potential RFD/RFW and informal exchange is used between the PI, ESA and the

Prime Contractor to the utmost possible extend.

8.7 *Deliverable Items Requirements*

EIDA-4890//

> ***EIDA R-652:*** *The PI shall deliver to the ESA Solar Orbiter Project Office and maintain under configuration control as a minimum the documents defined in Annex A9*

D: The objective and content of each document are specified in [NR-30]. 4891

D: The CAD Model check list properties are specified in Annex A6. 4892

EIDA-4893//

> ***EIDA R-653:*** *The PI shall include all document kept under configuration in a Document Delivery List.*

EIDA-4894//

> ***EIDA R-654:*** *The PI shall deliver the agreed models in line with the baseline instrument model philosophy (as per EID-A R-540) and by the deadlines agreed with the ESA Project Team to comply with the launch date of July 2017.*

EIDA-4901//

> ***EIDA R-655:*** *The PI shall deliver the instrument SW relevant to the delivered instrument models, including the executable code(s)*

EIDA-4902//

> ***EIDA R-657:*** *The PI shall provide together with each delivered Instrument Model, an End-Item Data Package (EIDP), as defined in Annex A10*

D: A TBC tailored content of the STM EID-P is defined in Annex A 11. 12726

D: ESA will propose and agree possible tailoring of the content of the EID-P for the EM instrument models. 4903

EIDA-4904//

> ***EIDA R-662:*** *The PI shall be responsible for the packing and shipment of both the various instrument deliverable models and the associated GSE, after their formal acceptance, to the delivery point designated by ESA.*

D: The points of delivery of all items will be determined later in the programme. 4905

EIDA-4906//

> ***EIDA R-663:*** *The PI shall be responsible for the shipment back of the instrument models in case of repair.*

EIDA-4907//

> ***EIDA R-664:*** *The PI shall be responsible for the transportation of all the relevant equipment back to his / her premises at the completion of the launch campaign.*

EIDA-4908//

> ***EIDA R-665:*** *The PI shall be responsible for any insurance deemed necessary for his equipment during shipment or whilst on the premises of the Agency, it's Prime Contractors or on the launch site.*

EIDA-4909//

> ***EIDA R-666:*** *The PI shall be responsible for the preparation of all ITAR papers necessary for shipment prior to the required shipment date*

EIDA-4910//

> ***EIDA R-667:*** *The PI shall remain responsible for the repair and maintenance of the instrument hardware, software and GSE after delivery up to the end of mission.*

EIDA-4911//

> ***EIDA R-668:*** *The PI shall make available the necessary resources to support the verification of updated instrument software at system level.*

EIDA-4912//

> ***EIDA R-669:*** *The PI shall deliver, together with each instrument model, suitable Mechanical Ground Support Equipment (MGSE) necessary to transport, handle and integrate the instrument*

EIDA-4913//

> ***EIDA R-670:*** *The PI shall deliver, together with each instrument model suitable Electrical Ground Support Equipment (EGSE) necessary to stimulate the instrument, to perform quick look analysis and functional test of instrument during system tests at the ESA, at the Prime Contractor premises and launch site*

D: interfaces between instrument EGSE connected to S/C EGSE will be agreed between the PI, ESA and the Prime Contractor. 4914

EIDA-4915//

> ***EIDA R-671:*** *The PI shall deliver, together with the MGSE and EGSE, appropriate documentation for its description and correct use, for proof load and for calibration certificates, if applicable.*

EIDA-4916//

> ***EIDA R-672:*** *The PI shall ensure that the delivered Instrument EGSE consists at least of the following items:*

4917

· One or more Instrument workstations in charge of processing P/L telemetry and to ask for delivery of telecommands.

· One or more equipment to generate electrical stimuli to the experiment (if needed). 4918

· A dedicated Interface Test Equipment to verify the health status of the Instrument stand-alone, prior integration to the spacecraft. 4919

· All cabling and ancillary items necessary to properly use and operate the abovementioned equipments. 4920

D: The instrument ground support equipment will remain at the spacecraft integration site until launch. 4921

EIDA-4922//

> ***EIDA R-673:*** *The PI shall replace or update the HW and/or SW of the EGSE at each instrument model delivery to maintain its compatibility.*

EIDA-4923//

> ***EIDA R-674:*** *The PI shall be responsible for the maintenance of his/her Ground Support Equipment*

EIDA-4924//

> ***EIDA R-675:*** *The PI shall deliver, if necessary, any special Ground Support Equipment in support of instrument calibration and verification*

9 INSTRUMENT DRIVEN SC REQUIREMENTS

9.1 SC Requirements

9.1.1 Pointing

D: In accordance with standards ECSS-E-ST-60-10C, the following pointing terminology applies: 4926

D: Absolute Pointing Error (APE): 4927

The absolute pointing error is the instantaneous value of the pointing error at any given time. The performance error index is applied to the difference between the commanded (intended) pointing of the instrument and the actual pointing. 4928

D: Relative Pointing Error (RPE): 4929

The relative pointing error is the difference between the instantaneous pointing error at a given time, and its mean value over a time interval containing that time. The relative pointing error is also known as pointing stability. 4930

D: Pointing Drift Error (PDE): 4931

The pointing drift error is defined as the difference between the means of the pointing error taken over two time intervals within a single observation period. 4932

D: Absolute Knowledge Error (AKE): 4933

The absolute knowledge error is the instantaneous value of the knowledge error at any given time. Knowledge requirements refer to the difference between the estimated pointing (sometimes known as the measured pointing, though this is misleading as the concept is more general than direct measurements) and the actual pointing. 4934

D: It should be noted that the pointing knowledge requirement can refer either to the knowledge available to the on-board controller in (near) real-time or the knowledge available for analysis after post-processing. 4935

EIDA-4936//

> ***EIDA R-676:*** *The Prime Contractor shall ensure that the spacecraft is capable of off-pointing from the centre of the solar disk in order to point the Remote Sensing instruments at any point of the solar disk including the Sun's limb.*

D: ESOC will define the pointing strategy for observation; the spacecraft will then perform autonomously the pointing strategy programmed by the ground and commanded to the spacecraft in the form of inertial attitude guidance profiles. 4937

EIDA-4938//

> ***EIDA R-677:*** *The Prime Contractor shall ensure that the spacecraft is capable of tracking a selected point on the solar disk as the sun rotates relative to the spacecraft and until this point reaches the solar limb.*

D: ESOC will define the pointing strategy for observation; the spacecraft will then perform autonomously the pointing strategy programmed by the ground and commanded to the spacecraft in the form of inertial attitude guidance profiles. 4939

EIDA-4940//

> ***EIDA R-678:*** *The Prime Contractor shall ensure that the spacecraft pointing errors do not exceed the values specified in the table below (Table 9.1-1), except during the following predefined operational disturbances:*

- Wheel offloading events 4941
- HGA stowage/deployment/steering events for communication purposes 4942
- SA rotations 4943
- S/C roll events (for communication purposes) if deemed necessary 4944

- Re-pointing slews during science windows 4945
- Delta V manoeuvres 4946

4947

Pointing Parameter	Line of Sight (X_{Op})	Around Line of Sight
APE : Absolute Pointing Error	< 3.5 arcmin	< 20 arcmin
PDE : Pointing Drift Error	< 1 arcmin / 10 days	< 10 arcmin / 10 days
RPE : Relative Pointing Error	< 1.0 arcsec / 10 sec	< 2.0 arcsec/ 10 sec
AKE : Absolute Knowledge Error	< 3 arcmin	< 3 arcmin

Table 9.1-1: Spacecraft provided Pointing Performances. 4968

D: All pointing error requirements are expressed in terms of 95% confidence level. 4969

D: When a pointing requirement (e.g. APE) is defined with a 95% confidence in the mixed interpretation above, it is understood as meaning that given a *random combination of errors and external disturbances* (i.e. given a random member of the ensemble) *at a random time*, there is a 95% probability that the spacecraft pointing performance will be within the required value. This means that the 5% probability of requirement being exceeded could be due either to temporal variations of certain errors or to a particularly unfavourable combination of internal or external factors (e.g. temperature, STR attitude-dependent bias, etc). 10269

D: However, it should be clear that the ensemble component of the mixed interpretation is used to evaluate budgets with numerous uncorrelated errors (with adequate margins, but whose value can vary across the ensemble) in a statistically meaningful way, avoiding having to take the worst-case error in each case. This interpretation should not be understood as measuring the likelihood that the requirement will never be met, since the individual errors all include adequate margins.

D: Two-axis pointing errors of the instrument line of sight are determined by a half-cone angle. 4970

D: Three-axis pointing performance is determined by a half-cone angle of a given line and, separately, a rotation about this line. 4971

D: The above specified pointing requirements do not include contributions due to instrument internal effects (e.g misalignment, thermo-elastic effects, etc). 4972

D: The pointing performances specified in Table 9.1-1 are applicable to the mechanical interface of the Remote Sensing instruments 4973

D: During the NMP/EMP (outside of science windows), the pointing and pointing stability of the spacecraft is compatible with the operational requirements of the In-Situ payloads, as specified in the EID-Bs 8957

9.1.2 EMC

D: Some Solar Orbiter instruments have demanding scientific requirements which translate into specific EMC requirements applicable to the spacecraft provided by the SO Prime Contractor. 4975

9.1.2.1 *Electromagnetically Quiet Operational Phases*

EIDA-4977//

> ***EIDA R-679:*** *The Prime Contractor shall ensure that the spacecraft provides EMC quiet phases with nominal EMC performance as needed to meet scientific objectives. The detailed characteristics of EMC quiet phases are specified in the following subsections of paragraph 9.1.2.*

The following exceptions/disturbances as needed for mission operations (non-quiet phases) are allowed: 4978

· Wheel offloading events 4979

· HGA stowage/deployment and steering events 4980

· SA rotation and flipping events 4981

· S/C roll events (for communication purposes) if deemed necessary 4982

· Re-pointing slews during science windows 4983

· Delta V manoeuvres 4984

EIDA-4985//

> ***EIDA R-794:*** *The PIs shall ensure that their instrument provides magnetically quiet phases with nominal EMC performance as needed to meet scientific objectives of all instruments, with the exceptions/disturbances of instrument reconfigurations, as needed for mission operations (non-quiet phases).*

EIDA-4986//

> ***EIDA R-699:*** *The Prime Contractor shall ensure that electromagnetically quiet phases amount to at least 70% of the operational orbit duration. During these EMC quiet phases contiguous intervals of quietness shall last at least one hour.*

EIDA-4987//

> ***EIDA R-795:*** *The PIs shall ensure their instrument operations are coordinated with other units and platform events as defined in R-679 and R-794 and minimise their disturbances to the electromagnetically quiet phases. During these EMC quiet phases, contiguous intervals of quietness shall last at least one hour.*

9.1.2.2 *DC Magnetic Field*

EIDA-4989//

> ***EIDA R-680:*** *The Prime Contractor shall ensure that the DC magnetic field at the location of the outboard magnetometer sensor is lower than 20 nT.*

D: In order to meet scientific objectives fully, the magnetic field should be below 10 nT. 4990

D: The maximum allowed magnetic moments for instrument units contributing to the magnetic field at the location of the magnetometer outboard sensor is defined **EIDA R-796**. 4991

EIDA-4992//

> ***EIDA R-681:*** *The PIs and Prime Contractor shall ensure that during EMC quiet periods, the only spacecraft-generated magnetic fields at the location of the outboard magnetometer sensor, on timescales between 1/64s and 1s, are:*
>
> *· Transients as defined below, superimposed to the DC value (which is limited by R-680) with maximum peak- to-peak amplitude of 1 nT.*
>
> *· Field variations of amplitude less than 10 pT.*

D: Magnetic field transients are defined as non-periodic variations of the magnetic field with a duration of less than a second and an amplitude above 10 pT. This includes step-functions. 4993

EIDA-10894//

> ***EIDA R-842:*** *The PIs shall ensure that the only instrument-generated magnetic fields at a distance of 1 metre from the corresponding unit on time scales between 1/64 s and 1 s are:*
>
> *· Transients with maximum peak-to-peak amplitude specified in the table associated with R-796 (Table 4.10-1).*
>
> *· Field variations of amplitude less than specified in the table associated with R-796 (Table 4.10-1).*

EIDA-4994//

EIDA R-682: *The PIs and Prime Contractor shall ensure that magnetic field transients induced by payload or platform, and happening during EMC quiet phases, shall be reported in TM with time tag and identification of source.*

Cyclical, or pre-defined sequences causing a series of transients need only to be reported at the start of the series. If not pre-determined, the list of events within that sequence shall also be reported.

EIDA-13326//

EIDA R-863: *The PIs and Prime Contractor shall ensure that the precision of the time-tag requested in EIDA R-682 is 1s or better with respect to the magnetic transient.*

EIDA-4995//

EIDA R-683: *The PIs and Prime Contractor shall ensure that the cumulative time of contiguous intervals of at least one hour duration that do not contain platform-generated magnetic transient as defined in R-681 are within EMC quiet phases and amount to at least 70% of the orbit duration.*

D: The PIs will report in the EIDB an analysis of the number of transients including the timeline during the magnetic quiet periods. 10897

EIDA-4996//

EIDA R-684: *The Prime Contractor shall ensure that during EMC quiet phases, at the location of the outboard magnetometer sensor, the peak-to-peak variations of the magnetic field of the platform of medium time scale fluctuations, as defined below, averaged over 1 second, do not exceed 5 pT over a period of 1 hour.*

D: *Medium time scale fluctuations are defined as periodic and non-periodic changes of the magnetic field on time scales of 1 second to 1 hour.*

D: *Transients as defined in R-681 are excluded from this requirement*

EIDA-4998//

EIDA R-685: *The Prime Contractor shall ensure that during EMC quiet phases, at the location of the outboard magnetometer sensor, the peak-to-peak variations of the magnetic field of long-term fluctuations, as defined below, averaged over 1 hour, do not exceed:*

- *1.0 nT for spacecraft distances to the sun smaller than 0.5 AU*
- *0.5 nT for spacecraft distances to the sun larger than 0.5 AU over a period of 100 days.*

D: Long time scale fluctuations are defined as changes of the magnetic field on time scales larger than 1 hour. 5001

EIDA-5002//

EIDA R-686: *The PIs and Prime Contractor shall ensure that the frequency of 15360 Hz and its harmonics up to the 4th harmonic are reserved for exclusive use by MAG. The reserved bandwidth around these frequencies shall be +/- 20 Hz, +/-40 Hz, , +/- 320 Hz.*

EIDA-10899//

EIDA R-843: *The Prime Contractor shall ensure that the magnetic field variation at MAGOBS as a result of power changes shall be less than 0.38pT per Watt.*

D: For scientific operations, MAGOBS requires the total variation in magnetic field to be less than 10pT over one hour. 10900

9.1.2.3 *Integrated DC Magnetic Field*

EIDA-5004//

> ***EIDA R-700:*** *The Prime Contractor shall ensure that outside a cone with a half-cone angle of 50°, centred around the +X-axis of the spacecraft and originating at the location of the SWA-EAS sensor, the integrated magnetic field due to the spacecraft and payload, measured along all lines of sight of the SWA-EAS sensors, except those that pass through the Solar Arrays or HGA, shall be less than 40 nTm.*

D: For this value contributions to the magnetic field coming from the EAS sensor itself shall not be considered. 5005

EIDA-5006//

> ***EIDA R-701:*** *The Prime Contractor shall ensure that within the field of view (FoV) of the SWA-PAS sensor, as defined through the relevant SWA EID-B, the integrated magnetic field due to*
>
> *the spacecraft and payload, measured along all lines of sight of the SWA-PAS sensor, shall be less than 21000 nTm.*
>
> ***D:*** *For this value contributions to the magnetic field coming from the PAS sensor itself shall not be considered.*

EIDA-5008//

> ***EIDA R-702:*** *The Prime Contractor shall ensure that within the field of view (FoV) of the SWA-HIS sensor, as defined through the relevant SWA EID-B, the integrated magnetic field due to the spacecraft and payload, measured along all lines of sight of the SWA-HIS sensor, shall be less than 47000 nTm.*
>
> ***D:*** *For this value contributions to the magnetic field coming from the HIS sensor itself shall not be considered.*

EIDA-13380//

> ***EIDA R-868:*** *The Prime Contractor shall ensure that within the field of view (FoV) of the EPD-STEP sensor, the integrated magnetic field due to the spacecraft and payload, measured along all lines of sight of the STEP sensor, shall be less than 4000 nTm. For this value contributions to the magnetic field coming from the STEP sensor itself shall not be considered.*

9.1.2.4 *AC Magnetic Field*

EIDA-5011//

> ***EIDA R-703:*** *The PIs and the Prime Contractor shall ensure that on ground, at the location of the RPW-SCM, the overall AC magnetic field emitted by the spacecraft and the external environment, when measured with a 1Hz bandwidth, shall be at least 6dB below the red line in figure (Figure 9.1-1) below.*
>
> *Frequency stable narrow band spikes up to but not exceeding the red line are permitted, but the frequency space they occupy shall be less than 10% of the respective frequency decade (1Hz to 10Hz, 10Hz to 100Hz, etc.).*

D: Verification method: test. 5013

D: Definition of “frequency stable”: The short term stability of potential narrow band emission lines will be better than 10E-5 for a period of 1 hour. 5014

D: Goal is less than 1% per decade occupied by spikes across the full spectrum. 5015

EIDA-5016//

> ***EIDA R-704:*** *The PIs and the Prime Contractor shall ensure that in flight at the location of the RPW SCM, the emitted AC magnetic field shall be below the black line in the figure (Figure 9.1-1) below when measured with bandwidths specified in requirement EIDA R-705. Frequency stable narrow band spikes up to but not exceeding the red line are permitted in accordance with Requirement EIDA R-703.*

D: Verification method: Analysis by the Prime Contractor, using test results from EIDA R-705 5017

EIDA-5018//

EIDA R-705: *The Prime Contractor, for the purposes of verification of requirement EIDA R-704, shall ensure that units will be tested for their AC magnetic field emissions with the following frequency bandwidths:*

- *1 Hz to 128 Hz: 0.125 Hz bandwidth*
- *128 Hz to 2048 Hz: 2Hz bandwidth*
- *2048 Hz to 12288 Hz: 12Hz bandwidth*
- *12288 Hz to 200 kHz: 122Hz bandwidth*
- *200 kHz to 1.002 MHz: 21kHz bandwidth*

D: Verification method: test 5024

D: AC magnetic characterisation will be carried out at unit level by testing at close proximity to the unit (typically less than 1 m). The results will be combined to provide an analytical verification of **EIDA R-**704. 5025

D: The physical location of the equipment on the spacecraft will be taken into account to derive the pass/fail criterion for requirement **EIDA R-**704, scaled to unit level. For this, the black and red lines of the figure below (Figure 9.1-1) may be scaled according to the distance between the unit under test and the location of the RPW-SCM using a factor of $1/r^2$. 5026

13327

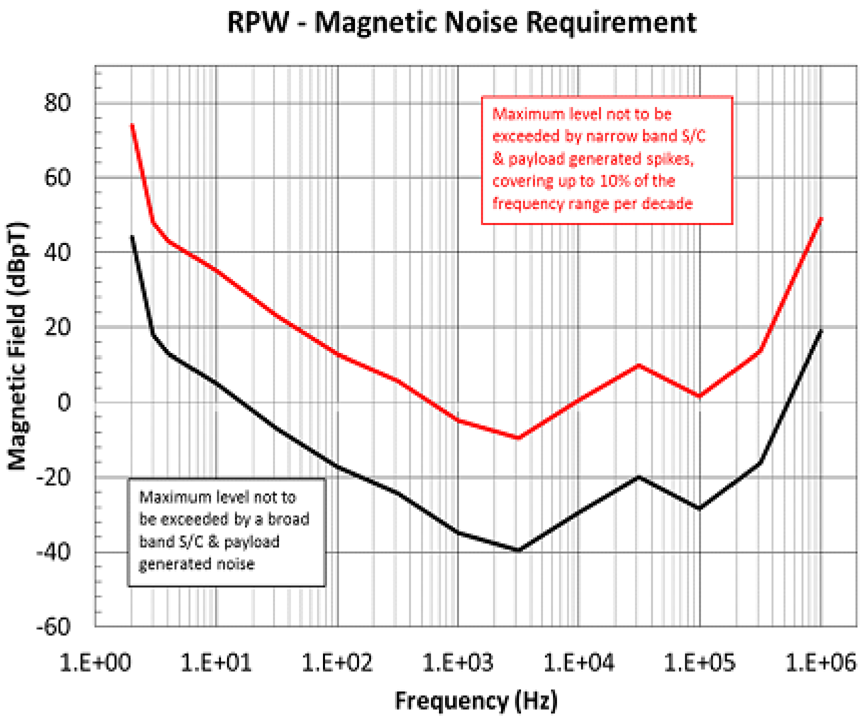


Figure 9.1-1: Broadband noise at RPW-SCM, B^{nim}_{noise} (black), and (B^{nim}_{noise} + 30 dB) (red). 5028

5029

Frequency (Hz)	Noise level (dB pT)
2	44
3	18
4	13
10	5
31.6	-7.0
100	-17.2
316.2	-24.2

Frequency (Hz)	Noise level (dB pT)
1000	-34.9
3162.3	-39.5
1.0E4	-29.3
3.16E4	-20
1.0E5	-28.4
3.16E5	-16.3
1.0E6	19.0

Table 9.1-2: Broadband noise at RPW-SCM. 5075

EIDA-5076//

EIDA R-783: *The characterisation tests shall have a sensitivity such that the levels defined by the black line in Figure 9.1-1 are achieved. The distance at which the measurements are taken shall be scaled using a square law by reference to the distance between the locations of the unit and the SCM. Distances are given in Table 9.1-3.*

12728

Equipment	Distance to SCM / m
EPD EPT-HET 1	2.75
EPD EPT-HET 2	2.90
EPD ICU	3.17
EPD SIS	3.22
EPD STEP	3.17
EUI EBOX	2.73
EUI OB	3.56
MAG ELB	3.07
MAGIBS	1.00
MAGOBS	1.25
METIS MOU	3.90
METIS MPPU	2.59
PHI EBOX	3.03
PHI OB	3.48
RPW ANT 1	3.56
RPW ANT 2	4.14
RPW ANT 3	4.23
RPW MEB	2.57
RPW SCM	0.00
SEB	3.50
SOLOHI	3.26
SOU	3.18
STIX DEM	3.41
STIX IMG	3.95
SWA DPU	3.72
SWA EAS	2.20
SWA HIS	3.97
SWA PAS	4.36

Table 9.1-3: Distances between instrument equipments and SCM. 5078

EIDA-5132//

EIDA R-784: *The PI shall measure the radiated H-field emissions of each unit at the time of internal switching transients that will occur during normal operation, excluding switch-on/off and redundancy switching.*

D: *Measurement distance will be defined on a case by case basis. The test set-up shall be photographed in each configuration used.*

9.1.2.5 *AC Electric Field:*

EIDA-5134//

EIDA R-706: *The Prime Contractor shall ensure that all electrical and electronic equipment units shall be measured to determine the E-field emissions with a background noise level better than reported in figure below (Figure 9.1-2).*

D: *Measurement distance will be defined on a case by case basis. The test set-up shall be photographed in each configuration used.*

D: *Units are defined as external if they are mounted external to or protrude through the spacecraft external shielding structure.*

D: *Units are defined as active if they contain electrical or electronic components and they are powered or operated during the scientific quiet periods of Solar Orbiter orbit.*

10914

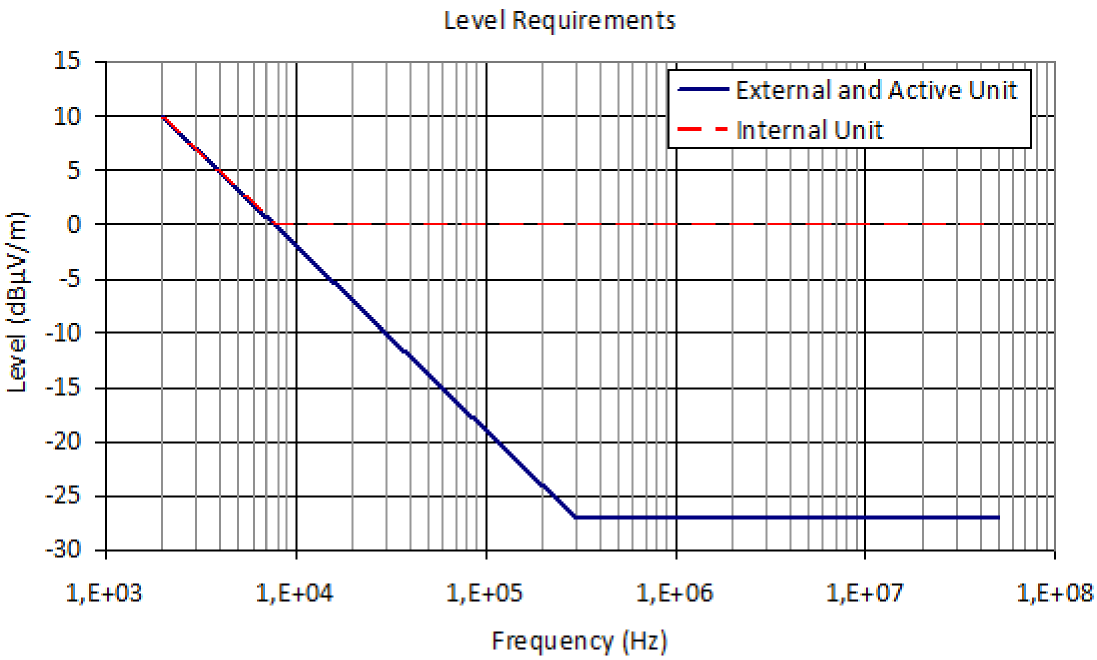


Figure 9.1-2: Background noise level for radiated E-field measurement. 5138

EIDA-5139//

EIDA R-785: *The PI shall characterise the radiated E-field emissions of each unit using the frequency ranges and background noise as in Figure 9.1-2.*

D: *Measurement distance will be defined on a case by case basis. The test set-up shall be photographed in each configuration used.*

EIDA-5145//

EIDA R-707: *The Prime Contractor shall assess the overall expected E-field emissions at the location of the RPW ANT-preamplifiers against RPW desired performance, as given in figure (Figure 9.1-3) below, based on the unit test data and assuming no interaction between units.*

13379

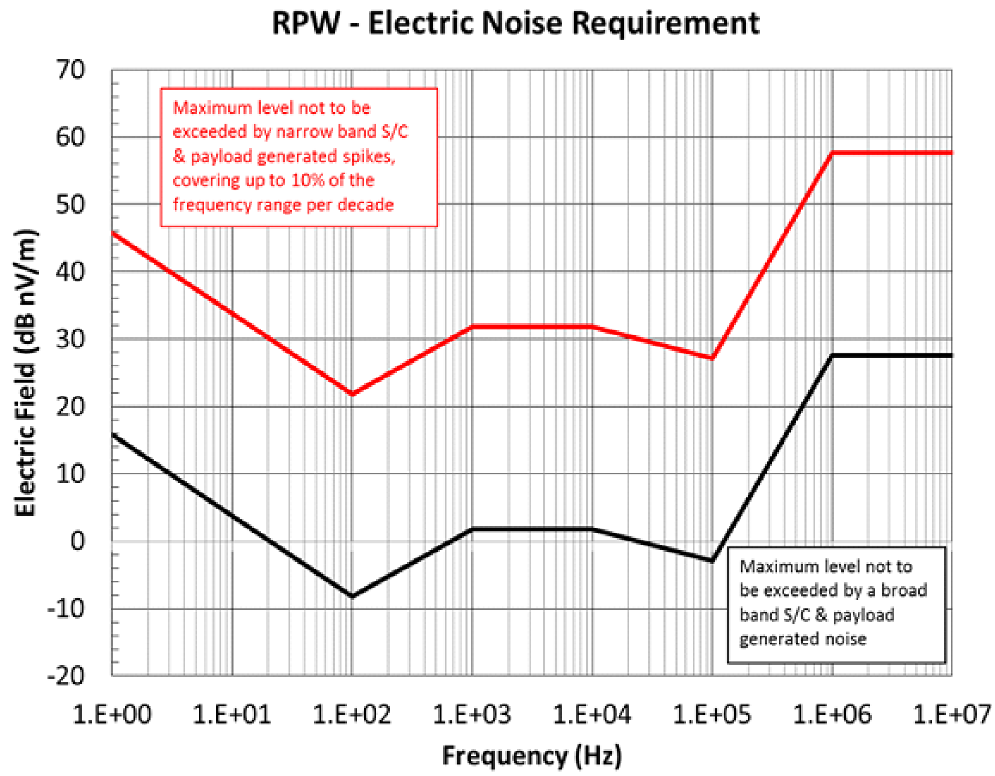


Figure 9.1-3: Broadband E-field noise at RPW ANT, E^{nim}_{noise} (black), and (E^{min}_{noise} + 30 dB) (red). 5147

5148

Frequency (Hz)	Noise level (dB nV/m)
1	15.8
10	3.8
100	-8.2
1.0E3	1.8
1.0E4	1.8
1.0E5	-2.9
1.0E6	27.6
2.0E7	27.6

5176

Table 9.1-4: Broadband E-field noise at RPW ANT.

D: The black curve represents the minimum noise (E^{min}_{noise}) that will not be exceeded at the location of the ANT pre-amplifiers by any broad-band noise generated by the spacecraft and the payload. The values of E^{min}_{noise} are given in the table above (Table 9.1-4). The red curve represents the minimum noise (E^{min}_{noise} + 30 dB) that will not be exceeded at the location of the RPW-ANT pre-amplifiers by frequency stable narrow-band spikes generated by the spacecraft and the payload and covering up to 10% of the frequency range per decade (1Hz to 10Hz, 10Hz to 100Hz, etc). 5177

D: Definition of "frequency stable": The short term stability of potential narrow band emission lines will be better than 10E-5 for a period of 1 hour. 5178

D: Goal is less than 1% per decade occupied by spikes across the full spectrum. 5179

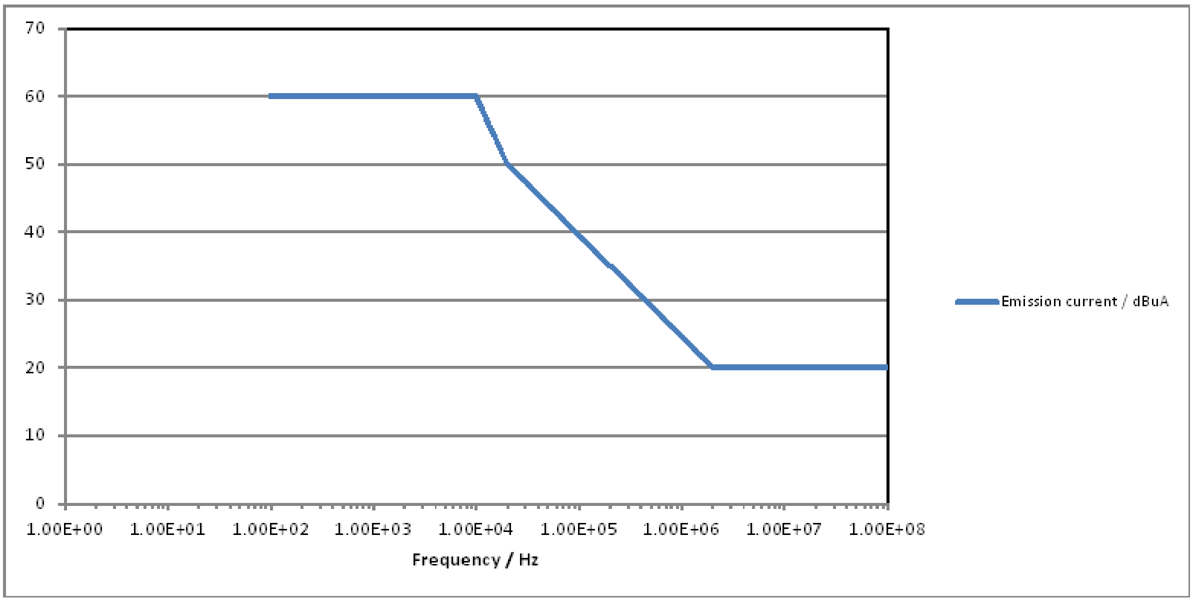
EIDA-5180//

> ***EIDA R-708:*** *The PIs shall ensure that Common Mode (CM) current characterisation will be performed at unit level to obtain reference information relevant to the RPW desired performance with maximum background noise levels as below and as shown in Figure 9.1-4 (Common mode level):*
>
> - *60dBuA over the frequency range 30Hz to 10kHz,*

- *Reducing to 50dBuA over the frequency range 10kHz to 20kHz,*
- *Reducing to 20dBuA over the frequency range 20kHz to 2MHz,*
- *20dBuA over the frequency range 2MHz to 100MHz*

D: The Prime Contractor makes the commitment to request characterisation of the platform equipments to these levels. 10907

10915



10908

Figure 9.1-4: Maximum background noise level for current emissions from equipments.

EIDA-5181//

EIDA R-709: *The Prime Contractor shall ensure that CM current characterisation will be performed on the external harness at spacecraft level to obtain reference information relevant to the RPW desired performance with maximum background noise levels as below and as shown in Figure 9.1-5 (Common mode level):*

- *60dBuA over the frequency range 30Hz to 10kHz,*
- *Reducing to 50dBuA over the frequency range 10kHz to 20kHz,*
- *Reducing to 20dBuA over the frequency range 20kHz to 2MHz,*
- *20dBuA over the frequency range 2MHz to 100MHz*

10916

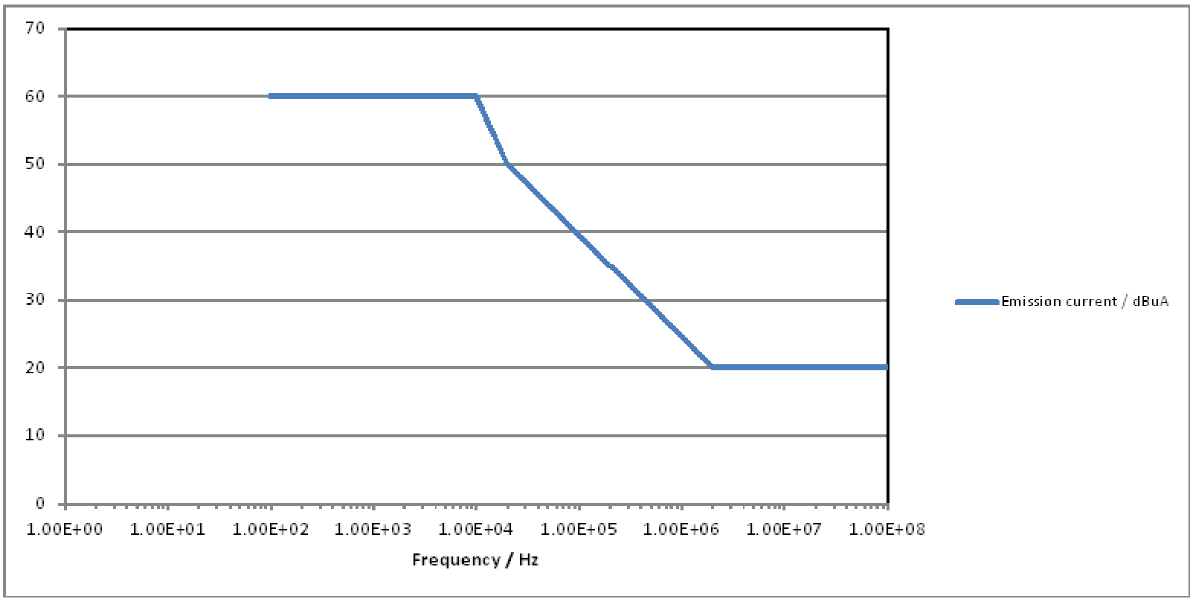


Figure 9.1-5: Maximum background noise level for current emissions from external harness. 10909

9.1.2.6 *Electrostatic Field:*

D: For the intended scientific objectives the electrostatic field around the spacecraft, which interacts with the plasma of the solar wind, is required to be as homogeneous and symmetrical as possible. During flight, the difference of electric potential between any two points on the surface of the spacecraft should be below 1 V. Large conductive surfaces exposed to the plasma on the sunward and anti-sunward side of the spacecraft are needed. 5183

EIDA-5184//

> ***EIDA R-710:*** *The PIs and the Prime Contractor shall ensure that all external surfaces of the spacecraft, including external instruments, shall be conducting.*
>
> *The following known exceptions are allowed:*
>
> - *Front side of solar arrays (cover glasses, OSRs),*
> - *Instrument and AOCS sensor apertures and doors,*
> - *High Gain Antenna dish (front, rear)*

EIDA-5189//

> ***EIDA R-711:*** *The electrical resistance between any point on an external conducting surface, exposed to space plasma, to spacecraft reference ground, as defined in the S/C Electrical ICD (Ground Reference Rail, GRR), shall be < 3 kOhm.*

D: (Exposed) thermal blankets or other external structural elements, will be bonded to each other and/ or to the spacecraft with adequate bonding methods, resulting in a conductive path to the main bonding strap. 5190

9.1.3 Cleanliness Requirements

EIDA-5192//

> ***EIDA R-687:*** *The PIs shall provide all necessary means for maintaining and monitoring the required cleanliness level of the instrument up to handover of the instrument to ESA at the Prime Contractor premises.*

EIDA-5193//

***EIDA R-688:** The Prime Contractor shall maintain the required external cleanliness levels at the instrument aperture after handover of the instrument to the spacecraft for integration by*

a. Maintain an ISO 8 clean room 5194

b. Supply a cleanliness purging system to the instruments 5195

c. Keep aperture covers in place unless they have to be removed for AIT purposes. Should the covers need to be removed for AIT purposes (e.g. Thermal Vacuum Test etc), they shall only be removed against dedicated procedures, approved by the Prime and ESA. The objective of this requirement is to ensure that exposure is kept to a manageable minimum and minimise unnecessary contamination. 5196

d. When covers are removed, operator access will be restricted (to a maximum of 3 operators for example) by the application of dedicated procedures, approved by Prime and ESA. In addition, clean-room clothing classification may be increased for specific purposes as required by the dedicated procedure, for example, the use of full cover-alls and face masks. 5197

EIDA-5198//

***EIDA R-807:** The Prime Contractor shall monitor, after handover of the instrument to the spacecraft for integration, the cleanliness level of the instrument aperture area by mounting cleanliness witness plates near the instrument apertures during AIT activities.*

D: Dedicated inserts will be placed in the heat-shield and structure so that the mounting positions of the witness plates are near the apertures (i.e. not 3 metres away) and represent the orientation of the aperture. 5199

EIDA-5200//

***EIDA R-808**: The PI shall ensure that protection devices are incorporated in the design and that cleaning of sensitive areas at later integration phases, if necessary, are identified.*

D: During the design of the instrument it must be kept in mind that the environment encountered during the integration phase and launch preparations of the spacecraft (usually class 8) is not of the same high cleanliness standard which can be achieved in a laboratory where sensitive equipment is assembled. 5201

EIDA-9450//

***EIDA R-829:** The PIs shall ensure that Vacuum Thermal Bakeout be applied to all materials and internal equipments to reduce evolution of outgas products and to remove (or stabilise) molecular surface contamination. The vacuum thermal bake-out shall be monitored in real-time by means of TQCMs until the outgassing rate reaches a significantly reduced and almost steady state (ie. until the rate of change as measured by the QCM has reduced to between 0% and 5% per hour when measured over a period of not less than 3 hours).*

D: The Vacuum Thermal Bakeout procedure specified in Appendix 12 is recommended. 9452

9.1.3.1 *Purging*

EIDA-5203//

***EIDA R-689:** The PI shall specify the purging requirements for the each instrument unit during spacecraft integration and testing, transportation and the launch campaign.*

EIDA-5204//

***EIDA R-690:** The PIs shall specify individual purge rates for each unit.*

EIDA-5205//

***EIDA R-691:** The Prime Contractor shall provide flow-controlled purging for the relevant instrument units for use from physical delivery to lift off.*

EIDA-13328//

EIDA R-864: *The PI shall implement a ¼ inch stainless steel Swagelok fitting (a fitting that conforms to Swagelok general designation “SS-400-", male connector) for the spacecraft purge interface to the instrument, plus suitable plug for when there is no purge pipe fitted.*

D: Where required, in–line filters should be included behind the purge inlet on the instrument 13329

D: Exceptions to this must be agreed with the Prime Contractor and ESA. 13330

EIDA-13331//

EIDA R-865: *The instruments shall be able to survive 14 days in the launch configuration with all protective covers and bags removed in an ISO 7 cleanroom.*

D: purging will be active for this period. 13332

EIDA-13333//

EIDA R-866: *For instruments sensitive to particulate contamination, the PI shall implement a particulate filter at the instrument entrance inlet for the purge line.*

EIDA-13334//

EIDA R-867: *The PI shall define the instrument venting concept (path and flow rate) in coordination with ESA and AirbusDS.*

9.1.3.2 *Particulate and Molecular Cleanliness Requirements*

D: A potentially major risk for the programme is the UV fixation of out-gassing materials on the instrument optics. 5207

D: To estimate the AIT contamination budget it can be assumed that purging of the instrument apertures will be available throughout the AIT sequence except during TB/TV tests. 5208

EIDA-9446//

EIDA R-827: *The PIs shall define the tolerable levels of contaminant inside each instrument (ie: on sensitive and critical elements) at delivery to ESA and at EoL. They shall reconcile and express these levels in terms of the maximum amount of contamination which may enter each Instrument Entrance Aperture (and feedthrough filters, heat rejection openings and venting holes) following delivery to Spacecraft AIT until EoL.*

D: Spacecraft level contamination analysis will only predict the amounts of contaminant likely to enter each Instrument Entrance Aperture (and feedthrough filters, heat rejection openings and venting holes) between delivery to AIT and EoL). 9447

D: The PIs should model with an accuracy compatible with their need and predict the manner in which predicted contaminant will behave *within* each Instrument to settle on sensitive and critical elements in order to verify that the predicted level of contamination likely to enter each Instrument Entrance Aperture during the mission shall not have accumulated on critical or sensitive surfaces by EoL in such quantities as to exceed the limit specified by the PI. 9448

D: Design considerations should take into account the following factors: 9449

- Manufacturing Environments;
- Inspection/Test Environments;
- Transportation & Storage;
- AIT which will be performed in ISO 8 (Class 100,000) environment;
- Thermal Vacuum Testing;
- Vibration Testing;
- Launch Ascent;

- Commissioning and on station.
- The use of baffles and covers

`

D: To estimate the molecular contamination level at the end of the S/C AIT sequence, the following inputs are considered: 5209

· Typical contamination 10^{-6} g/cm^2/year in a clean room environment. 5210

· Typical contamination 5E10^{-8} g/cm^2 for the thermal vacuum facilities. 5211

EIDA-11648//

EIDA R-849: *The PIs shall provide the Prime Contractor with the emission and re-emission rate of the outgassing materials to be used for the SC contamination model.*

EIDA-5212//

EIDA R-693: *The PIs shall comply with the particulate and molecular values at delivery to the Prime Contractor, as specified in the table below (Table 9.1-5).*

EIDA-5213//

EIDA R-694: *The Prime Contractor shall comply with the particulate and molecular values at EOL, as specified in the table below (Table 9.1-5).*

12362

Instrument	Unit	Element	Particulate ppm coverage		Molecular ng/cm2	
			At delivery to Prime Contractor	EOL	At delivery to Prime Contractor	EOL
SWA	EAS	Microchannel plates	34	100	100	500
		Aperture	169	267	200	500
		External surfaces	252	1045	200	1000
	PAS	CEM	72	100	100	500
		Aperture	204	267	200	500
		External surfaces	252	1045	200	1000
	HIS	Microchannel plates	34	100	100	500
		solid state detectors	148	267	100	500
		Carbon foils	148	267	100	500
		External surfaces	252	1045	200	1000
EPD	EPT	Solid state detector	300	3800	200	5000
		rare earth magnet	300	NA	200	5000
		parylene foil	300	3800	200	5000
		external surfaces	300	NA	200	NA
	HET	Solid state detector	300	3800	200	5000
		External surfaces	300	NA	200	NA
	STEP	Solid state detector	300	3800	200	5000

Instrument	Unit	Element	Particulate ppm coverage		Molecular ng/cm2	
		Deflection plates	300	3800	200	5000
		External surfaces	300	NA	200	NA
	SIS	Solid state detector	300	2250	200	100
		Aperture foils	300	2250	200	100
		microchannel Plates	300	2250	200	100
		Interior surfaces	300	3800	200	100
		External surfaces	300	9600	200	500
MAG			300	NA	200	NA
RPW	ANT		300	NA	200	NA
	SCM		300	NA	200	NA
PHI		HRT/FDT entrance filter	300	10000	100	500
		HRT optics	300	500	50	100
		FDT optics	300	500	50	100
		HRT polarisation modulation package	300	500	50	100
		Image stabilisation system	300	500	50	100
		Filter optics and focal plane assembly	300	500	50	100
		Internal optical surfaces	25	50	10	10
		Thermal hw,MLI	300	100000	100	1000
		Electronic box	300	100000	100	1000

10775

Table 9.1-5: Particulate and molecular contamination allocation values at delivery to Prime Contractor and at EOL.

11649

Instrument	Unit	Element	Particulate ppm coverage		Molecular ng/cm2	
			At delivery to Prime Contractor	EOL	At delivery to Prime Contractor	EOL
EUI		Entrance baffle	54	300	50	370
		entrance filter front side	54	100	50	370
		entrance filter inside	54	100	50	370
		Primary mirror	54	100	50	370
		Secondary mirror	54	100	50	370
		Focal plane assembly	54	100	50	370
		Optical bench,	54	100	50	370

Instrument	Unit	Element	Particulate ppm coverage		Molecular ng/cm2	
		Internal baffle External hw	100	300	100	500
SPICE	external surfaces	UV blocking filter	300	3800	200	1000
		heat rejection Mirror	300	3800	200	1000
		External surface	300	15000	200	2000
	interior surfaces	Heatshield feed through (ASU)	–	–	–	–
		Telescope	160	330	100	200
		Pre-Slit	27	54	100	200
		Grating Assembly	27	54	100	200
		Detector Assembly	27	54	100	200
		Interior walls	27	54	100	200
STIX		X-Ray Windows	300	50600	200	4000
		Grids	300	NA	200	NA
		Aspect Lens	300	NA	200	5000
		Detector Electronic Module	300	NA	200	NA
METIS		Inverted External Occulter (IEO)	3.3	100	200	1500
		Telescope UV optics (M1, M2,IO,Lyot)	3.3	31	100	333
		Telescope UV filter	3.3	31	100	200
		ICCD Photocathode	3.3	31	100	100
		Visible light polarimeter Optics and CCD	3.3	31	200	1000
		Heat rejection Mirror	3.3	16	200	1000 TBC
		Telescope interior	3.3	54	200	1000
		Exterior surfaces outside thermal blankets	144	3814	200	2000
		Exterior surfaces inside thermal blankets	54	1274	200	2000
		Electronic box exterior	144	3814 or more	200	2000
SoloHI	SIM	APS detector	3.3	21	200	1000
		Detector readout board	16	54	200	1000
		FPA interior	7	21	200	1000
		O1front surface	16	120	200	1000
		other optics	16	54	200	1000

Instrument	Unit	Element	Particulate ppm coverage		Molecular ng/cm2	
		Front baffle top edge	35	120	200	1000
		Interior baffle top edge	35	120	200	1000
		Front baffles	35	82	200	1000
		Interior baffles, F4 aft	35	120	200	1000
		Side baffle,side wall	35	120	200	1000
		SiIM structure interior, Non optical surfaces	35	320	200	1000
		Baffle coverdoor interior	7	1270	200	2000
		Baffle coverdoor exterior	35	1270	200	2000
		FPA radiator	82	670	200	2000
		CIE exterior	82	1270	200	2000
		SIM exterior	82	1270	200	2000
	SCE	SCE exterior	145	2250	200	2000

10776

Table 9.1-6: Particulate and molecular contamination allocation values at delivery to Prime Contractor and at EOL (cont).

9.1.4 Payload allocated Resources

D: The table (Table 9.1-7) below specifies the overall mass, power and data rate resources provided by the spacecraft to the SO payload. The allocations per instrument, as well as the specific rules on margins, are specified in chapter 4. 5217

EIDA-5218//

EIDA R-692: *The Prime Contractor shall ensure that the resources specified in the table below (Table 9.1-7) are available at EOL.*

5219

Mass [kg]	Power [W]	Data Rate [kbps]
208.7	245	120

5228

Table 9.1-7: Spacecraft provided resources to SO payload.

10 NORMATIVE AND INFORMATIVE DOCUMENTS

10.1 *Normative References*

Normative References [NR] are applicable in their entirety or partially to this document and are listed below as dated or undated references. These normative references may be cited at appropriate places in the text of the EID-A. 5230

[NR-01] Solar Orbiter Space Segment Requirements Document, Sol-EST-RS-1717, issue 3, rev.4 5231

[NR-02] ECSS-E-ST-10C, System engineering general requirements 5232

[NR-03] ECSS-E-ST-10-02C, Verification 5233

[NR-04] ECSS-E-10-03, rev.1, Testing 5234

[NR-05] ECSS-E-ST-10-04C Space Environment 5235

[NR-06] ECSS-E-10-12C, Methods for the calculation of radiation received and its effect 5236

[NR-07] ECSS-E-ST-20C, Electrical and electronic, general principles 5237

[NR-08] ECSS-E-ST-20-06C, Spacecraft charging 5238

[NR-09] ECSS-E-ST-20-07C, Electromagnetic compatibility 5239

[NR-10] ECSS-E-ST-31C, Thermal control, general requirements 5240

[NR-11] ECSS-E-ST-32C Rev.1, Structural general requirements 5241

[NR-12] ECSS-E-ST-32-01C Rev.1, Fracture Control 5242

[NR-13] ECSS-E-ST-32-08C, Materials 5243

[NR-14] ECSS-E-ST-33-01C, Mechanisms 5244

[NR-15] Intentionally left blank 5245

[NR-16] ECSS-E-ST-50-12C, SpaceWire – Links, nodes, routers and networks 5246

[NR-17] ECSS-E-ST-50-14C, Spacecraft discrete interfaces 5247

[NR-18] SOL.S.ASTR.RS.00038, Solar Orbiter SpaceWire Application Protocol Specification, issue 6 5248

[NR-19] ECSS-E-ST-70-41A, Telemetry and Telecommand Packet Utilization 5249

[NR-20] ESA PSS-01-606, Capability Approval Programme for Hermetic Thick Film Hybrid Micro-Circuits 5250

[NR-21] ESA PSS-01-605, Capability Approval Programme for Hermetic Thin Film Hybrid Micro-Circuits 5251

[NR-22] MIL-HDBK-5, Metallic materials and elements for aerospace vehicle structures 5252

[NR-23] TEC-EES-03-034/JS, issue 3 rev.1, Solar Orbiter Environmental Specification 5253

[NR-24] SOL-ASTR-RS-0014, issue 3, rev. 0, Payload Reduced Thermal Model Specification 5254

[NR-25] SOL-EST-RS-1937, issue 2, rev. 1, Product Assurance Requirements for Instruments 5255

[NR-26] SCI-S/2007/157, issue 1.0, rev. -, Science Management Plan 5256

[NR-27] SO-ESC-RS-05001, issue 1 rev. 8, Solar Orbiter Operations Requirements Document 5257

[NR-28] SOL.S.ASTR.TN.0079, issue 7, Solar Orbiter TM/TC- and Packet Structure ICD 5258

[NR-30] SOL-EST-LI-2241, issue 1, rev. 0, Solar Orbiter Data Requirement Document for SO Payload 5260

[NR-31] DDR_DT0772935_02_00_00_I-boom Unit Positions 5261

[NR-32] Intentionally left blank 8933

[NR-33] SOL.S.ASTR.ICD.00009, Issue 2, Solar Orbiter Flight Procedures Generation Plan 8934

[NR-34] SOL.S.ASTR.ICD.00011, Issue 4, Solar Orbiter Spacecraft SRDB Payload ICD 9456

[NR-35] SOL.S.ASTR.RS.00061, Issue 4, Solar Orbiter Spacecraft SRDB Naming Convention and Population Rules 9457

[NR-36] SOL.S.ASTR.RS.00097, Issue 1, Instrument MGSE General Requirement Specification 10331

[NR-37] SOL.S.ASTR.RS.00087, Issue 1, Instrument EGSE General Requirement Specification 10332

[NR-38] SOL-EST-RS- 3188, issue1, rev. 0, Requirements and clarifications on software development and qualification for Solar Orbiter instruments 10348

[NR-39] SOL-EST-RS-4095, Issue 1, Revision 1, 'Solar Orbiter Instrument User Manual DRD'. 11458

[NR-40] ECSS-Q-70-71, 11647

[NR-41] SOL.S.ASTR.PL.00077, Issue 2, Payload Assembly, Integration and Verification Plan 12056

[NR-42] DT0670978, Issue 2, Heat shield shadow_8 deg, Reduced CAD model of spacecraft 29112012 12713

10.2 *Informative References*

Informative References are documents, which provide supplementary information. They do not contain directly applicable requirements. However, clauses of informative documents may have been copied directly, or modified, into Normative Documents, through which these clauses are then applicable. 5263

The following documents as of the current issue, as indicated or most recent in the event of updates, are possible sources of clarification for the content of Solar Orbiter EID. 5264

[IR-01] SOL-EST-SP-00705, – issue 6, Solar Orbiter Payload Definition Document 5265

[IR-02] ESA/SRE(2011)14, July 2011, Definition Study Report. 5266

[IR-03] SO-ESC-RP-05500, Issue 3 rev. 1, 2012-10-12, Solar Orbiter Consolidated Report on Mission Analysis 5267

[IR-04] SOL-EST-WG-1725, issue 1, rev. 0, Instrument EMC Requirements 5268

[IR-05] SOL-EST-WG-1726, issue draft, Cleanliness Working Group Recommendations 5269

[IR-06] SOL-EST-RS-1858, issue 2, revision 0, Solar Orbiter Science Requirements Document 5270

[IR-07] Intentionally left blank 5271

[IR-08] SOL.S.ASTR.RS.00011, Issue 02, Mechanical FEM Requirement Specification 5272

[IR-09] (removed) 5273

[IR-10] (removed) 5274

[IR-11] (removed) 5275

[IR-12] (removed) 5276

[IR-13] (removed) 5277

[IR-14] (removed) 5278

[IR-15] (removed) 5279

[IR-16] (removed) 5280

[IR-17] (removed) 5281

[IR-18] (removed) 5282

[IR-19] SOL.S.ASTR.TN.00088, issue 4, Science Telemetry Management 5283

[IR-20] SO-ESC-RS-05002, issue 1 draft rev. -, Solar Orbiter Generic Frame and Packet Structure Document 5284

[IR-21] SOL.S.ASTR.TN.00098, issue 3, Solar Orbiter Radiation Analysis 10333

10334

[IR-22] SOL.S.ASTR.ICD.00008, Issue 3, Solar Orbiter SSUM Standard Volume Definition Document

[IR-23] SOL.S.ASTR.TN.00235 issue 1, Input Format Required for Spacecraft Level Instrument Test Procedures 13336

[IR-24] SOL.S.ASTR.PL.00101, issue 1 rev 0, OBCP Generation and Development Plan 18944

[IR-25] SOL.S.ASTR.TN.00117, issue 2 rev 0, Solar Orbiter OBCP Concept 18945

11 ACRONYMS

ABCL	As Built Configuration List	5286
AC	Alternating Current	
AFT	Abbreviated Functional Test	
AIT	Assembly, Integration and Test	
AIV	Assembly, Integration and Verification	
AOCS	Attitude and Orbit Control System	
APE	Absolute Pointing Error	
BOL	Beginning of Life	
CCB	Configuration Control Board	
CCSDS	Consultative Committee for Space Data Systems	
CE	Cold Element	
CoG	Centre of Gravity	
CIDL	Configuration Item Data List	
CoM	Centre of Mass	
CPU	Central Processing Unit	
DC	Direct Current	
DDV	Design Development Validation	
DMS	Data Management System	
DPU	Digital Processing Unit	
DTMM	Detailed Thermal Model	
EAS	Electron Analyzer System	
ECR	Engineering Change Request	
ECSS	European Cooperation for Space Standardization	
EGSE	Electrical Ground Support Equipment	
EID	Experiment Interface Document	
EIDP	End Item Data Package	
EGSE	Electrical Ground Support Equipment	
EMC	Electromagnetic Cleanliness/Compatibility	
EMI	Electromagnetic Interference	
EOL	End of Life	
EPD	Energetic Particle Detector	
EPS	Electrical Power Subsystem	
EPT	Electron and Proton Telescope	
EQM	Electrical Qualification Model	
ESD	Electro-Static Discharge	
EUI	Extreme Ultraviolet Imager	
EUS	Extreme Ultraviolet Spectrometer	
EUV	Extreme Ultra-Violet	
FDIR	Failure Detection Isolation and Recovery	
FDT	Full Disc Telescope	
FEE	Front End Electronics	
FEM	Finite Element Model	
FFT	Full Functional Test	
FM	Flight Model	
FMECA	Failure Modes, Effects and Criticality (Analysis)	
FoR	Field of Regard	
FOSY	Factor of Safety - Yield	
FOV, FoV	Field of View	
FS	Flight Spare	
GAM	Gravity Assist Maneuver	
GSE	Ground Support Equipment	
HE	Hot Element	

ABCL	As Built Configuration List
HELEX	Heliophysical Explorers
HET	High Energy Telescope
HGA	High Gain Antenna
HIS	Heavy Ion Sensor
HRT	High Resolution Telescope
HSIA	Hardware Software Interaction Analysis
H/W	Hardware
IBS	In-Board Sensor
ICDR	Instrument Critical Design Review
ILS	Instrument Line of Sight
I/O	Input/Output
IPDR	Instrument Preliminary Design Review
IR	Infra Red
LEOP	Launch and Early Orbit Phase
LCL	Latching Current Limiters
LISN	Line Impedance Stabilization Network
LOS	Line Of Sight
MAG	Magnetometer
MGA	Medium Gain Antenna
MGSE	Mechanical Ground Support Equipment
MICD	Mechanical Interface Control Document
MLI	Multi Layer Insulation
MOC	Mission Operations Centre
MTL	Mission Time Line
NCR	Non-Conformance Report
NIEL	Non-Ionizing Energy Loss
OBS	Out Board Sensor
PA	Product Assurance
PAS	Proton and Alpha particle Sensor
PDE	Pointing Drift Error
PCDU	Power Conditioning and Distribution Unit
PI	Principal Investigator
PS	Project Scientist
QA	Quality Assurance
QM	Qualification Model
RF	Radio Frequency
RFW	Request for Waivers
RMS	Radiated Magnetic Susceptibility
RPE	Relative Pointing Error
RPW	Radio and Plasma Wave analyzer
RTU	Remote Terminal Unit
S/C	Spacecraft
SEL	Single Event Latch-up
SEU	Single Event Upset
SIS	Supra-thermal Ion Spectrograph
SMM	Structural Mathematical Model
SOC	Science Operations Centre
SpW	Space Wire
SRP	System Reference Point
SSGS	Solar Orbiter Science Ground Segment
SSMM	Solid State Mass Memory
STEP	SupraThermal Electrons and Protons

ABCL	As Built Configuration List
STIX	Spectrometer Telescope Imaging X-rays
STM	Structural Thermal Model
SVT	System Verification Test
SWA	Solar Wind Analyzer
SWT	Science Working Team
TBC	To Be Confirmed
TBD	To Be Determined
TC/ TM	Telecommand / Telemetry
TCM	Trajectory Control Manoeuvre
TCS	Thermal Control System
TM	Telemetry
UFOV, UFoV	Unobscured Field of View
URF	Unit Reference Frame
URP	Unit Reference Point
UV	Ultra-Violet
WBS	Work Breakdown Structure

12 APPENDICES

12.1 A1 INSTRUMENT COMPLEMENT AND ACCOMMODATION

D: The table below describes the 10 instrument payload complement on board Solar Orbiter. 5643

The harness units interconnecting the sensor units to the respective electronics units are not explicitly listed in the table. 5644

5645

Instrument	Acronym	Unit	Acronym	Number of Units
Remote Sensing Instrument				
Extreme UV Imagers	EUI	Optical Bench	OBS	1
		Common Electronics Box	CEB	1
Multi-Element Telescope for Imaging and Spectroscopy	METIS	METIS Instrument	MOU	1
		METIS Processing and Power Unit	MPPU	1
Polarimetric and Helioseismic Imager	PHI	Optics Unit	OPT	1
		Electronics box	ELE	1
		HRT entrance window filter	HEW	1
		FDT Entrance Window filter	FEW	1
Solar Orbiter Heliospheric Imager	SoloHI	SoloHI Instrument Module	SIM	1
		SoloHI Control Electronics	SCE	1
Spectral Imaging of the Coronal Environment	SPICE	SPICE Optics Unit	SOU	1
		SPICE Electronics Box	SEB	1
		SC-mounted TQCM	STQCM	1
		TQCM Read-out Box	STQCMB	1
Spectrometer/Telescope for Imaging X-rays	STIX	Imager Module	IMA	1
		Sunshade/ apertures	Window	2
		Detector Electronics Module	DEM	1
In-Situ Instrument				
Energetic Particle Detector	EPD	Suprathermal Ion Spectrograph	SIS	1
		SupraThermal Electron & Protons	STEP	1
		Electron and Proton Telescope - High Energy Telescope	EPT-HET	2
		Instrument Controller Unit	ICU	1

Instrument	Acronym	Unit	Acronym	Number of Units
Magnetometer	MAG	Magnetometer Outboard Sensor	MAGOBS	1
		Magnetometer Inboard Sensor	MAGIBS	1
		Magnetometer Electronics Box	MAGELB	1
Radio and Plasma Waves Experiment	RPW	Antenna	ANT	3
		Search Coil Magnetic Sensor	SCM	1
		Main Electronics Box	MEB	1
Solar Wind Analyzer	SWA	Electron Analyzer System	EAS	1
		Proton Alpha Sensor	PAS	1
		Heavy Ion Sensor	HIS	1
		Data Processing Unit	DPU	1

Table 12.1-1: The instrument payload complement on Solar Orbiter. 10414

D: The instrument units allocated dynamic envelopes and the transformation matrices of the externally mounted sensors are specified in the following IRDs: 13025

13026

Instrument	Unit	Document number	Issue
EPD	EPD-HETEPT	DT0651828	4
EPD	EPD-ICU	DT0662230	4
EPD	EPD-STEP	DT0856446	1
EPD	EPD-SIS	DT0657109	3
EUI	EUI OBS	DT0647138	6
EUI	EUI CEB	DT0662228	2
MAG	MAG OBS/IBS	DT0650516	3
MAG	MAG E-box	DT0662229	4
METIS	METIS IFE	DT0644662	6
METIS	METIS MPPU	DT0662231	2
PHI	PHI OU	DT0645660	7
PHI	PHI ELE	DT0662226	2
PHI	PHI-HEW/ FEW	DT0786438	1
RPW	RPW-MEB	DT0662224	2
RPW	RPW-ANT MY	DT0662536	3
RPW	RPW-ANT PY	DT0662538	3
RPW	RPW-ANT PZ	DT0662541	3
RPW	RPW-SCM	DT0650521	4
SOLOHI	SOLOHI	DT0657105	4
SPICE	SPICE SOU	DT0656924	7
SPICE	SPICE SEB	DT0662225	2
SPICE	TQCM	DTxxxxxxx	TBA
STIX	STIX	DT0649959	4
STIX	STIX windows	DT0794250	1
SWA	SWA-EAS	DT0650519	3
SWA	SWA-DPU	DT0662227	3

Instrument	Unit	Document number	Issue
SWA	SWA-PAS	DT0657099	4
SWA	SWA-HIS	DT0657102	4

Table 12.1-2: The payload IRDs. 13167

D: For the units with feedthroughs, the feedthrough dimensions are defined in the following IRDs: 5836

13169

Instrument	Feedthrough	Document number	Issue
EUI	EUI FT	DT0794254	1
EUI	EUI HRI FT	DT0794258	1
METIS	METIS FT	DT0794246	1
PHI	PHI HRT/FDT FT	DT0786438	1
SPICE	SPICE FT	DT0794255	1
STIX	STIX FT	DT0794250	1
SWA	SWA HIS FT	DT0795960	1
SWA	SWA PAS FT	DT0795962	1

Table 12.1-3: IRD references that contain the feedthrough geometries for the relevant instruments. 10416

D: Harness corridor volumes are defined in the following IRDs: 5874

11325

Instrument	Acronym	Description	CAD model number	Issue
Extreme UV Imagers	EUI	int. harness	DT0755663	2
Multi-Element Telescope for Imaging and Spectroscopy	METIS	int. harness	DT0755662	2
Polarimetric and Helioseismic Imager	PHI	int. harness	DT0755659	3
Solar Orbiter Heliospheric Imager	SolOHI	int. harness	N/A	N/A
Spectral Imaging of the Coronal Environment	SPICE	int. harness	DT0755665	3
Spectrometer/Telescope for Imaging X-rays	STIX	N/A	N/A	N/A
Energetic Particle Detector	EPD	int. harness	DT0755671	4
	EPD	ext. harness	DT0925119	2
Magnetometer	MAG	int. harness	DT0755669	5
Radio and Plasma Waves Experiment	RPW	int. harness	DT0755674	2
	RPW PZ-ANT	ext. harness	DT0829494	2
	RPW PY-ANT	ext. harness	DT0829495	2
	RPW MY-ANT	ext. harness	DT0829497	2
	RPW-SCM	ext. harness	DT0844765	2
Solar Wind Analyzer	SWA	int. harness	DT0755668	3
	SWA-HIS	ext. harness	DT0952884	1
	SWA-PAS	ext. harness	DT0952886	1

Table 12.1-4: The harness corridor IRDs 10415

12.2 A2 (intentionally blank)

12.3 A3 Thermal Interfaces

This annex contains the latest information on the payload / spacecraft thermal interfaces. These interface values are applicable to both the payload and the spacecraft design. 6024

6025

However these interface values will naturally evolve according to design evolutions on both the payload and spacecraft sides of the interface.

Therefore, these interface values are understood to come from the latest consolidated design and form part of the latest configured baseline. 6026

The values below are those to be used in any analysis when quoting performance characteristics for the spacecraft. 6027

12.3.1 A3.1 Design Interface Heat Flows

The table below defines the maximum allowable conductive and radiative heat rejection from the payload interfaces. 6029

The table below defines also the instrument interface design temperature ranges (non-operational, operational and switch on) for thermally coupled ("C") and thermally insulated ("NC") units. The radiative heat flux exchanged by the instrument optical units with the S/C internal cavity is indicated with "R". 6030

The heat flows represent the current best understanding based on analysis from the instrument proposals and available EID-B's at the time of issuing this EID-A; The S/C TCS assumes no conductive link between the feedthrough and the instrument. 6031

The interface temperatures ranges represent the current best understanding of the thermal interface for the instruments based on analysis from the instrument proposals and available EID-B's at the time of issuing this EID-A. The non-operating temperature ranges are applicable to the unit survival temperature. 6032

6033

Instrument	Unit	Location	Coupled	Interface Ref (*****)	Radiative or Conductive Max Heat Rejection to S/C (W) (***)	Temp Range (deg C) Non-op Min	Temp Range (deg C) Non-op Max	Temp Range (deg C) Operational Min	Temp Range (deg C) Operational Max	Temp Range (deg C) Switch-on (**) Min	Temp Range (deg C) Switch-on (**) Max
PHI	OU	INT	NC	CE	**3**	-35	60	-25	-10	-35	0
PHI	OU	INT	NC	HE	**13.7**	-30	60	-20	50	-30	60
PHI	OU	INT	NC	HE	**10.2**	-30	60	-20	50	-30	60
PHI	OU	INT	NC	HE	**3.1**	-30	60	-20	50	-30	60
PHI	OU	INT	NC	R	1	-30	60	-20	50	-30	60
PHI	OU	INT	NC	SRP	1	-30	60	-20	50	-30	60
PHI	EB	INT	C	URP	**24.5**	-30	60	-20	50	-30	60
SPICE	OU	INT	NC	CE	8.6	-47.5	60	-47.5	-37.5	-47.5	-22.5
SPICE	OU	INT	NC	R	5	-30	60	-20	50	-30	60
SPICE	OU	INT	NC	SRP	1	-30	60	-20	50	-30	60
SPICE	EB	INT	C	URP	24	-30	60	-20	50	-30	60
EUI	OU	INT	NC	CE	5.0	-75	60	-65	-50 *1	**-75**	**-40**
EUI	OU	INT	NC	CE	3.5	**-75**	60	-65	-50 *1	**-75**	**-40**
EUI	OU	INT	NC	HE	21	-30	60	-20	50	-30	60
EUI	OU	INT	NC	ME	3.5	-40	60	-30	20	-40	**30**
EUI	OU	INT	NC	ME	2	-40	60	-30	20	-40	**30**
EUI	OU	INT	NC	R	6.5	-30	60	-20	50	-30	60
EUI	OU	INT	NC	SRP	1	-30	60	-20	50	-30	60
EUI	EB	INT	C	URP	**21**	-30	60	-20	50	-30	60
METIS	OU	INT	NC	CE	4.2	**-85**	60	-75	-60	**-85**	**-50**
METIS	OU	INT	NC	HE	6	-30	60	-20	50	-30	60
METIS	OU	INT	NC	ME	3.9	**-35**	60	**-25**	-10	-35	**0**
METIS	OU	INT	NC	R	**1**	-30	60	-20	50	-30	60
METIS	OU	INT	NC	SRP	**1**	-30	60	-20	50	-30	60

Instrument	Unit	Location	Coupled	Interface Ref (*****)	Radiative or Conductive Max Heat Rejection to S/C (W) (***)	Temp Range (deg C) Non-op Min	Temp Range (deg C) Non-op Max	Temp Range (deg C) Operational Min	Temp Range (deg C) Operational Max	Temp Range (deg C) Switch-on (**) Min	Temp Range (deg C) Switch-on (**) Max
METIS	EB	INT	C	URP	15	-30	60	-20	50	-30	60
STIX	Imager	INT	C	R	**2**	-30	60	-20	50	-30	60
STIX	Imager	INT	C	SRP	**1**	-30	60	-20	50	-30	60
STIX	EB	INT	C	CE	2	-45	50	-45	-25	-45	**-15**
STIX	EB	INT	C	URP	2	-30	60	-20	50	-30	60
SOLOHI	EB+OU	EXT	NC	SRP	±1	-40	50	-40	50	-40	50
EPD	STEP	EXT	NC	SRP	±1	-40	50	-40	50	-40	50
EPD	ICU	INT	C	URP	5	-30	60	-20	50	-30	60
EPD	HET-EPT(2x)	EXT	NC	SRP	±1	-40	50	-40	50	-40	50
EPD	SIS	EXT	NC	SRP	±1	-40	50	-40	50	-40	50
SWA	DPU	INT	C	URP	5.7	-30	60	-20	50	-30	60
SWA	EAS	B	NC	SRP	±1	-190	-50 (****)	-190	-50 (****)	-190	-50 (****)
SWA	HIS	EXT	NC	SRP	±1	-40	50	-40	50	-40	50
SWA	PAS	EXT	NC	SRP	±1	-40	50	-40	50	-40	50
RPW	MEB	INT	C	URP	16.8	-30	60	-20	50	-30	60
RPW	ANT	EXT	NC	SRP	±1	-40	50	-40	50	-40	50
RPW	SCM	B	NC	SRP	±1	-190	-50 (****)	-190	-50 (****)	-190	-50 (****)
MAG	ELB	INT	C	URP	4.1	-30	60	-20	50	-30	60
MAG	IBS	B	NC	SRP	±1	-190	-50	-190	-50	-190	-50

Instrument	Unit	Location	Coupled	Interface Ref (*****)	Radiative or Conductive Max Heat Rejection to S/C (W) (***)	Temp Range (deg C) Non-op Min	Temp Range (deg C) Non-op Max	Temp Range (deg C) Operational Min	Temp Range (deg C) Operational Max	Temp Range (deg C) Switch-on (**) Min	Temp Range (deg C) Switch-on (**) Max
							(****)		(****)		(****)
MAG	OBS	B	NC	SRP	±1	-190	-50 (****)	-190	-50 (****)	-190	-50 (****)

(*1) EUI Temperatures. At the time of SORA PDR closeout, the following should be noted (for the revised conductive heat-fluxes) – all figures are estimated TBC by system-level analysis: 17807

Analysis indicates non-compliance on Max operating temp:

- At perihelion less than 5C non-compliance
- With heat-pipe failure less than 10C non-compliance.

(**) Minimum and maximum start-up temperatures: minimum and maximum temperatures at which the unit can be switched on (e.g. for monitoring reasons) in flight. Full performances are requested only in the operational limits. 6794

(***) ±1 W is the allowed conductive flux through the interface with spacecraft of thermally insulated units. Meaning: 1 W is the maximum flux allowed to be conductively transmitted to spacecraft in hot cases, 1 W is the maximum flux allowed to be extracted from the spacecraft in cold cases. 6795

(****) The non-operating and operating maximum limits given in the table are relevant to sun pointing attitudes. In cases when the sun-pointing attitude is not maintained and during GAMs the maximum operating, non-operating and switch-on limits becomes +80 C. 6796

The PI will then define the need to stay operational or non-operational. 6797

(*****) For thermally coupled internally units, the URP temperature is also representing the internal radiative environment. 6798

Table 12.3-1: Maximum allowable conductive and radiative heat rejection from the payload interfaces. 10417

12.3.2 A3.2 Available Survival Heater Power

6800

Instrument	Unit	Location	Coupled	Average survival heater power (W) *	Installed survival heater power (W) **	Max allowable duty cycle	Nominal heater lines	Redundant heater lines	Thermistor channels
SOLOHI	EB + OU	EXT	NC	8.4 (door	12.7	70 %	1	1	8

Instrument	Unit	Location	Coupled	Average survival heater power (W) *	Installed survival heater power (W) **	Max allowable duty cycle	Nominal heater lines	Redundant heater lines	Thermistor channels
				closed) 9.4 (door open)					
EPD	HET-EPT 1	EXT	NC	4.5	9	50 %	1	1	3
EPD	HET-EPT 2	EXT	NC	4.5	9	50 %	1	1	3
EPD	SIS	EXT	NC	4.3	8.6	50 %	1	1	3
EPD	STEP	B	NC	4.4	8.8	50%	1	1	3
SWA	EAS	B	NC	4	8	50 %	1	1	4 (****)
SWA	HIS	EXT	NC	5	10	50 %	1	1	3
SWA	PAS	EXT	NC	3.5	7	50 %	1	1	3
RPW	ANT	EXT	NC	1.5	4	N/A	1	1	3
RPW	ANT	EXT	NC	1.5	4	N/A	-	-	3
RPW	ANT	EXT	NC	1.5	4	N/A	-	-	3
RPW	SCM	B	NC	2.25	4.5	50 %	1	1	3
MAG (***)	IBS+OBS	B	NC	3.3	6.6	50 %	1	1	6
Total budget				49.6	96.2		13	13	48
Allocation				50	97		13	13	55

(*) The average heater power is computed by averaging over a period (Tav) of 3 hours (TBC). Tav will be determined by the thermal analysis, which will provide the time necessary for the stabilisation of the temperature profile as a result of the thermal cycle. 18224

(**) The installed heater power is the power drawn by the heaters when supplied by 27V (see EID-A R-752) 18225

(***) The MAG heater budget includes the power needed by the MAG electronics box for DC/AC power conversion. 7010

(****) single redundant heater line for both sensor heads and one additional non-critical monitor 7011

Table 12.3-2: Available Survival Heater Power. 18376

12.3.3 A3.3 Payload Feedthrough Thermal Models

The following table contains the feedthrough thermal models and accompanying report with relevant instructions to model each thermal model case, door closed case and off-pointing cases, and any special case. 17808

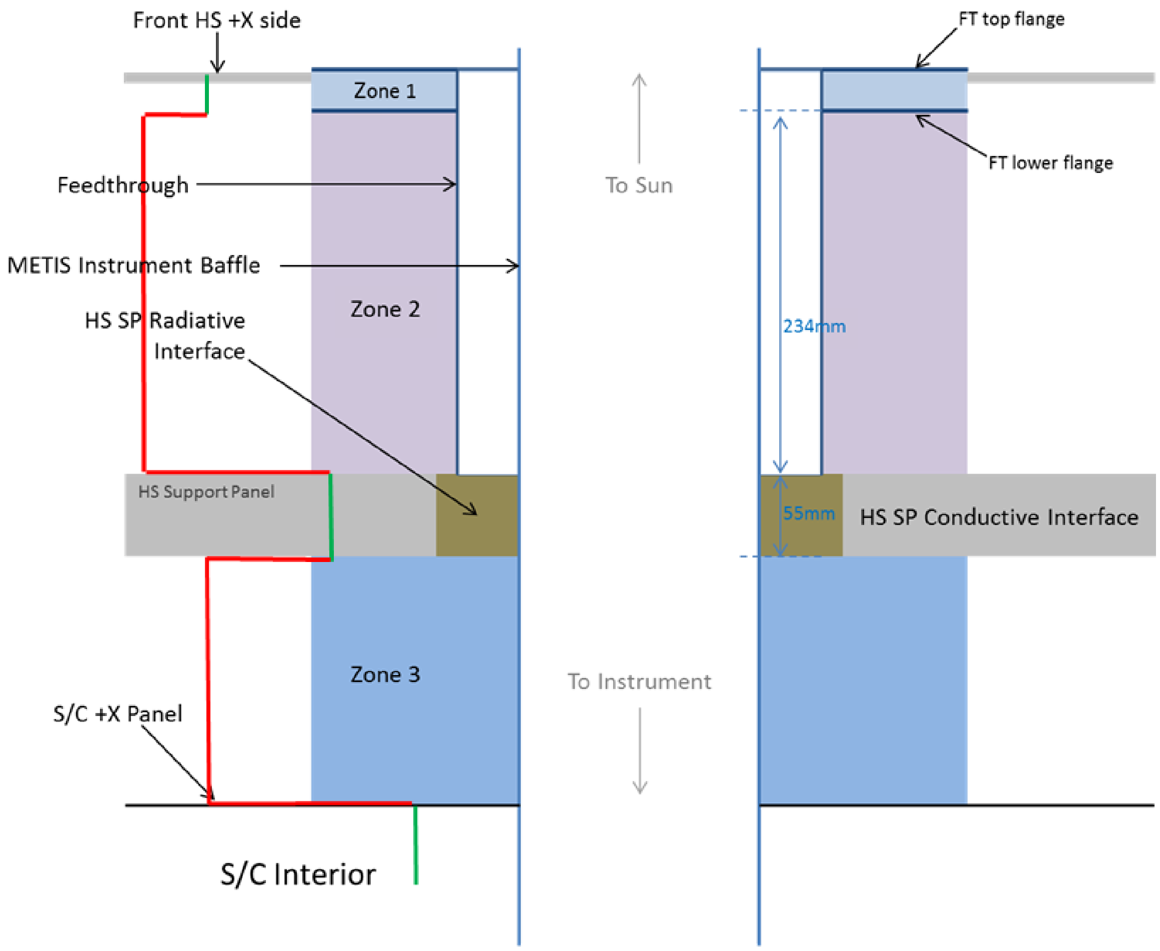
17861

Instrument	Acronym	Feedthrough	Thermal Model: Reference/Report/Memo Number	Issue	T sinks
Extreme Ultraviolet Imager Extreme Ultraviolet Image	EUI EUI	EUI-FSI FT EUI-HRI FT	SOL.S.ASTR.LE.00509	1	Table 12.3-4
Polarimetric and Heliospheric Imager Polarimetric and Heliospheric Imager	PHI PHI	PHI-HRT FT PHI-FDT FT	SOL.S.ASTR.LE.00510	1	Table 12.3-5
Spectrometer / Telescope for Imaging X-rays	STIX	STIX	SOL.S.ASTR.LE.00512	1	Table 12.3-6
Spectral Imaging of the Coronal Environment	SPICE	SPICE FT	SOL.S.ASTR.LE.00513	1	Table 12.3-7
Multi-Element Telescope for Imaging and Spectroscopy	METIS	METIS FT	SOL.S.ASTR.LE.00511	1	Table 12.3-8
Solar Wind Analyzer	SWA	SWA-HIS FT	SOL.S.ASTR.LE.00515	1	Table 12.3-9
Solar Wind Analyzer	SWA	SWA-PAS FT	SOL.S.ASTR.LE.00514	1	Table 12.3-10

17911

Table 12.3-3: Feedthrough Thermal Models.

18817



Modelling of Feedthrough Environment , Including METIS 18368

The external surface of the cylinders to be modelled should be made inactive.

SINK ZONE 1*: to be modelled by a cylinder closing the cavity between the two upper flanges of the FT (indicated in green)*

SINK ZONE 2*: to be modelled by two discs and one cylinder (indicated in red). The lower disc shall have an internal dia of 210 mm (dia of the hole in the HS support panel).*

"HS SP radiative IF" SINK: to be modelled by a cylinder with 210 mm dia and located on the egde of the HS support panel (indicated in green)

SINK ZONE 3*: to be modelled by two discs and one cylinder (indicated in red). The upper disc shall have an internal dia of 210 mm, the lower one the same dia of the FT.*

"S/C +X Panel H/C" SINK*: to be modelled by a cylinder located close to the FT at the same level of the S/C panel*

"S/C Environment"*: is used to model the internal radiative environment of the S/C.*

NOTE: This diagram is applicable to the following tables - Table 12.3-4, Table 12.3-5, Table EDIA-17914, Table 12.3-7 and Table 12.3-8. 18367

Figure 12.3-1: *Modelling of Environment Surrounding Instrument Feedthroughs*. 18370

17923

EUI FSI

Environment Component	**0.28AU**	**0.8AU**	**0.95AU**	**1.47AU**
Front HS +X side	520	155	120	35
Front HS -X side	275	40	15	-30
Front HS average (Zone 1)	395	95	65	5
Feedthrough door	535	105	70	-10
HS Upper Gap (Zone 2)	190	-15	-35	-75
HS SP Conductive Interface	170	-35	-50	-85
HS SP Radiative Interface	170	-35	-50	-85
HS Lower Gap (Zone 3)	80	-75	-85	-105

EUI HRI

Environment Component	**0.28AU**	**0.8AU**	**0.95AU**	**1.47AU**
Front HS +X side	520	155	120	35
Front HS -X side	275	40	15	-30
Front HS average (Zone 1)	395	95	65	5
Feedthrough door	535	125	85	5
HS Upper Gap (Zone 2)	185	-20	-35	-75
HS SP Conductive Interface	170	-35	-50	-85
HS SP Radiative Interface	165	-35	-50	-85
HS Lower Gap (Zone 3)	80	-70	-80	-95

The region described by '**Front HS average**' applies to region between flanges at the top of the feedthrough

Refer to Figure 12.3-1 for details of the Modelling Environment Surrounding Instrument Feedthrough affecting EUI 18371

Table 12.3-4: EUI RTMM Tsinks. 17912

17924

PHI HRT				
Environment Component	**0.28AU**	**0.8AU**	**0.95AU**	**1.47AU**
Front HS +X side	525	160	120	40
Front HS -X side	270	35	15	-30
Front HS average (Zone 1)	400	100	70	5
Feedthrough door	540	125	85	5
HS Upper Gap (Zone 2)	180	-25	-45	-85
HS SP Conductive Interface	165	-35	-55	-85
HS SP Radiative Interface	160	-35	-55	-85
HS Lower Gap (Zone 3)	60	-85	-95	-105

PHI FDT				
Environment Component	**0.28AU**	**0.8AU**	**0.95AU**	**1.47AU**
Front HS +X side	525	160	120	40
Front HS -X side	270	35	15	-30
Front HS average (Zone 1)	400	100	70	5
Feedthrough door	535	110	70	-5
HS Upper Gap (Zone 2)	185	-20	-40	-75
HS SP Conductive Interface	165	-35	-55	-85
HS SP Radiative Interface	155	-35	-55	-85
HS Lower Gap (Zone 3)	70	-80	-90	-100

Refer to Figure 12.3-1 for details of the Modelling Environment Surrounding Instrument Feedthrough affecting PHI 18372

Table 12.3-5: PHI RTMM Tsinks. 17913

17925

STIX				
Environment Component	**0.28AU**	**0.8AU**	**0.95AU**	**1.47AU**
Front HS +X side	520	155	115	35
Front HS -X side	275	40	15	-30
Front HS average	395	95	65	0
Feedthrough door	n/a	n/a	n/a	n/a
HS Upper Gap	190	-20	-40	-80
HS SP conductive IF	170	-35	-55	-85
HS SP radiative IF	165	-35	-50	-85
HS Lower Gap	75	-80	-90	-110

Refer to Figure 12.3-1 for details of the Modelling Environment Surrounding Instrument Feedthrough affecting STIX 18373

Table 12.3-6: STIX RTMM Tsinks. 17914

17926

SPICE				
Environment Component	**0.28AU**	**0.8AU**	**0.95AU**	**1.47AU**
Front HS +X side	525	155	115	35
Front HS -X side	275	40	15	-30
Front HS average (Zone 1)	400	95	65	0
Feedthrough door	535	95	60	-15
HS Upper Gap (Zone 2)	185	-20	-40	-80
HS SP Conductive Interface	165	-40	-60	-90
HS SP Radiative Interface	160	-35	-55	-85
HS Lower Gap (Zone 3)	60	-85	-95	-110
The region described be HS average applies to region between flanges at the top of the feedthrough				

Refer to Figure 12.3-1 for details of the Modelling Environment Surrounding Instrument Feedthrough affecting SPICE 18374

Table 12.3-7: SPICE RTMM Tsinks. 17915

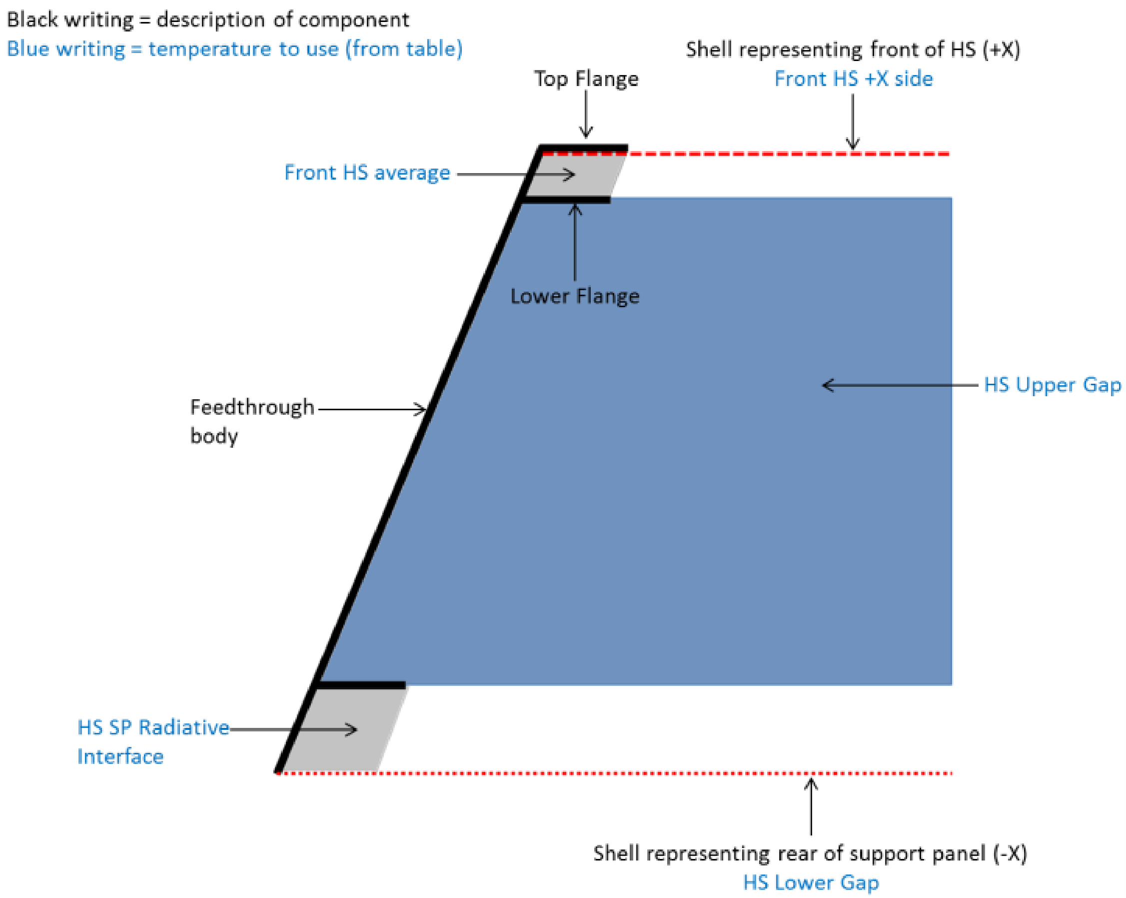
17927

METIS	**Temperature of component [°C]**			
Environment Component	**0.28AU**	**0.8AU**	**0.95AU**	**1.47AU**
Front HS +X side	525	155	120	35
Front HS -X side	280	40	15	-30
Front HS average (Zone 1)	400	95	65	5
Feedthrough door	540	120	85	5
HS Upper Gap (Zone 2)	185	-20	-40	-75
HS SP conductive IF (node 999990)	165	-35	-50	-85
HS SP radiative IF	160	-35	-50	-85
HS Lower Gap (Zone 3)	80	-70	-85	-100
S/C +X Panel H/C	50	-20	-30	-30
S/C Environment	50	-20	-20	-30

Refer to Figure 12.3-1 for details of the Modelling Environment Surrounding Instrument Feedthrough affecting METIS 18375

Table 12.3-8: METIS RTMM Tsinks. 17916

18818



This diagram is applicable to Table 12.3-9 and Table 12.3-10. 18525

Figure 12.3-2: ***Modelling of Environment Surrounding Instrument Feedthroughs (ii).*** 18523

17928

SWA HIS				
Environment Component	**0.28AU**	**0.8AU**	**0.95AU**	**1.47AU**
Front HS +X side	520	155	115	35
Front HS -X side	280	45	20	-30
Front HS average (Zone 1)	400	100	70	0
Feedthrough door	n/a	n/a	n/a	n/a
HS Upper Gap (Zone 2)	250	20	0	-45
HS SP Conductive Interface	190	-30	-50	-85
HS SP Radiative Interface	310	10	-15	-75
HS Lower Gap (Zone 3)	130	-75	-85	-110
The region described be HS average applies to region between flanges at the top of the feedthrough				

Refer to Figure 12.3-2 for details of the Modelling Environment Surrounding Instrument Feedthrough affecting SWA HIS 18527

17917

Table 12.3-9: SWA HIS RTMM Tsinks.

18171

SWA PAS				
Environment Component	**0.28AU**	**0.8AU**	**0.95AU**	**1.47AU**
Front HS +X side	520	155	115	35
Front HS -X side	280	40	20	-30
Front HS average (Zone 1)	400	100	65	0
Feedthrough door	n/a	n/a	n/a	n/a
HS Upper Gap (Zone 2)	250	20	0	-45
HS SP Conductive Interface	190	-20	-40	-80
HS SP Radiative Interface	285	5	-20	-75
HS Lower Gap (Zone 3)	100	-125	-130	-130
The region described be HS average applies to region between flanges at the top of the feedthrough				

Refer to Figure 12.3-2 for details of the Modelling Environment Surrounding Instrument Feedthrough affecting SWA PAS 18528

17918

Table 12.3-10: SWA PAS RTMM Tsinks.

18533

Thermo-optical Properties	HS Front Surface	Support Panel Edge	S/C +X Panel (-X side)	S/C Internal Environment
Emissivity (IR)	0.81	0.05	0.05	1.00
Absorbtivity (UV)	0.96	0.20		N/A
Diffuse reflectivity (IR)	0.19	0.05	0.05	0.00
Diffuse Reflectivity (UV)	0.04	0.05	0.05	0.00
Specular Reflectivity (IR)	0.00	0.90	0.90	0.00
Specular Reflectivity (UV)	0.00	0.75	0.75	0.00

17919

Table 12.3-11: Thermo-optical Properties for Feedthrough environment.

12.3.4 A3.4 Spacecraft Feedthrough Temperature Ranges (doors closed)

<this section not now used> 17920

12.3.5 A3.5 Spacecraft Feedthrough Temperature Ranges (doors open)

<this section not now used> 7491

12.3.6 A3.6 Maximum IR and solar fluxes between Payload and Feedthroughs

<this section not now used> 17921

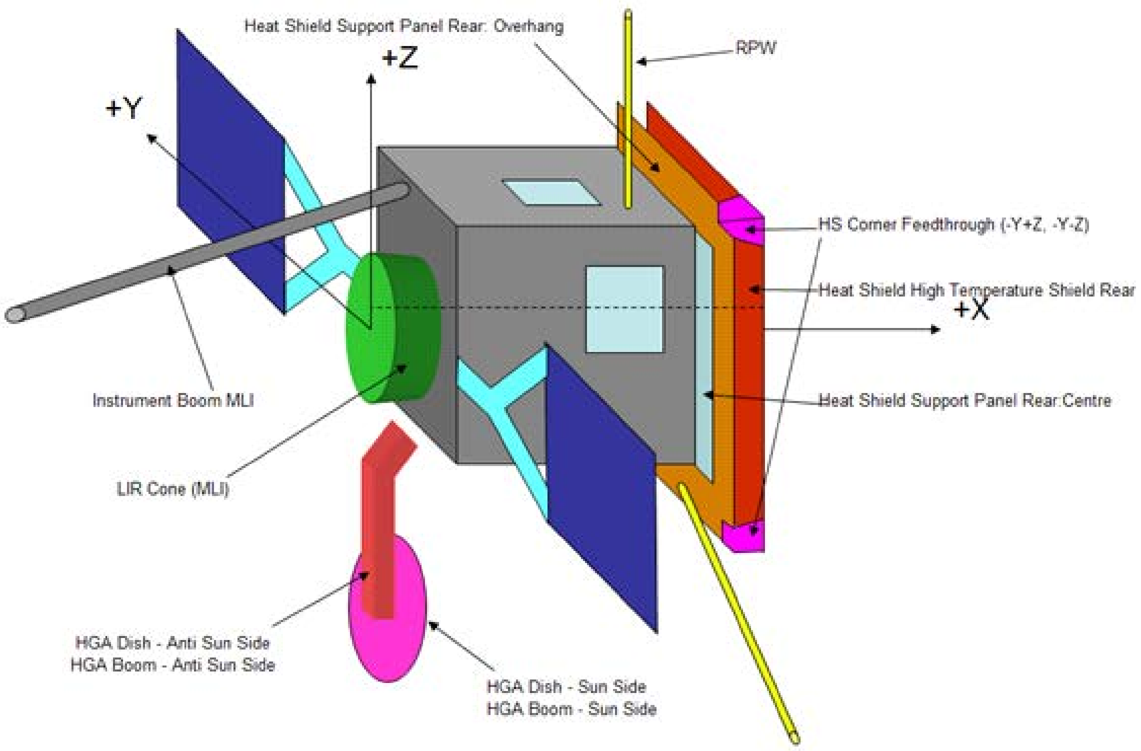
12.3.7 A3.7 Radiative Environment

12.3.7.1 Spacecraft External Surfaces

D: The radiative environment for instrument units installed inside the S/C are given in Section A3.1. 7782

D: The radiative environment for instrument units installed externally to the S/C is given in the Figure 12.3-3 below. 7783

17932



The radiators shown are represented symbolically and bear no resemblance to actual implementation. The configuration and dimensions of radiators are shown in Figure 12.3-4 and Figure 12.3-5 18223

Figure 12.3-3: The radiative environment for instrument units installed externally to the S/C. 10421

12.3.7.2 Spacecraft External Surface Temperatures

D: External temperatures of the spacecraft as a function of distance from the sun are provided. 7785

D: The temperatures in the following tables relate the external spacecraft temperatures to the separation between the sun and the spacecraft. The temperatures are intended to provide an enveloping external radiative environment. The values in the table will evolve as the spacecraft design progresses. Hence all values are TBC. 7786

18170

Sun Distance Range	0.28AU - 0.95AU		Venus/Earth Flyby		Stowed Spacecraft		Cruise: 0.95AU - 1.47AU ϙ				
S/C Orientation	+X Sun Facing		+X Sun Facing		+X Sun Facing		+X Sun Facing		Surface in Sun*		
Range	Max	Min	Max	Min÷	Max	Min	Max	Min	Max (normal to surface)	Max (45° to surface)	Min
+Y (Radiator)	50	-30	40	-30	30	-40	30	-40	50	50	-40
-Y (Radiator)	-10	-80	10	-80	0	-40	10	-90	-10	-10	-90
+Z (Radiator)	-30	-100	-20	-100	-30	-90	-10	-100	50	50	-90
Solar Array Panel - Sun Facing Side	185	0	120	-100	30#	-100#	40	-20	Solar array tracks the sun (Sun Facing side remains sun facing)		
Solar Array Panel - Non-Sun Facing Side	140	0	120	-100	30#	-100#	30	-20			
S/A Yoke - Outside Shadow Cone Sun Facing Side	200	-30	50	-40	30#	-50#	-100	-120			
S/A Yoke - Outside Shadow Cone Non-Sun Facing Side	50	-150	50	-150	30#	-50#	50	-120			
Solar Array Yoke - Within Shadow Cone	50	-150	50	-150	30#	-50#	50	-120			
HGA Dish - Sun Side	450	40	170	0	30#	-180#	80	0	*	*	*
HGA Dish - Anti Sun Side	100	-180	-70	-180	30#	-180#	-120	-180	*	*	*
HGA Boom - Sun Side	450	40	140	-150	30#	-180#	80	0	*	*	*
HGA Boom - Anti Sun Side	100	-180	-100	-180	30#	-180#	-120	-180	*	*	*
RPW - Outside Shadow Cone	350	10	190	-60	70	-180	70	-20	*	*	*
RPW - Within Shadow Cone	20	-180	80	-180	50	-180	-100	-180	*	*	*
Heat Shield Support Panel Rear	120	-80	10	-80	-50	-80	-50	-100	10	130	-100
Heat Shield High Temperature Shield Rear"	250	-30	190	-160	10	-160	10	-60	-30	240	-60
HS Corner Feedthrough (-Y+Z, -Y-Z)	330	0	120	-60	40	-60	40	-100	90	50	-100
Instrument Boom MLI	-130	-180	80	-190	-160	-180	-160	-180	170	170	-170

* The +X Sun facing values to be used
ϙ For surfaces not exposed to the sun during the values for the +X sun facing case shall be used
÷ In eclipse. For initial conditions before eclipse use the Min values for 0.28AU-0.95AU +X Sun Facing. Assume instantaneous temperature transition on eclipse entry
" Uniform temperature across the -X Surface of the heat shield support panel (centre and overhang)
Equipment stowed against the spacecraft platform
* Depending on the S/C orientation with respect to the sun assumed in the thermal analysis the S/C surface temperature will vary if sun exposed, temperature relavant when the sun is normal to surface
+ When sun direction is normal to the -X surface
++ When sun direction is 45° to the -X surface

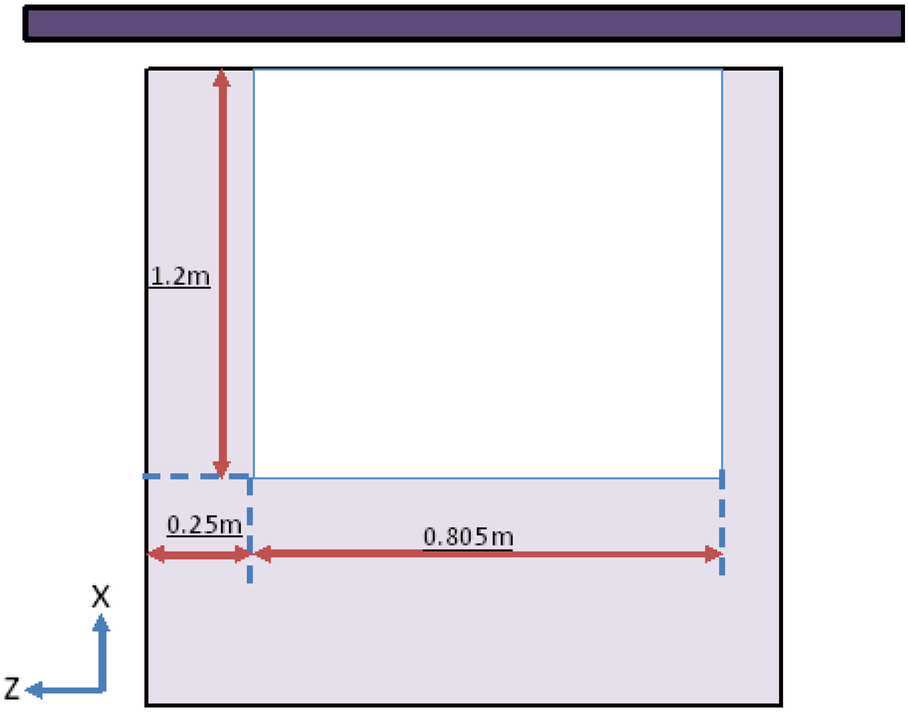
18377

Table 12.3-12: Spacecraft External Surface Temperatures.

12.3.7.3 Radiator Areas on the Spacecraft

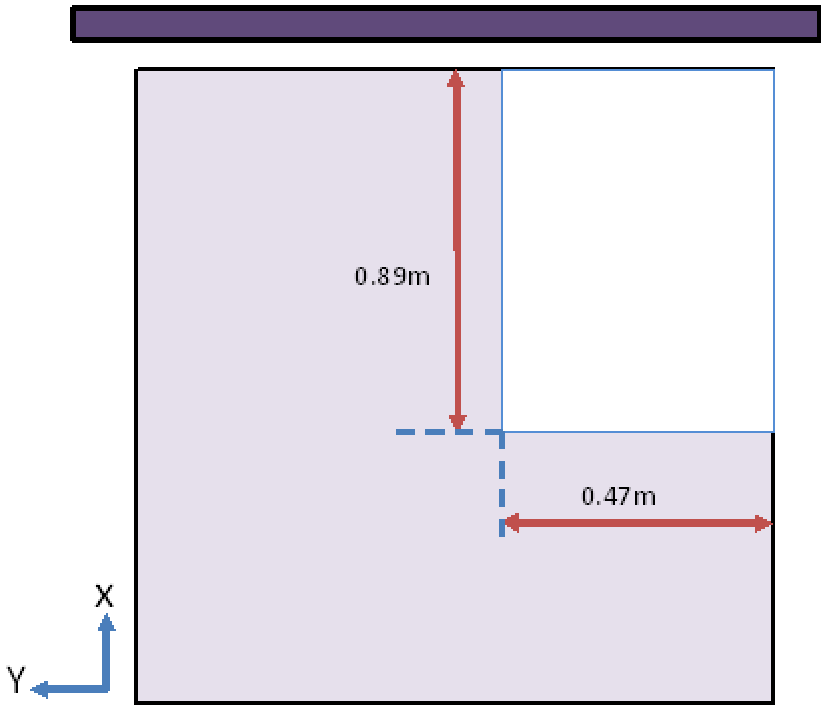
The regions to be considered as radiators are shown below. The optical properties to be considered can be found in Table 12.3-13. 18203

18204



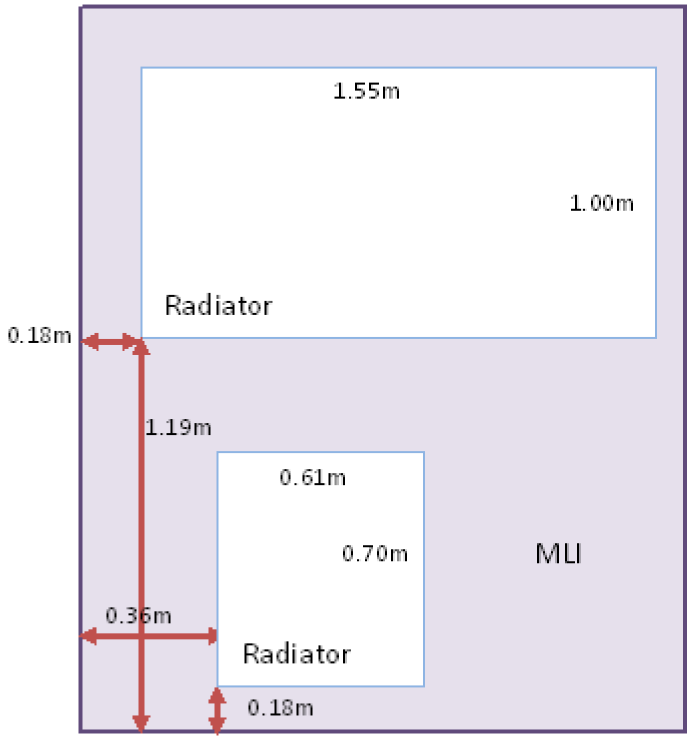
(not to scale) 18577

18819



(not to scale) 18821

Figure 12.3-4: Radiator Areas - MY wall and PZ wall (MZ wall is fully covered with MLI) 18205

 18579

(not to scale) 18580

Figure 12.3-5: Radiator Area - PY wall 18206

12.3.7.4 Modelling of the MLI External walls

The MLI on the spacecraft shall be modelled as a diffusion node coupled to a boundary node that represents the temperature of the spacecraft structure. The parameters necessary to achieve this are listed below : 18218

Assumptions :

GL = 0.019 W/m^2

GR = 0.014 m^2/m^2

Couple the MLI to a boundary node :

+50degC for hot case

-20degC for the cold case

To ensure robustness to the S/C MLI design, include a +/-50% uncertainty in the MLI coupling such that the most conservative MLI temparature is used in the analysis (as recommended by ECSS).

18637

The values to be used for the optical properties are shown in Table 12.3-13. 18638

7979

Surface	Region on surface	ε	α EOL	Finish
+Z External Wall	MLI	0.84	0.93	Diffuse
	Radiator	0.79	0.23	Specular
-Z External Wall	MLI	0.84	0.93	Diffuse
	Radiator	0.79	0.23	Specular

Surface	Region on surface	ε	α EOL	Finish
+Y External Wall	MLI	0.84	0.93	Diffuse
	Radiator	0.79	0.23	Specular
-Y External Wall	MLI	0.84	0.93	Diffuse
	Radiator	0.79	0.23	Specular
+X External Wall	MLI	0.05	0.14	Specular
-X External Wall	MLI	0.84	0.93	Diffuse
HGA	Coating	0.8	0.2 (B0L) 0.8 (EOL)	Diffuse
Heat Shield Panel Rear - overhang	Low Emissivity Finish	0.05	0.14	Specular
Heat Shield Panel Rear - centre	OSR	0.79	0.23	Diffuse
Solar Array Yoke	OSR	0.79	0.23	Specular
Solar array Panels	Cells/OSR	0.794	0.595	Specular
Instrument Boom	MLI	0.84	0.93	Diffuse

10424

Table 12.3-13: The optical properties of external surfaces.

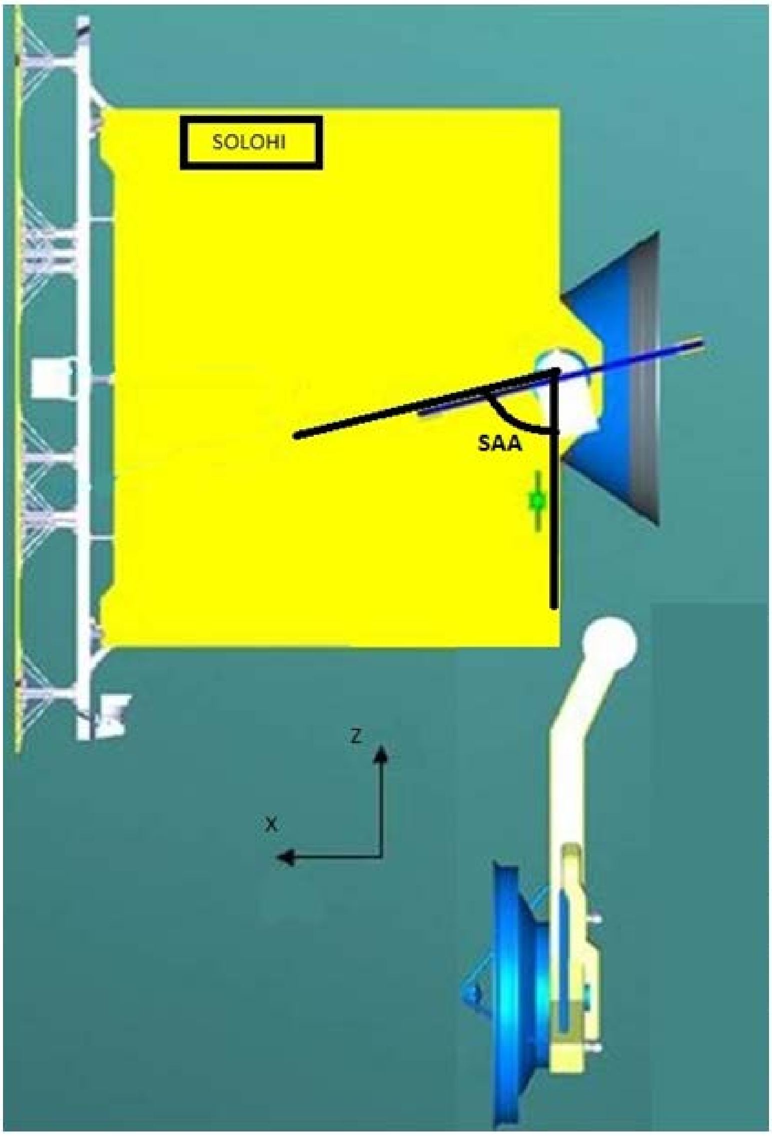
D: As radiator positions may change during the evolution of the spacecraft design, the optical properties chosen should provide a conservative environment for analysis. 8097

As the RPW-ANT is still evolving, black body optical properties are to be assumed. This will be updated as the design progresses. 8098

D: The underside of the heat shield support panel has two optical finishes, as indicated in the table above. 8099

D: The solar array (or aspect) angle varies with the distance between spacecraft and the sun. As such, the view factor from some externally mounted equipment to the solar array will vary. The steering law is indicated in the figure below (Figure 12.3-6) 8102

18940



Sun separation (AU)	Solar Aspect Angle (°)
0.28-0.44	75.5
0.44-0.53	75.0
0.53-0.80	62.0
0.80-1.05	50.0
1.05-1.20	35.0
1.20-1.45	20.0
1.45-1.50	0.0

(The angles shown are not the final angles and are only indicative) 18942

Figure 12.3-6: The Solar Array aspect angle variation with distance between the S/C and the Sun. 18941

12.4 A4 (intentionally blank)

D: Kept intentionally blank 8273

12.5 A5 Boom-mounted Instruments Harness Specifications Format

This annex provides the expected format for all the boom-mounted instruments harness technical specifications. Values here reported, are for information only at this stage and in case of conflict with the values specified in the respective EID-Bs and EICDs, the latter will take precedence. 8276

8277

Source	Signal	Connector no	Connector type	Destination	Connector no.	Connector type	No. of cores	Core gauge	Screened Y/N	Current direction	Maximum current for purpose of magnetic analysis
I-boom Interface bracket	MAGOBS sig 1	P003	Dsub15	MAGOBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	300mA
I-boom Interface bracket	MAGOBS sig 2	P003	Dsub15	MAGOBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 3	P003	Dsub15	MAGOBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 4	P003	Dsub15	MAGOBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 5	P003	Dsub15	MAGOBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 6	P003	Dsub15	MAGOBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 7	P003	Dsub15	MAGOBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 8	P004	Dsub15	MAGOBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	300mA
I-boom Interface bracket	MAGOBS sig 9	P004	Dsub15	MAGOBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 10	P004	Dsub15	MAGOBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 11	P004	Dsub15	MAGOBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 12	P004	Dsub15	MAGOBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 13	P004	Dsub15	MAGOBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 14	P004	Dsub15	MAGOBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 1	P005	Dsub15	MAGIBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	300mA
I-boom Interface bracket	MAGIBS sig 2	P005	Dsub15	MAGIBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 3	P005	Dsub15	MAGIBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 4	P005	Dsub15	MAGIBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 5	P005	Dsub15	MAGIBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 6	P005	Dsub15	MAGIBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 7	P005	Dsub15	MAGIBS I/F bkt	P001	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 8	P006	Dsub15	MAGIBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	300mA
I-boom Interface bracket	MAGIBS sig 9	P006	Dsub15	MAGIBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 10	P006	Dsub15	MAGIBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 11	P006	Dsub15	MAGIBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 12	P006	Dsub15	MAGIBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 13	P006	Dsub15	MAGIBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS sig 14	P006	Dsub15	MAGIBS I/F bkt	P002	Dsub15	2	26	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS sig 15	P009	Dsub9	MAGOBS I/F bkt	P003	Dsub9	3	26	Y	Core 2 to core 1	50mA
I-boom Interface bracket	MAGOBS sig 16	P009	Dsub9	MAGOBS I/F bkt	P003	Dsub9	3	26	Y	Core 1 to core 3	50mA
I-boom Interface bracket	MAGIBS sig 15	P010	Dsub9	MAGIBS I/F bkt	P003	Dsub9	3	26	Y	Core 2 to core 1	50mA
I-boom Interface bracket	MAGIBS sig 16	P010	Dsub9	MAGIBS I/F bkt	P003	Dsub9	3	26	Y	Core 1 to core 3	50mA
I-boom Interface bracket	MAGOBS Htr P	P101	Dsub25	MAGOBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom Interface bracket	MAGOBS Htr R	P102	Dsub25	MAGOBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom Interface bracket	MAGOBS Thm1	P103	Dsub37	MAGOBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS Thm2	P104	Dsub37	MAGOBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGOBS Thm3	P105	Dsub37	MAGOBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS Htr P	P101	Dsub25	MAGIBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom Interface bracket	MAGIBS Htr R	P102	Dsub25	MAGIBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom Interface bracket	MAGIBS Thm1	P103	Dsub37	MAGIBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS Thm2	P104	Dsub37	MAGIBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom Interface bracket	MAGIBS Thm3	P105	Dsub37	MAGIBS I/F bkt	FLD	FLD	2	28	Y	Core 1 to core 2	1mA

8278

Table 12.5-1: MAGOBS / MAGIBS Harness definition.

8279

Source	Signal	Connector no	Connector type	Destination	Connect or no.	Connector type	No. of cores	Core gauge	Screened Y/N	Current direction	Maximum current for purpose of magnetic analysis
I-boom interface bracket	RPW SCM sig 1	P007	Dsub25	RPW SCM	P001	Dsub25	2	28	Y	Core 1 to core 2	100mA
I-boom interface bracket	RPW SCM sig 2	P007	Dsub25	RPW SCM	P001	Dsub25	2	28	Y	Core 1 to core 2	100mA
I-boom interface bracket	RPW SCM sig 3	P007	Dsub25	RPW SCM	P001	Dsub25	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	RPW SCM sig 4	P007	Dsub25	RPW SCM	P001	Dsub25	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	RPW SCM sig 5	P007	Dsub25	RPW SCM	P001	Dsub25	4	28	Y	Core 2 to core 1	1mA
I-boom interface bracket	RPW SCM sig 6	P007	Dsub25	RPW SCM	P001	Dsub25	4	28	Y	Core 3 to core 1	1mA
I-boom interface bracket	RPW SCM sig 7	P007	Dsub25	RPW SCM	P001	Dsub25	4	28	Y	Core 4 to core 1	1mA
I-boom interface bracket	RPW SCM sig 8	P011	Dsub9	RPW SCM	P002	Dsub9	3	26	Y	Core 2 to core 1	50mA
I-boom interface bracket	RPW SCM sig 9	P011	Dsub9	RPW SCM	P002	Dsub9	3	26	Y	Core 1 to core 3	50mA
I-boom interface bracket	RPW SCM Htr P	P101	Dsub25	RPW SCM	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom interface bracket	RPW SCM Htr R	P102	Dsub25	RPW SCM	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom interface bracket	RPW SCM Thm1	P103	Dsub37	RPW SCM	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	RPW SCM Thm2	P104	Dsub37	RPW SCM	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	RPW SCM Thm3	P105	Dsub37	RPW SCM	FLD	FLD	2	28	Y	Core 1 to core 2	1mA

8280

Table 12.5-2: RPW-SCM Harness definition.

8283

Source	Signal	Connector no	Connector type	Destination	Connect or no.	Connector type	No. of cores	Core gauge	Screened Y/N	Current direction	Maximum current for purpose of magnetic analysis
I-boom interface bracket	SWA EAS 1 SpW 1	P007	MDM9	SWA EAS sensor 1	P001	MDM9	8	26	Y	Core 1 to core 2	10mA
I-boom interface bracket	SWA EAS 1 SpW 2	P007	MDM9	SWA EAS sensor 1	P001	MDM9	8	26	Y	Core 3 to core 4	10mA
I-boom interface bracket	SWA EAS 1 SpW 3	P007	MDM9	SWA EAS sensor 1	P001	MDM9	8	26	Y	Core 5 to core 6	10mA
I-boom interface bracket	SWA EAS 1 SpW 4	P007	MDM9	SWA EAS sensor 1	P001	MDM9	8	26	Y	Core 7 to core 8	10mA
I-boom interface bracket	SWA EAS 2 SpW 1	P008	MDM9	SWA EAS sensor 2	P001	MDM9	8	26	Y	Core 1 to core 2	10mA
I-boom interface bracket	SWA EAS 2 SpW 2	P008	MDM9	SWA EAS sensor 2	P001	MDM9	8	26	Y	Core 3 to core 4	10mA
I-boom interface bracket	SWA EAS 2 SpW 3	P008	MDM9	SWA EAS sensor 2	P001	MDM9	8	26	Y	Core 5 to core 6	10mA
I-boom interface bracket	SWA EAS 2 SpW 4	P008	MDM9	SWA EAS sensor 2	P001	MDM9	8	26	Y	Core 7 to core 8	10mA
I-boom interface bracket	SWA EAS 1 sig 1	P012	Dsub9	SWA EAS sensor 1	P002	Dsub9	2	22	Y	Core 1 to core 2	400mA
I-boom interface bracket	SWA EAS 1 sig 2	P012	Dsub9	SWA EAS sensor 1	P002	Dsub9	2	22	Y	Core 1 to core 2	400mA
I-boom interface bracket	SWA EAS 2 sig 1	P013	Dsub9	SWA EAS sensor 2	P002	Dsub9	2	22	Y	Core 1 to core 2	400mA
I-boom interface bracket	SWA EAS 2 sig 2	P013	Dsub9	SWA EAS sensor 2	P002	Dsub9	2	22	Y	Core 1 to core 2	400mA
I-boom interface bracket	SWA EAS 1 sig 3 (HV)	P014	MDM9	SWA EAS sensor 1	P003	MDM9	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	SWA EAS 2 sig 3 (HV)	P015	MDM9	SWA EAS sensor 2	P003	MDM9	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	SWA EAS 1 Htr P	P101	Dsub25	SWA EAS sensor 1	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom interface bracket	SWA EAS 1 Htr R	P102	Dsub25	SWA EAS sensor 1	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom interface bracket	SWA EAS 1 Thm1	P103	Dsub37	SWA EAS sensor 1	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	SWA EAS 1 Thm2	P104	Dsub37	SWA EAS sensor 1	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	SWA EAS 1 Thm3	P105	Dsub37	SWA EAS sensor 1	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	SWA EAS 2 Htr P	P101	Dsub25	SWA EAS sensor 2	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom interface bracket	SWA EAS 2 Htr R	P102	Dsub25	SWA EAS sensor 2	FLD	FLD	2	28	Y	Core 1 to core 2	300mA
I-boom interface bracket	SWA EAS 2 Thm1	P103	Dsub37	SWA EAS sensor 2	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	SWA EAS 2 Thm2	P104	Dsub37	SWA EAS sensor 2	FLD	FLD	2	28	Y	Core 1 to core 2	1mA
I-boom interface bracket	SWA EAS 2 Thm3	P105	Dsub37	SWA EAS sensor 2	FLD	FLD	2	28	Y	Core 1 to core 2	1mA

8284

Table 12.5-3: SWA-EAS Harness definition.

12.6 A6 Instrument CAD model check list

D: 8287

	File format and filename convention	**Status**
0	the delivered model is ITAR free	
1	File format: STEP file according to ISO 10303, AP 203 or AP214	
2	Every CAD model is accompanied by MICD drawing with corresponding name (see below)	
3	File name convention for STEP file: instrument_unit_ddmmyy_xxx.stp where ddmmyy is the date of creation and xxx an issue or identification number	
4	File name convention for MICD file: instrument_unit_ddmmyy_xxx.pdf where ddmmyy is the date of creation and xxx an issue or identification number	
5	CAD is modelled around URF (coordinates referred to URF): in other words the URF should be the origin in the CAD model	
6	Units are in SI-Metric (mm, etc.)	
	Contents	
7	For models having multiple components, all components are assembled in flight configuration.	
8	For instrument (components) having a launch/ stowed configuration and a flight/ deployed configuration, two models and MICDs should be generated.	
9	URF is explicitly indicated in CAD model & MICD Note: at any update, the MICD and the related CAD model should be delivered at the same time, with their URF consistently identified in both the MICD and the CAD model	
10	All external connectors are modelled (incl. EGSE/Test interface)	
11	All mounting holes/fixings are modelled (incl. MGSE/hoisting interfaces or OGSE interfaces)	
12	For each unit the bonding stud and the bonding strap is included in the model and MICD	
13	Where mirror cubes are required for alignment purposes, these are indicated in the CAD model and the MICD	
14	Thermal interfaces are modelled with indication of URP	
15	Purging interfaces are modelled	
16	External geometry is complete, including MLI	
17	If available the CoG should be indicated in the MICD	
	Any stayout-volumes around the instrument should be included. These can be defined for :	
18	connectors/harness connectivity	
19	volumes swept by mechanisms (if applicable)	
20	Volume swept during deployment (if applicable)	
21	tooling access to make alignment adjustements	
22	MGSE attachments, red-tag attachments	
23	other (please specify)	
24	Field-of-View (FoV) and Unobstructed Field-of-View (UFoV) requirements are unambiguously defined in the MICD drawing. Corresponding volumes or surfaces must be present as individually selectable items in the CAD model.	
25	Field-of-Regards is defined similarly to UFoVs. Field-of-Regards are volumes in which any protruding parts of the S/C must be controlled because of stray light issues for instance.	
26	Internally mounted remote sensing instruments have their volume envelope defined in both the MICD and the CAD model. The instrument is positioned within the volume envelope so that the desired distance to the heat-shield feed-through is obtained with the volume recessed by the agreed distance (instrument dependent).	

18380

Table 12.6-1: Instrument CAD model check list. 10431

12.7 A7 (intentionally blank)

D: Kept intentionally blank 8405

12.8 A8 (intentionally blank)

D: Kept intentionally blank 10427

12.9 A9 Instrument Hardware And Software Documentation Deliverable to ESA

12058

Documents Title	Schedule	Comments
Experiment Interface Document, part B (EID-B)	- consolidated draft at SC SRR - 1st formal issue at Instrument PDR - update at instrument CDR - final at instrument AR - update as revised	- MICD of each instrument unit, including the interconnecting harness, will be a self standing drawing, each of them referenced in the EID-B - The EID-B for the SWA, EPD, RPW, MAG will include the necessary electrical interface control information related to the harness for instrument units mounted on the boom
Detailed Budgets Report (mass, power, TM/TC)	-draft at Instrument PDR - final at Instrument CDR - update at each iteration	
Instrument Requirements Specification	- final at Instrument PDR - update at instrument CDR - update as revised	
Instrument Units Specifications	-draft at Instrument PDR - final at Instrument CDR - update at each iteration	
Test Specifications	- update 4 weeks prior to STM test campiagn starts - update 4 weeks prior to EM test campiagn starts - final 4 weeks prior to FM EM test campiagn starts - updates as revised.	
Instrument Engineering Plan (alias Instrument Design, Development & Verification Plan)	- final at Instrument PDR - update at instrument CDR - update as revised	- Including the qualification plan - Including life test plan fro mechanisms - Including Fligh SW development plan - Including BreadBoard and prototype development plan - Including the performance verification plan
Instrument Assembly, Integration and Test Plan	-draft at at instrument PDR - update 4 weeks prior to STM test campiagn starts - update 4 weeks prior to EM test campiagn starts - final 4 weeks prior to FM EM test campiagn starts - updates as revised.	- Including Fligh SW test plan - Including the performance test plan - Including calibration plan
Instrument Management	- final at Instrument PDR	

Documents Title	Schedule	Comments
Plan	- update at instrument CDR - update as revised	
EMC Control Plan	- final at instrument PDR - update at instrument CDR - update as revised	
Radiation Control Plan	- final at instrument PDR - update at instrument CDR - update as revised	
Cleanliness - Contamination Control Plan.	- final at instrument PDR - update at instrument CDR - update as revised	
Reduced Fracture Control Plan	- final at instrument PDR - update at instrument CDR - update as revised	-
Product Assurance Plan (PA Plan)	- final at instrument PDR - update at instrument CDR - update as revised	Incl. Quality Assurance Plan, Incl. Part Control Plan
Instrument Design Report	- draft at Instrument PDR - final at Instrument CDR - update as revised	- Including the description of the MGSE, EGSE, OGSE
Scientific Performance Report (SPR)	-draft at instrument PDR - update at instrument CDR - update as revised	Based on the instrument Science requirements and the Instrument Requirements Specification
BreadBoard and prototype development Report	-final at instrument PDR - update as revised	
Reliability Assessment Report	-draft at instrument PDR - final at instrument CDR - update as revised	
Thermal Analysis	-draft at Instrument PDR - final at Instrument CDR - update at Instrument AR - update as revised	
Progress Reports	- every month	
Structural Analysis Report : strength and stiffness	-draft at Instrument PDR - final at Instrument CDR - update at Instrument AR - update as revised	
Contamination Analysis Report	-draft at Instrument PDR - final at Instrument CDR - update at Instrument AR - update as revised	
Straylight Analysis Report	-draft at instrument PDR - final at instrument CDR - update as revised	Only for Optical Units
Reduced Fracture Control Report	- draft at at instrument CDR - final at instrument AR	-
Radiation Analysis & Report(s)	-draft at instrument PDR - final at instrument CDR - update as revised	
Mechanism(s) functional Analysis	-draft at instrument PDR - final at instrument CDR - update as revised	
Instrument User Manual	- 1st draft at at instrument CDR - 2nd draft at Instrument EM	- includes the Software User's Manual

Documents Title	Schedule	Comments
	delivery - final at instrument AR	- includes the GSE description and its User's Manuals - for those instruments which do not plan to deliver an EM, a first draft of the User Manual is still due at the specified EM delivery date - includes the instrument inputs to the "Flight Operations Plan" - includes the Flight SW user guide
Instrument / Unit Structural Mathematical Model (SMM) Instrument ReducedThermal - Geometrical Mathematical Model (RTMM-RGMM) CAD model Instrument Optical Model: namely : Optical Design file - Optical tolerance analysis	-draft at Instrument PDR - final at Instrument CDR - update at Instrument AR - update as revised	- Incl. SMM reports and description Incl. Thermal reports and description
Drawings and MICDs / Diagrams and Diagrams	-draft at Instrument PDR - final at Instrument CDR - update at Instrument AR - update as revised	Including: - Drawing Tree - Top-Level Assembly drawings(s) - Electrical diagrams / schematics as a minimum of relevant SC electrical interfaces
Instrument Master Schedule	- update every three months - update at Instrument PDR - update at instrument CDR - update at instrument AR	
Flight Software Requirement Document	-draft at Instrument PDR - final at Instrument CDR - update at each iteration	
Flight Software Architectural Design Document (On-Board ADD)	-draft at Instrument PDR - final at Instrument CDR - update at each iteration	
Flight Software Detailed Design Description (On-Board DDD)	-draft at Instrument PDR - final at Instrument CDR - update at Instrument AR - update at each iteration	
Instrument Flight SW Data Base (IDB)	- Draft at PDR - First formal delivery 6 months before EM: 1 feb 2014 - Last update : FM delivery : Jan 2015 **D:** Updates after the first formal delivery will be accommodated on the spacecraft ETB on a best effort basis.	
Instrument TM/TC ICD	- Draft at PDR	

Documents Title	Schedule	Comments
	- First formal delivery 6 months before EM: 1 feb 2014 - Last update : FM delivery : Jan 2015 **D:** Updates after the first formal delivery will be accommodated on the spacecraft ETB on a best effort basis.	
Configuration Item Data List (CIDL)	-draft at instrument PDR - final at instrument CDR - update at instrument AR - update as revised	
Critical Item List (CIL)	-draft at instrument PDR - final at instrument CDR - update at instrument AR - update as revised	CIL can be part of the FMEA document
Single Point Failure List (SPF)	-draft at instrument PDR - final at instrument CDR - update as revised	SPF can be part of the FMEA document
Fault Tree Analysis (FTA)	-draft at instrument PDR - final at instrument CDR - update as revised	FTA can be part of the FMEA document
Worst Case Circuit Analysis (WCA)	-draft at instrument PDR - final at instrument CDR - update as revised	
Part Stress Analysis and derating analysis (PSA)	-draft at instrument PDR - final at instrument CDR - update as revised	
Electronic, Electrical and Electromechanical Components List (EEE)	-draft at instrument PDR - final at instrument CDR - update as revised	- Including Long Lead Items List '- Project Approved Parts at Instrument PDR - As Designed Parts List at instrument CDR - As Built Parts List at instrument AR
Declared Material List (DML)	-draft at instrument PDR - final at instrument CDR - update at instrument AR - update as revised	
Declared Mechanical Parts List (DMPL)	-draft at instrument PDR - final at instrument CDR - update at instrument AR - update as revised	
Declared Process List (DPL)	-draft at instrument PDR - final at instrument CDR - update at instrument AR - update as revised	
Failure-Modes, Effects Analysis (FMEA)	-draft at instrument PDR - final at instrument CDR - update as revised	
Hardware Software Interaction Analysis (HSIA)	-draft at instrument PDR - final at instrument CDR - update as revised	As part of the FMECA document

Documents Title	Schedule	Comments
Failure Detection, Isolation & Recovery (FDIR)	-draft at instrument PDR - final at instrument CDR - update as revised	
Engineering Change Request (ECR)	- throughout the life cycle up to (P)FM delivery - first collected set at instrument PDR - second collected set at instrument CDR - final collected set at instrument AR	
Request for Waivers / Request for Deviations (RFW / RFD))	- throughout the life cycle up to (P)FM delivery - first collected set at instrument PDR - second collected set at instrument CDR - final collected set at instrument AR	
Non-Conformance Reports (NCR)	- throughout the life cycle up to (P)FM delivery - first collected set at instrument PDR - second collected set at instrument CDR - final collected set at instrument AR	
Logbooks	- at Instrument STM model delivery - at Instrument EM model delivery - at Instrument AR - at FS delivery, if necessary	
Key and Mandatory Inspection Points (KIP/MIP) reports	- at STM model delivery - at EM model delivery - at FM model delivery - at FS delivery, if necessary	
Instrument Operations Concept Document	-draft at instrument PDR - update at instrument CDR - update as revised	
Traceability & Verification Matrix	-draft at at instrument PDR - update 4 weeks prior to STM test campiagn starts - update 4 weeks prior to EM test campiagn starts - final 4 weeks prior to FM EM test campiagn starts - updates as revised.	The Compliance Matrix, called up in the EID-A, to the Instrument Baseline Requirement documents can be part of the Traceability and Verificatuion Matrix
Test Procedures	- update 4 weeks prior to STM test campiagn starts - update 4 weeks prior to EM test campiagn starts - final 4 weeks prior to FM EM test campaign starts - updates as revised.	Including Instrument Integration and Checkout procedures
Test and Verification Reports	10 working days after test completion	
Instrument and Ground	-draft at instrument CDR	

Documents Title	Schedule	Comments
Support Equipment Packaging, Storing, Transport and Handling Procedures	- final at instrument AR - update as revised	
Instrument Preliminary Design Review (PDR) Data Package	- 2 weeks before instrument PDR kick-off	
Instrument Critical Design Review (CDR) Data Package	- 4 weeks before instrument CDR kick-off	
Instrument Structural-Thermal Model (STM) Acceptance Data Package	- 4 weeks before instrument STM delivery	
Instrument Engineering Model (EM) Acceptance Data Package	- 4 weeks before instrument EM delivery	
Instrument Flight Model(FM) Acceptance Data Package	- 4 weeks before instrument AR kick-off	

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HW, SW, GSE		
Item	**Schedule**	**Comments**
Mechanical Ground Support Equipment (MGSE)	With relevant STM, or EM or FM model delivery	Accompanied with appropriate documentation and proof load and calibration certificates
Electrical Ground Support Equipment (EGSE)	With relevant STM, or EM or FM model delivery	
Special Ground Support Equipment (SGSE)*	With relevant STM, or EM or FM model delivery	*If needed
Structural and Thermal Model (STM)	By the delivery date specified in the EID-A	
Electrical Model (EM)	By the delivery date specified in the EID-A	
Flight Model (FM)	By the delivery date specified in the EID-A	
Flight Spares (FS)	By the delivery date specified in the EID-A	
On-Board Software	With relevant STM, or EM or FM model delivery	

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Table 12.9-1: Instrument hardware and software deliverables.

12.10 A10 Instrument End-Item Data Package Content

8686

Section	
1	Title Page
2	Table of Contents
3	Shipping Docs
4	Certificate of Conformance
	Hardware
	Cleanliness
5	Configuration Item Data List (CIDL)
6	Serielised Item List (SIL) (ABCL)
7	Historical record Sheets

Section	
8	Limited Life/Age Sensitive Item Records
9	Connector mating records
10	Problem Reports (PRs); -Problem Failure Reports (PFRs); Non Conformance Reports(NCRs)
11	List & copies of all Request for Waivers/Deviations (RFW/RFD)
12	Record of temporary removals and installations (e.g. Red Tag/Green Tag Items)
13	Packaging/Unpacking, Storing, Transport and Handling procedures
14	Record of open and deferred work or installations.
15	Installation Procedures
16	Drawings (as necessary to use the item, Can be part of user manual)
17	User's manual (including Flight Software User's Guide) (can be in one part for installation and one part for operation).
18	Qualification Status List with reference to applicable Qualification Reports and with identification of differences/modifications between the item used for qualification and the item being offered for acceptance.
19	Test procedures
20	Test Reports and Analyses (All including also contamination and calibration, inspections..)
21	Verification Matrix
22	Overall Test Flow Chart and copies of all Inspection and Test Reports
23	Calibration Data Record, Instrument Data Base
24	Residual Hazard Sheets with applicable safety procedures
25	Proof Load Certificate for Handling/Lifting Equipment, Safety Certificates for GSE
26	Software
27	Preship Review and Delivery Review Board : Minutes of Meetings
28	Pictures (can be part of user manual)
29	Declared marterial and process list (including PL)
30	Trending data reports (part of test reports and analysis)
31	Elec. Assembly Procedures (part of user manual)
32	Flight SW Project Rreference Database (PRD) Document
33	Document covering Scripts, TLM Pages, Equations
34	Special Tools List
35	Loose Items List
36	Residual Risk List
37	Lower level EIDP

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Table 12.10-1: End item data package content.

12.11 A11 STM End Item Data Package Content (TBC)

11130

Section #	Section Title	Applicability to STM End-Item Data Package	Comment
1	Title Page	Yes	-
2	Table of Contents	Yes	-
3	Shipping List	Yes	Including also list of "loose items" and "special tools", if applicable
4	Certificate of Conformance 4a: Hardware 4b: Cleanliness	Yes	-
5	Configuration Item Data List (CIDL)	No	-
6	As Built Coonfiguration List (ABCL)	Yes	-

Section #	Section Title	Applicability to STM End-Item Data Package	Comment
7	Historical record Sheets	No	-
8	Limited Life/Age Sensitive Item Records	No	None expected for STM Units
9	Connector mating records	No	-
10	Problem Reports (PRs); Problem Failure Reports (PFRs); Non Conformance Reports(NCRs)	Yes	1- Only those related to STM 2- Copies for all MAYOR NCRs, PRs and PFRs (PRs and PFRs are NASA jargon) 3- Only list of Minor NCRs, PRs and PFRs
11	List & copies of all Request for Waivers/Deviations (RFW/RFD)	Yes	Only those related to STM
12	Record of temporary removals and installations (e.g. Red Tag/Green Tag Items)	Yes	Only if temporary installations are applicable to STM units
13	Packaging/Unpacking, Storing, Transport and Handling procedures	Yes	-
14	Record of open and deferred work or installations.	Yes	Only if open or deferred work is applicable to STM units
15	Integration guidelines of STM units on S/C	Yes	Only if specific limitations or instructions are to be followed for the STM units integration onto the S/C
16	Drawings, Diagrams & Pin functions 16a Mechanical Interface Control Drawings 16b Electrical Diagrams for heaters , temperature sensors, etc 16c Connectors Pin Function	Yes	1- Self-standing MICD for each delivered unit 2- Electrical drawins showing as a minimum, heaters & thermistors characteristics and location, wiring schemes 3- Pin function for all connectors
17	User Manual	No	-
18	Qualification Status List	No	-
19	Test procedures	Yes	Procedures can be part of the test reports (e. g.Vibration test procedure / test report)
20	Reports and Analyses 20a Test Reports 20b Inspection Reports 20c Correlation Analysis: Vibration results vs FEM predictions 20dxx Correlation Analysis: TB test results vs TMM predictions	Yes	-
21	Verification & Compliance Matrix	Yes	1- Only those EID-A requirements related to STM
22	Test Plan, Including overall Tests Flow Diagram	Yes	-

Section #	Section Title	Applicability to STM End-Item Data Package	Comment
23	Calibration Data Record, Instrument Data Base	No	-
24	Residual Hazard Sheets with applicable safety procedures	Yes	In general not expected for STM units; Possible exception are for example the Berillium Window for STIX
25	Proof Load Certificate for Handling/Lifting Equipment, Safety Certificates for GSE	Yes	-
26	Software	No	-
27	Preship Review and Delivery Review Board : Minutes of Meetings	Yes	-
28	Pictures of STM units	Yes	-
29	Declared marterials, parts and processes list	Yes	-
30	Trending data reports (part of test reports and analysis)	No	-
31	Electrical Assembly Procedures	No	-
32	Flight SW Project Rreference Database (PRD) Document	No	-
33	Document covering Scripts, TLM Pages, Equations	No	-
34	Special Tool List	No	To be included in the Shipping List (chapter 3)
35	Loose Items List	No	To be included in the Shipping List (chapter 3)
36	Residual Risk List	No	-
37	Lower level EIDP	No	-

12.12 A12 Recommended bake out procedure

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1 Vacuum Thermal Bakeout Procedure

The Vacuum Thermal Bakeout shall be controlled by a dedicated procedural specification which shall be submitted to ESA and Prime and approved by ESA and Prime before use.

The bakeout conditions (temperature, time, pressure) shall be selected such that there shall be no detrimental effect on the functionality of the material or item being baked out.

The bakeout temperature shall be selected using the following criteria:

- Maximum survivable temperature (without degradation) of the limiting material within the item / equipment / sub-system
- Maximum temperature on mission (whether in the operational or non-operational mode) - i.e.; the qualification temperature of the item / equipment / sub-system

As a general principle, the maximum temperature possible (subject to the limits above) shall be used for bakeout because this reduces the bakeout time.

C - It is usually more efficient & practical to perform vacuum thermal bakeout at the lowest possible product level because this usually permits the use of a higher bakeout temperature.

2) Thermal Vacuum Chamber - Setup and Certification (System)

The vacuum chamber shall be cleaned and certified prior to performing a vacuum thermal bake-out of Flight hardware or GSE.

A Test Readiness Review shall be convened prior to commencement of vacuum thermal chamber bakeout certification events. ESA and Prime shall be notified of the date and venue of the TRR at least 2 weeks prior to this event. ESA and Prime reserve the right to attend and participate in the TRR and subsequent TRB.

Chamber bakeout logbooks shall be kept for every chamber to help maintain visibility of prior bakeout items, and the test director shall determine whether the chamber and associated GSE had been left in a suitably clean condition. The level of cleanliness shall be based upon the materials used and TQCM frequencies observed during the previous thermal vacuum bake-out. The chamber shall be cleaned and certified following 'dirty' bake-outs (typically those having large amounts of polymeric material). The Cryopanel shall also have been solvent cleaned after the last use. The procedure for chamber system bake-out and certification shall be approved by ESA and Prime:

3) Scheduling of Certification Process

The system certification shall be conducted immediately prior to the hardware vacuum thermal bake-out, and the results of the certification shall form the first part of the hardware bake-out TRR. Any other use or operation of the system prior to hardware bake-out shall nullify the certification for the system; and in this eventuality recertification shall be performed.

4) Configuration during Certification

The vacuum chamber shall be configured for system certification in the manner it will be configured for hardware vacuum thermal bakeout. This implies that all GSE to be used for the Flight hardware bakeout shall be in place, including the Thermoelectric Quartz Crystal Microbalances (TQCM). All other support hardware required for the subsequent hardware vacuum thermal bake-out shall be included in the system certification exercise (e.g.; heating lamps, instrumentation, wiring/cables, etc.)

5) Thermal Vacuum Chamber Requirements

The vacuum chamber shall incorporate (by design) at least one “cryopanel” (Liquid Nitrogen cooled plate (“scavenger plate” or “cold trap”) to collect and trap the majority of outgassed components evolved during the bake-out (a proportion will be removed via the pumps).

The chamber shall be capable of achieving 10^{-5} Torr vacuum or better (1.333224e-6 kPa), but 10^{-6} Torr vacuum minimum is recommended.

It is recommended that the re-pressurisation lines be fitted with an ISO Class 5 (or better) HEPA filter. The re-pressurisation rate shall be low enough to ensure there is minimum risk of turbulence within the chamber resulting in particulate movement and re-distribution onto the hardware.

The maximum re-pressurisation rate shall be < 20mbar/min.

The preferred pumping methods are (in order of preference):

- Helium Cryopump
- Turbomolecular Pump.

NOTE: The following methods are **not** recommended:

- Ion Pump (generates a magnetic field)
- Oil Diffusion Pump (back-streaming of oil vapour)

6) Monitoring Apparatus

The required monitoring apparatus includes all devices used for measurement and recording of:

- chamber pressure
- temperature (shrouds, hardware, TQCMs, cryo-panel)
- frequency outputs of TQCMs

7) TQCMs (Thermoelectric Quartz Crystal Microbalances)

TQCMs are temperature-controlled quartz crystal microbalances which sense mass deposition via a change in resonance frequency from a matched set of quartz crystals (or other piezolectric devices).

The minimum sensitivity level required for these items in this application is 1.56 $ng.cm^{-2}.Hz^{-1}$. To achieve this sensitivity and long-term stability thermally matched 15 MHz crystals are required.

Precision temperature control shall be achieved using a Peltier (thermo-electric) cooler and a monitoring thermistor built into the sensor head for active temperature control. The whole sensor head shall be mounted on a temperature-controlled heat-sink. This combination provides for both the required sensitivity and long term stability for mass deposition rate monitoring.

At least one such device shall be used to monitor the bake-out (both for system certification and for flight hardware). It is recommended that three be used to obtain reliable integrated accumulation values (the accumulation rates can vary depending on the viewing conditions for each TQCM).

The TQCMs shall be mounted within the chamber such that each TQCM has a representative view of the flight hardware or is monitoring the hardware vent(s).

Note: Whenever the TQCM rate exceeds a specified frequency the crystal needs to be heated while at high vacuum to drive contaminants from the crystal. The frequency at which the TQCM is decontaminated is dependant on the TQCM type and this frequency shall be specified in the bake-out procedure. This can be done during the chamber certification, or as a separate activity. The manufacturer requirements for maximum temperature difference between the TQCM Crystal and TQCM heat-sink (typically 60°C) shall be observed during this activity and all TQCM operations.

8) Thermocouples

The unit controlling thermocouples shall be attached to that part of the item being monitored which is considered to have the greatest “thermal lag” (in the case of system certification, assume the largest item of GSE). A minimum of 3 thermocouples shall be assumed to be required for Flight hardware monitoring.

If other (optional) hardware monitoring thermocouples are to be used, these shall be included in the system certification bake-out.

9) Witness Samples

A minimum of one PFOmonitoring witness plate shall be installed in the chamber. This shall be sited at the lowest point possible immediately adjacent to the hardware (in the case of system verification, the GSE). A URAMEC PFO meter slide is the recommended method.

A minimum of one MOC witness sample shall be installed adjacent to the hardware; however the vertical placement for this sample is not critical. The recommended method is the stainless steel polished plate option (indirect method) per ECSS-Q-ST-70-05C.

The FTIR window method (direct method) is not considered suitable due to anticipated low values during Thermal Vacuum system certification, which would be below the measurement sensitivity for this method (see acceptance requirements, second bullet; below):

The MOC sample shall be handled and evaluated in accordance with AD-25.

The acceptance criteria for the witness samples are:

- PFO sample: 275 ppm/24 hours
- MOC sample: 30 ng/cm^2/24 hours*

10) Flight Hardware Vacuum Thermal Bake-Out

A Test Readiness Review shall be convened prior to commencement of Flight hardware vacuum thermal bakeout. ESA and Prime shall be notified of the date and venue of the TRR at least two weeks prior to this event. ESA and Prime reserve the right to attend and participate in the TRR and subsequent TRB. The purpose of the TRR is to ensure all facilities are appropriate and available, and that all the process procedures are understood and agreed.

In addition, authorisation for introducing the Flight hardware into the vacuum chamber is required from the previous thermal vacuum chamber system certification TRB.

Go-ahead for the bakeout procedure can only be authorised by the Flight hardware bake-out TRR.

The detailed procedure for performing the vacuum thermal bakeout of Flight hardware shall have been previously supplied to ESA and Prime at least 3 months before the anticipated event. ESA and prime shall approve this procedure before the vacuum thermal bakeout is scheduled.

The chamber requirements and monitoring requirements shall, as a minimum, be as for the chamber certification.

The vacuum thermal bake-out shall be monitored in real-time by means of TQCM's until the outgassing rate reaches a significantly reduced and almost steady state, ie. until the rate of change as measured by the QCM has reduced to between 0% and 5% per hour when measured over a period of not less than 3 hours

Once achieved, the unit will be brought to operational temperature and, once stabilised, the outgassing rate shall continue to be monitored by the TQCMs for a period of 24 hours and the TQCM output recorded (NOTE; this data will be used to generate dynamic outgassing input to the in-Flight contamination modelling tool).

11) Back-Filling of Thermal Vacuum Chamber (Re-pressurisation)

For protection of sensitive instruments, re-pressurisation of the chamber shall be by dry nitrogen gas of 99.999% purity through a 0.2 micron particulate filter. Ambient air shall not be used for thermal vacuum chamber re-pressurisation in these circumstances. Other instrument-specific purge gas purity levels as per the EID-Bs also apply for the instruments. The cryopanel shall be maintained during chamber re-pressurisation until the chamber pressure is greater than 10^{-3} Torr (0.133 Pa) to minimise the risk of contaminant return flux from the cryopanel to the Flight hardware during re-pressurisation.

12.13 A13 Discrete Electrical Interfaces

Instrument	Unit	PCDU								RIU											SSMM		Break-out panel
		LCL n		SH		DH		actuator		HPC		RSA		thermistors							SpW		HV enable/disable
		P	R	P	R	P	R	P	R	P	R	P	R	URP	SRP	Surv	Decon	HE	ME	CE	P	R	
PHI	OU			2	2										1			5		3			
PHI	EB	1	1	1	1					2	2	1	1	3							1	1	
SPICE	OU			2	2	1	1							1						3			
SPICE	EB	1	1	1	1					2	2	1	1	3							1	1	1
EUI	OU			3	3	1	1							2				1	2	2			
EUI	EB	1	1	1	1					2	2	1	1	2							1	1	
METIS	OU			3	3	1	1								1			3	3	3			
METIS	EB	1	1	1	1					2	2	1	1	3							1	1	
STIX	OU			1	1										1								
STIX	EB	1	1	1	1					2	2	1	1	3						3	1	1	
SOLOHI	SIM + SCE	1	1	1	1			1	1	2	2	1	1		1	6					1	1	
EPD	EB	1	1	1	1					2	2	1	1	3							1	1	
EPD	HET-EPT 1			1	1										1	3							
EPD	HET-EPT 2			1	1										1	3							
EPD	STEP			1	1										1	3							
EPD	SIS			1	1										1	3							1
SWA	EB	1	1							2	2	1	1	3							1	1	
SWA	EAS			1	1										1	4							1
SWA	PAS			1	1										1	3							1
SWA	HIS			1	1										1	3							1
RPW	EB	1	1	1	1					2	2	1	1	3							1	1	
RPW	ANT 1			2	2			3	3	2	2	2	2			3							
RPW	ANT 2			2	2			3	3	2	2	2	2			3							
RPW	ANT 3			2	2			3	3	2	2	2	2			3							
RPW	SCM			1	1										1	3							
MAG	EB	1	1	1	1					2	2	1	1	3							1	1	
MAG	IBS			1	1											3							
MAG	OBS			1	1											3							
SUM		10	10	36	36	3	3	10	10	26	26	16	16	29	12	46	0	9	5	14	10	10	5
																	115						
ALLOCATION		10	10	13	13	1	1	18(*)	18(*)	20	20	25	25	27	22	**55**	**5**				10	10	
																	109						
Thermal ICD														27	21	49	0						
																	97						

LCL n — Power line of LCL class n
SH — Survival Heater
DH — Decontamination Heater Line
actuator — frangibolt, shaped memory alloy heater, pin-puller, or anything else with specific arm-fire driver
HPC — High Power Command
RSA — Relay Switch Acquisition
SpW — SpaceWire

(*) — PCDU option

NOTE : RPW ANT interfaces are due for change (next EID-A update (Iss 6))

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Table 12.13-1: Discrete electrical interfaces.

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12.14 A14 EM EIDP Content 13371

The following table contains a list of the documentation to be delivered as part of the EM EIDP 13372

Solar Orbiter EM deliveries

	EM Instrument End-Item Data Package Content		
Section #	Section Title	Applicability to EM	Comment
1	Title Page	Yes	-
2	Table of Contents	Yes	-
3	Shipping List	Yes	Including also list of "loose items" and "special tools", if applicable.
4	Certificate of Conformance 4a: Hardware 4b: Cleanliness	Yes	Reminder: EGSE is required to be CE marked.
5	Configuration Item Data List (CIDL)	Yes	-
6	As Built Coonfiguration List (ABCL)	Yes	-
7	Historical record Sheets	Yes	Log book expected (for ASU to add to)
8	Limited Life/Age Sensitive Item Records	No	-
9	Connector mating records	Yes	Preferably as part of the logbook
10	Problem Reports (PRs); Problem Failure Reports (PFRs); Non Conformance Reports(NCRs)	Yes	
11	List & copies of all Request for Waivers/Deviations (RFW/RFD)	Yes	Only those related to EM
12	Record of temporary removals and installations (e.g. Red Tag/Green Tag Items)	Yes	Only if temporary installations are applicable to EM units
13	Packaging/Unpacking, Storing, Transport and Handling procedures	Yes	-
14	Record of open and deferred work or installations.	Yes	Only if open or deferred work is applicable to EM units
15	Integration guidelines of EM units onto ETB	Yes	
16	Drawings, Diagrams & Pin functions 16a Mechanical Interface Control Drawings 16b Electrical Diagrams for heaters , temperature sensors, etc 16c Connectors Pin Function	Yes	1- Self-standing MICD for each delivered unit 2- Electrical drawins showing as a minimum, heaters & thermistors characteristics and location, wiring schemes 3- Pin function for all connectors.
17	User Manual (including TM/TC ICD)	Yes	Scope can be reduced based on actual use of EM. Only Chapter 4 (in particular 4.1 and 4.5) of the SOL-EST-RS-4095 SoLO Instrument User Manual DRD.
18	Qualification Status List	No	
19	Test procedures	Yes	Limited to electrical and functional.
20	Reports and Analyses 20a Test Reports 20b Inspection Reports 20c Correlation Analysis: Vibration results vs FEM predictions 20dxx Correlation Analysis: TB test results vs TMM predictions.	Yes	Limited to electrical and functional.
21	Verification & Compliance Matrix	Yes	Only those EID-A requirements related to EM
22	Test Plan, Including overall Tests Flow Diagram	Yes	-
23	Calibration Data Record	Yes	Depending on the activities performed on the EM (it may not be necessary).
24	Residual Hazard Sheets with applicable safety procedures	Yes	Required if any hazards exist, otherwise a statement in the handling doc saying 'no hazards'.
25	Proof Load Certificate for Handling/Lifting Equipment, Safety Certificates for GSE	Yes	if applicable, in particular for the safety certification
26	Software	Yes	-
27	Preship Review and Delivery Review Board : Minutes of Meetings	Yes	-
28	Pictures of EM units	Yes	-
29	Declared marterials, parts and processes list	Yes	-
30	Trending data reports (part of test reports and analysis)	No	-
31	Electrical Assembly Procedures	No	-
32	Flight SW Instrument database (IDB)	Yes	-
33	Document covering Scripts, TLM Pages, Equations	No	It may be part of User Manual
34	Special Tool List	Yes	if applicable, can be in the handling document and shipping list docs
35	Loose Items List	No	To be included in the Shipping List (chapter 3)
36	Residual Risk List	No	-
37	Lower level EIDP	No	-

Table 12.14-1: Content for EM EID-Ps. 17699

DOCUMENT CHANGE DETAILS

ISSUE	CHANGE AUTHORITY	CLASS	RELEVANT INFORMATION/INSTRUCTIONS
3	SOL.S.ASTR.ECO.00054	0	First Issue from Astrium PDR Actions: PDR-MSA-12-1 PDR-MSA-18-1 PDR-AOS-77-1
4	SOL.S.ASTR.CN.00099 IN RESPONSE TO CR19 SOL.S.ASTR.CN.00131 IN RESPONSE TO CR28 SOL.S.ASTR.CN.00132 IN RESPONSE TO CR36 SOL.S.ASTR.CN.00165 IN RESPONSE TO CR45		
5	SOL.S.ASTR.CN.00372 IN RESPONSE TO CR74		

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