DOCUMENT

EChO
Experiment Interface Document EID-A

Prepared by	**ECHO Study Team**
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1 GENERAL

This chapter provides a short introduction to EChO – Exoplanet Characterisation Observatory, describes the 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.

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

1.1 Introduction

The Exoplanet Characterisation Observatory (hereafter referred to as EChO) is a mission candidate in the framework of the Cosmic Vision 2015-2025 programme of the Science and Robotic Exploration Directorate of the European Space Agency. The mission is one of several candidates for the third medium class mission launch opportunity in the Cosmic Vision programme.

1.2 Schedule

The planning for the phase A is indicated hereafter.

- *Release of AO: 21 Sep 2012*
- *Kick-off of industrial extension: Feb 2013*
- *Instruments selection: Feb 2013*
- *Instruments study activities: Feb-Sep 2013*
- *Final Presentation of industrial studies: July 2013*
- *Preliminary Requirements Review (ESA): Sep-Oct 2013*
- *Final version of 'yellow book': Oct 2013*
- *M3 selection by end 2013.*

1.3 Scope of the Experiment Interface Documents

The main purpose of the set of Experiment Interface Documents (one EID-A, and one EID-B) is to ensure that:

- The Principal Investigators (PIs) design, procure, build, qualify, test and calibrate their instrument in line with the technical and programmatic requirements and constraints defined in the EID-A. In the context of this EID-A, the PI should be understood as Principle Investigator/ Lead Funding Agency in line with the final management structure, which is currently tbd.
- The EChO Prime Contractor designs, builds and verifies the spacecraft such that the instrument can be successfully integrated and tested into the system, in line with the instrument interface definitions and resources provided in the EID-B.

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

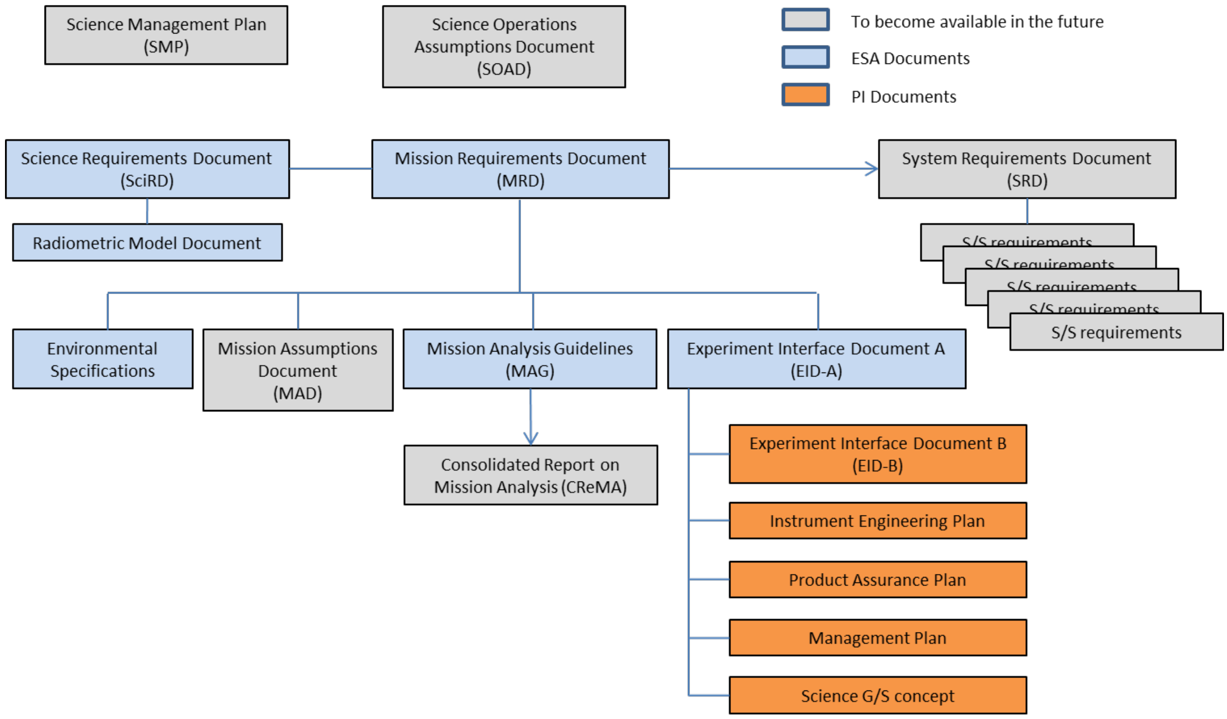

Figure 1: Top ESA Documents Tree

Each EID-B, in response to the instrument technical requirements of the EID-A, specifies in detail the instrument interface information. The EID-B is the formal interface control document between each instrument and the spacecraft.

Finally each EID-B defines the specific programmatic agreements between the ESA EChO Project Office and each EChO Principal Investigator.

> **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 documentation tree for the top ESA requirements is shown in Figure 1**

1.4 Conventions

All requirements in this document are written in *italic* and are identified by a unique identifier with the following format **EIDA-R XXXX.**

Some requirements refer to a table or a figure. This table or figure is to be considered as part of the requirements.

Additional statements are given with an identifier following the format **EIDA-S XXXX.** These statements reflect requirements applicable to the Prime contractor (via the SRD) and are given as information to the PI.

2 KEY PERSONNEL AND POINTS OF CONTACT

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Table 1 Key personnel

During the definition phase, the ESA study team will take over the role of the ESA project team as described in this EID-A.

3 SPACECRAFT DESCRIPTION

3.1 Mission Objectives

The primary objective of the EChO mission is to study the physics and chemistry of the atmospheres of a representative sample of known exoplanetary systems found around nearby stars. The differential technique of transit spectroscopy will be used over the optical to thermal IR wavebands (~0.4 – 16 micron) to determine the physical and chemical conditions of the atmospheres of a sample ~ 100 known exoplanets, with masses ranging from Jupiter-like to a ~few Earths, and equilibrium temperatures of 2000- to 300 K. Through detailed measurement of the spectral energy distribution and spectral features of exoplanetary atmospheres, it will be possible to establish the:

(a) chemical composition
(b) energy budget
(c) chemical abundances
(d) thermal structure
(e) optical albedo
(f) spatial and temporal variability of the atmospheric structure
(g) in the most favourable cases, determine all of the above, as a function of orbital phase

in a statistically significant sample of exoplanets, including those closest in mass and temperature to our own Earth. By considering these goals across the sample as a whole, we will be able to start to determine the mechanisms driving the formation of exoplanets, including the role of the host star. For the most favourable sources, the cadence of sampling should allow accurate recovery of the shape of the ingress and egress, which in turn will requires of order of 10 measurements across ingress/egress.

3.2 OBSERVATIONAL STRATEGY

Variations in the measured signal from spatially unresolved observations of an exoplanet at different points in its orbit around its host star will be used to determine the spectrum of the planetary atmosphere (see Figure below).

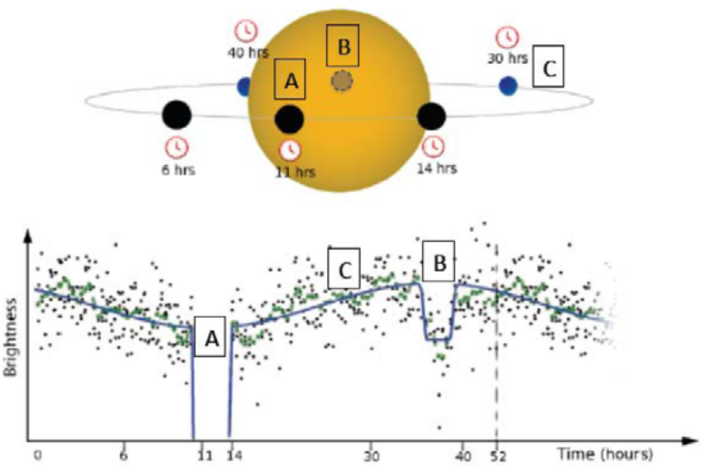


Figure 1: A schematic cartoon illustrating the orbit of an exoplanet around its host star and the resulting light curve measured from the combined star-exoplanet as a function of time, based on observations by Borucki et al (Science 2009, 325, 709) of HAT-P-7b with Kepler. Event **A** is referred to as a primary transit; **B** as occultation or a secondary eclipse and **C** as the orbital phase.

Figure 2 Orbit of an exoplanet around its host star and resulting light curve

The signal from both the star and exoplanet are collected simultaneously. The signal from the exoplanet – a very small fraction of the total – can be isolated by differencing observations made at various points of the exoplanet's orbit. Each of the three sets of observations detailed below enable different characteristics of the exoplanetary atmosphere to be probed.

- *Secondary eclipse/occultation spectroscopy*

During a secondary eclipse, or occultation, a planet moves behind its host star (Figure 2, event B). The planet is temporarily blocked from view, and the observed signal is that from the star alone. On either side of occultation the observed signal is the combination of stellar light, light reflected by the planet and a component due to emission from the planet itself.

- *Transmission spectroscopy – primary transits*

During a primary transit an exoplanet passes in front of its host star (Figure 2, event A). Stellar light passes through the limb of the planetary atmosphere as the planet transits. Part of the stellar light is absorbed: light passing through the planetary atmosphere bears absorption features that are characteristic of the constituents of the atmosphere.

- *Phase variation*

The fraction of the exoplanet illuminated by its host star, and so visible to the observer, changes with orbital phase: from a maximum at secondary eclipse to a minimum at primary transit. Varying fractions of the day- and night-side of the planet are visible during periods between.

3.3 System description

The EChO spacecraft consists of two main modules:

- the EChO PayLoad Module (EPLM) which includes the telescope, the instrument and the passive cooling (V-grooves + radiator) down to 50K
- the EChO SerVice Module (ESVM) which comprise all the conventional spacecraft subsystems, the sun shield (tbc) and the solar arrays.

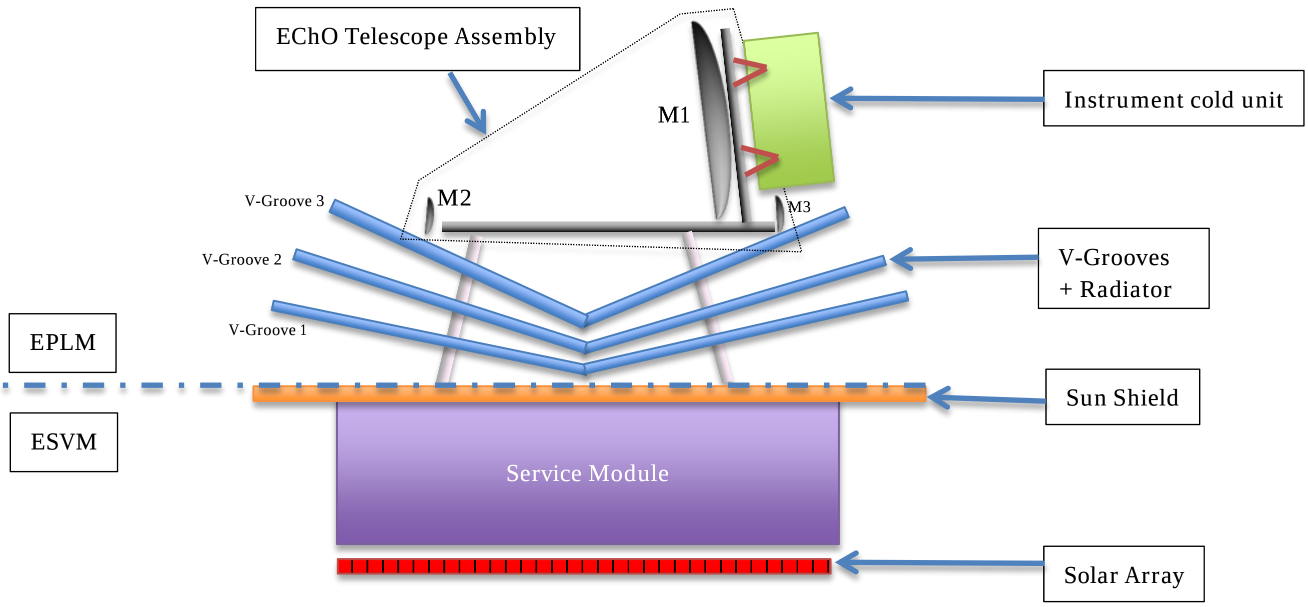


Figure 3 EChO System schematics

The mission baseline is for EChO to be launched by a SOYOUZ ST 2-1B from French Guyana Space Centre before end of 2024.
The EChO spacecraft will be placed into an orbit around L2. The EChO nominal in-orbit operation phase that includes commissioning and scientific operation is 5 years.

3.4 Reference Payload complement

The EChO reference payload complement consists of:

- The EChO Telescope Assembly (ECTA) including the reflective Off axis afocal Korsch telescope, which uses 3 mirrors M1, M2 and M3 plus flat folding mirrors to redirect the beam to the instrument compartment.

- The common optics, which include:
  - a 1st dichroïc mirror separating the wavelengths above and under the long wavelength cut of the visible science channel (0.8-1 µm tbc)(later referred to as DM Vis)
  - a 1st Beam Splitter dividing the visible light into 2 optical paths for the science visible channel and the FGS.
- The instrument: Science instrument, split into several channels
- The Fine Guidance Sensor (FGS), being part of the AOCS system

It is assumed, that the common optics, the Fine Guidance Sensor and the instrument are mounted on a single Instrument Optical Bench, which will be integrated behind the primary mirror M1.

While the extent of the wavelength range of the science instrument is a requirement (0.55µm to 11µm required and 0.4µm to 16µm as a goal) , the cut-offs between each successive channel are design dependent and hence subject to evolution. Each channel is isolated using dichroïc mirrors, while the FGS is separated from the 1st science channel thanks to a beam splitter.

On top of these payload elements, some payload support equipment is also necessary. Of critical importance is the cryogenic chain necessary:

- To sufficiently cool the telescope and the instrument box(es) for thermal background reduction. This is assumed to be achievable by passive means (or with a negligible amount of extra cooling power required by the active cryo-coolers.
- To sufficiently cool the detectors for dark current reduction. This is assumed to be achieved by a combination of passive/active cryo-cooling means.

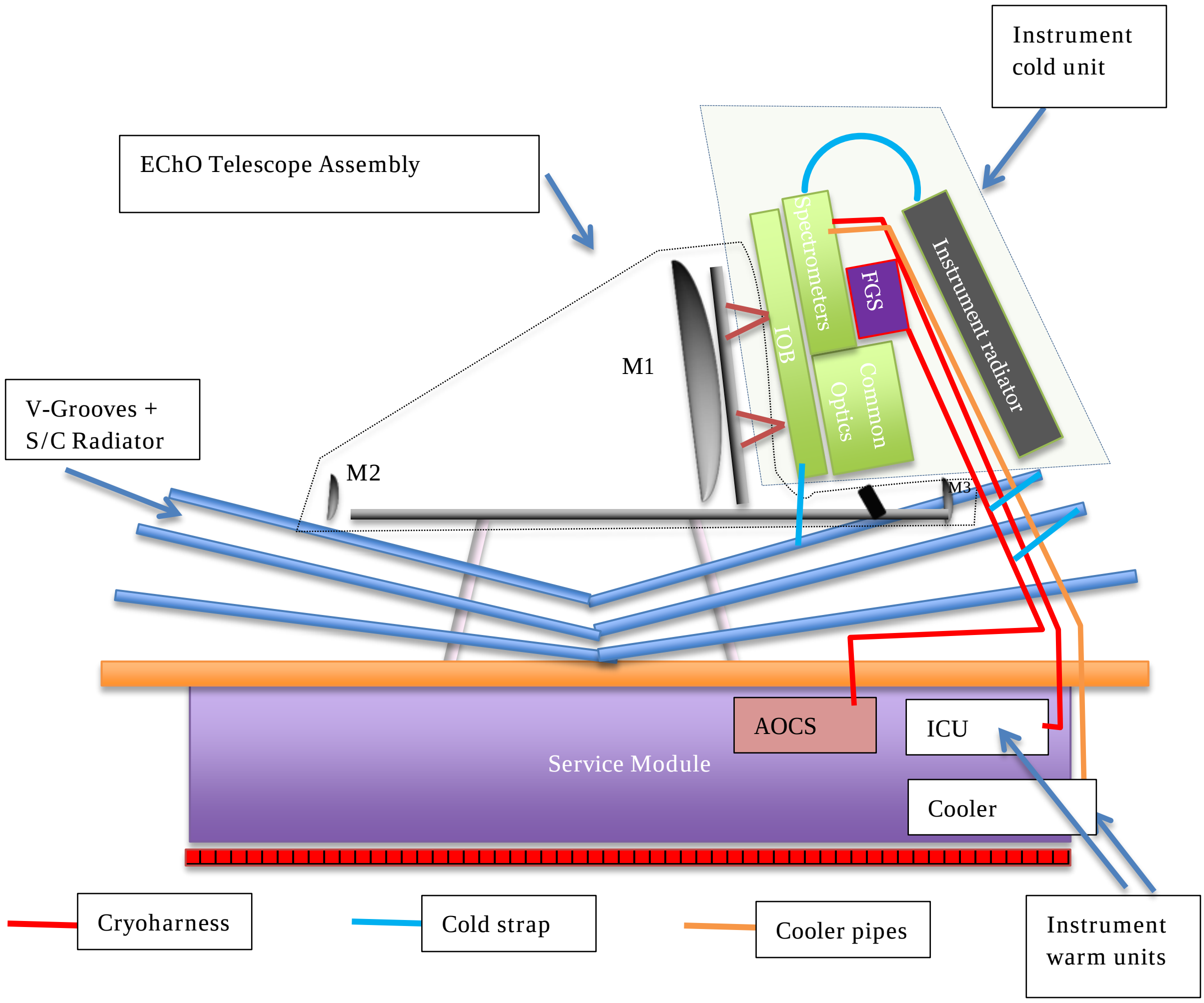


Figure 4 EChO Reference Payload complement

3.4.1 *EChO Telescope Assembly*

The EChO Telescope Assembly (ECTA) shall include:

- primary Mirror M1
- secondary mirror M2
- tertiary mirror M3
- Telescope Mounting Structure (TMS), including a Telescope Optical Bench (TOB) to mount the primary Mirror serving as:
    - An interface to the SVM.
    - A structural support on which to mount the telescope.
    - A structural support from which to mount the IOB.
    - Support structure for M1, M2 and M3
- If required, any mechanism on M2 (e.g. refocusing mechanism)
- Any flat fold mirrors (with eventual fine steering mechanism)
- Thermal control (e.g. decontamination heaters, radiators)
- Baffles for straylight and contamination control, if required

The main parameter of the telescope are as follows:

- Off axis Korsch
- Entrance pupil diameter 1286.5 mm
- Exit pupil diameter 36.5915 mm
- Effective focal length (for a 300mm focal length focusing lens) 10568.31 mm

The optical prescription of the telescope is provided in RD23 Since the exact accommodation of the instrument FPA is tbd, the exact location and number of flat folding mirrors as defined in RD23 can be revised by the PI and agreed by ESA

3.5 EChO service module (ESVM)

There are 8 major subsystems that constitute the EChO Satellite system, located primarily in the ESVM:

- Attitude and Orbit Control (AOCS): the AOCS provides the hardware and associated onboard software to acquire, control and measure the attitude of the satellite during all mission phases and modes according to the system requirements. The Fine Guidance Sensor, being part of the AOCS system is located in the EPLM
- Data Handling (Command and Data Management, CDMS): The Command and Data management Subsystem collects all telemetry data from the satellite. These data include the scientific data, the science instrument housekeeping (HK) and the spacecraft housekeeping data. The data will be conditioned, digitised and encoded for transmission to ground via the TT&C subsystem. The CDMS will also process the up-link command signals received by the TT&C subsystem and decode, validate and distribute the commands to the users for execution.
- Communications (Tracking, Telemetry and Command): The Telemetry, Tracking and Command (TT&C) subsystems manage the reception and transmission of radio frequency signals for science and housekeeping data telemetry, telecommand and tracking. It is able to operate in both ways (up-link and down-link) during all mission phases when there is ground station contact
- Electrical Power (PCDU, Batteries and Solar array): the Power Control Subsystem conditions, controls and distributes the electrical power generated by the solar array to all payload instruments and spacecraft subsystems/units.
- Structure: the structure subsystems of the SVM supports the SVM units, carries the PLM, and provide interface to the launcher.
- Thermal Control: the thermal control subsystem (TCS) maintains the required SVM and PLM thermal environment for proper operations of equipment, taking into account the different environmental conditions. The SVM and PLM are thermally de-coupled.
- Propulsion: the propulsion subsystem comprises the propellant storage tanks, pipes, necessary valves and pressure transducers and the thrusters. The thrusters are commanded by the AOCS.
- Harness: The SVM harness provides all electrical connections between all electrical equipment in the service module. It includes harnesses for power supplies, signals and synchronisation. It includes also harnesses for connections with the PLM, the umbilical and test connectors.

3.6 Operating modes

The following minimum operating modes are defined for the EChO Spacecraft:

- Launch mode identifies the S/C state until separation from the launcher
- Sun Acquisition Mode is first reached after separation, permits the initial rate damping and the Sun acquisition
- Science Mode is the normal mode of operation during science observations and commissioning providing:
    - Fine pointing for image acquisition;

- Orbital Control Mode: the mode is entered to perform orbital control manoeuvres.
- Safe Mode is reached in case of major/critical problem. Sun tracking is performed by limiting the SAA in order to provide enough power generation to keep critical sub-system alive and for heaters to maintain the temperatures within the qualification range of each equipment in PLM and SVM.
- Communications Mode where communication is performed.

4 INSTRUMENT DESIGN AND INTERFACES REQUIREMENTS

This chapter specifies the design requirements and the interface requirements applicable to the instrument in addition to the higher level requirements of the MRD/SRD (AD03 .a. AD04) applicable to the instrument; it also provides the main resources allocated to the instrument.

4.1 General Design Requirements

Note: chapter 4.1 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO, except chapter 4.1.3, 4.1.5 which are already tailored for EChO

4.1.1 *HW Identification and Labelling*

EIDA-R-0010. The PI shall ensure that each instrument unit bears a unit identification label containing the following information:
Unit identification code
Instrument model (e.g. STM, EM, PFM, FM, FS)

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

EIDA-R-0020. The PI shall ensure that the unit identification code is composed of the following three parts:

- 3 characters for instrument/channel identification, (e.g. VIS, IR1 ... etc.)
- 3 characters for unit identification, (e.g. Digital Processing Unit, DPU)
- 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) .

EIDA-R-0030. The PI shall use identification labels also for each unit connector and for units interconnecting harness.

EIDA-R-0040. 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
- a “P” character is used for each harness mounted connectors, followed by a 2 digit number.
- after this number, an additional character is used to identify the type of contact: “P” for male and “S” for female contact.

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

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

EIDA-R-0050. The PI shall ensure that all items to be removed prior to test shall be coloured red and tagged stating "REMOVE BEFORE TEST"

These items are known as “red-tag” items.

EIDA-R-0060. The PI shall ensure that all items to be removed prior to flight shall be coloured red and tagged stating "REMOVE BEFORE FLIGHT"

These items are known as “red-tag” items.

4.1.2 *Standard Metric System*

EIDA-R-0070. The PI shall use the International System (SI) Metric Standard (seeAD04 R-SYS-010)

4.1.3 *Lifetime Requirements*

EIDA-R-0080. The PI shall ensure that the instrument HW survives and functionally operates during the mission lifetime as specified in the MRD (AD04).

Life time starts at launch and finishes after decommissioning, which defines the end of the science mission phase, ie a 5 year period plus 1 year extension (TBC).

EIDA-R-0090. The PI shall ensure that the overall instrument design is compatible with an on ground lifetime of tbd years

EIDA-R-0100. The PI shall ensure that for items which degrade with usage and /or storage the life time is 1.5 times (TBC) the ground life time specified in EIDA-R-0090.

Exceptions are the mechanisms where specific requirements apply.

4.1.4 *Maintainability*

EIDA-R-0110. 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(to be defined at a later stage in the project).

EIDA-R-0120. The Prime Contractor will define late-access accessibility rules for the PL/instrument units.

4.1.5 *Single Point Failure*

EIDA-R-0130. The instrument design shall avoid, unless agreed with the EChO project office, singe point failure. If single point failures are part of the design, this shall be clearly identified along with the likelihood of failure and any strategies to mitigate the failure.

4.1.6 *Fault Tolerance*

EIDA-R-0140. The PI shall ensure that no single instrument failure or single operator error shall have level 1 or level 2(tbc) effect severity as defined in EIDA-R-7110

The PI shall ensure that no combination of:

- two independent instrument failures,
- an instrument failure and an operator error, or
- two independent operator errors.

shall have level 1 effect severity as defined in EIDA-R-7110

Safety inhibits shall be independent, verifiable, stable and stay in a safe position even in case of energy failure.

Inhibit is any design feature that provides a physical interruption between an energy source and a function actuator.

Failures which result from common-cause or common-mode failure mechanism shall be analysed as single failures for determining failure tolerance.

For a description of common-mode and common-cause analysis see section 7.5.4.

EIDA-R-0150. The PI shall ensure that for an agreed set of instrument failures to be defined in the EID-B, the instrument will automatically reconfigure in order to continue science operations.

Detail recovery procedure(s) will be verified before FM delivery and launch, for each individual failure/recovery case.
It is assumed that automatic reconfiguration is performed internally to the instrument without any need for action or reaction by the EChO spacecraft.

EIDA-R-0160. The PI shall ensure that the instrument enters a safe state in the event of an agreed set of failures and TM records of the fault are transferred to the spacecraft.

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 instrument safe mode definitions are described in the EID-Bs

EIDA-R-0170. The PI shall ensure that, for any autonomous reconfiguration, the instrument reports TM event packets about the fault to the spacecraft.

EIDA-R-0180. The PI shall ensure that recovery from Safe Mode is done through ground telecommand.

EIDA-R-0190. The PI shall ensure that, for set of agreed events to be defined in the EID-B, the instrument take adequate measures to be prepared within TBD seconds for a removal of power.

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

4.1.7 *Venting*

EIDA-R-0200. The PI shall provide adequate venting of each unit to preserve its structural integrity during launch depressurisation, thermal vacuum tests and thermal vacuum balance tests, by the provisions of typically 2mm² venting cross-section per litre gas volume.

EIDA-R-0210. The PI shall ensure that each instrument unit can operate within a pressure range of 1 bar to 1E-10 mbar.

EIDA-R-0220. The PI shall ensure that, for each relevant thermal hardware (MLI, tapes, heater mats, etc.), venting provisions are incorporated.

EIDA-R-0230. 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-R-0240. 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.

4.2 Co-ordinate System

Note: chapter 4.2 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO, except chapter 4.2.1, is already tailored for EChO

4.2.1 *S/C Coordinate Systems*

The spacecraft and telescope co-ordinate systems are defined and described in MRD, chapter 5.1.2

Item	Definition
Origin	The EChO S/C reference frame shall be defined by three orthonormal axes (X_{EChO}, Y_{EChO}, Z_{EChO}), with an origin at the geometrical centre of the separation plane between the LV adapter and the S/C.
+ Z_{EChO}	The longitudinal axis $+Z_{EChO}$ (roll axis) shall be coincident with the LV symmetry axis, and pointing in the positive direction from the LV – S/C separation plane up to the tip of the S/C.
+X_{EChO},	$+X_{EChO}$ shall be defined, in the separation plane between the LV adapter and the S/C, as pointing in the positive direction along the telescope pointing axis $Z_{E\text{-}TEL}$ projected in the separation plane.
+Y_{EChO}	$+Y_{EChO}$ shall be defined to complete the right-handed orthonormal triad with $+X_{EChO}$ and $+Z_{EChO}$.

Table 2 S/C co-ordinate system definition (TBC).

Item	Definition
Origin	The EChO telescope pointing reference frame shall be defined by three orthonormal axes ($X_{E\text{-}TE}L$, $Y_{E\text{-}TEL}$, $Z_{E\text{-}TEL}$), with an origin in the vertex of the telescope's primary mirror.
+ $Z_{E\text{-}TEL}$	The telescope's pointing axis +ZE-TEL shall be defined from the reference frame's origin, in the positive direction going towards the centre of the targeted FoV.
+$X_{E\text{-}TEL}$	$+X_{E\text{-}TEL}$ shall be defined from the reference frame's origin towards the centre of the Sun shield (average Sun direction), projected onto the plane orthogonal to $+Z_{E\text{-}TEL}$.
+$Y_{E\text{-}TEL}$	$+Y_{E\text{-}TEL}$ shall be defined to complete the right-handed orthonormal triad with $+X_{E\text{-}TEL}$ and $+Z_{E\text{-}TEL}$.

Table 3 Telescope co-ordinate system definition (TBC).

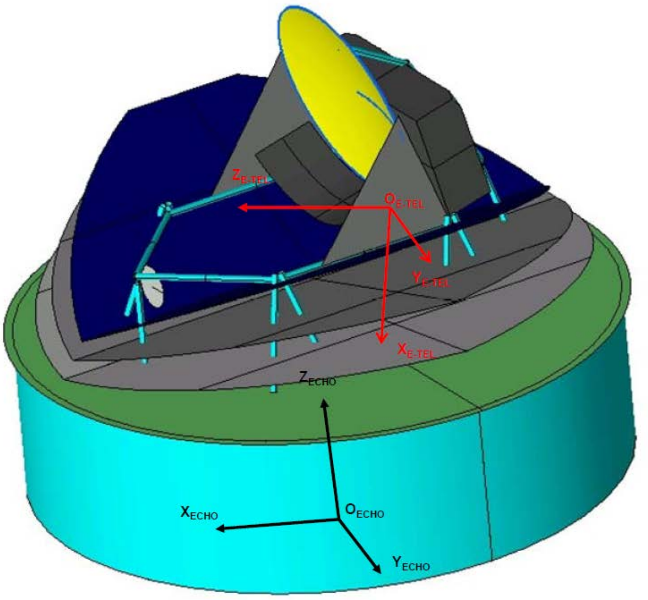


Figure 5 S/C Coordinate system (TBC).

4.2.2 *Unit co-ordinate System*

4.2.2.1 Unit Physical Reference Frame

EIDA-R-0300. The PI shall use the Unit Physical Reference Frame (URF) for describing the relevant physical properties of each unit (e.g dimensions, CoG, MoI)

The URF, shown in Figure 6, is defined in Table 4.

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

Table 4 Unit Physical Reference Frame (URF) definition.

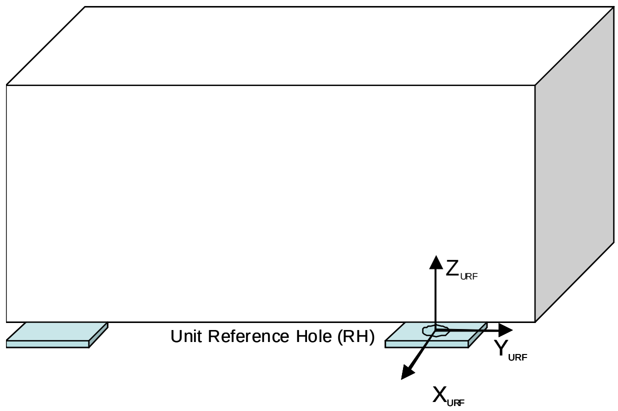


Figure 6Unit Physical Reference Frame (URF) visualization.

4.2.2.2 Unit Alignment Reference Frame

EIDA-R-0310. The PI shall define the Unit Alignment Reference Frame (UARF), for unit internal alignment purposes and for unit (co)-alignment purposes once integrated into the spacecraft.

4.2.2.3 Instrument Line-of-Sight Reference Frame

EIDA-R-0320. The PI shall define the Line-of-Sight Reference Frame (ILS), for relevant units, for the definition of the instrument pointing.

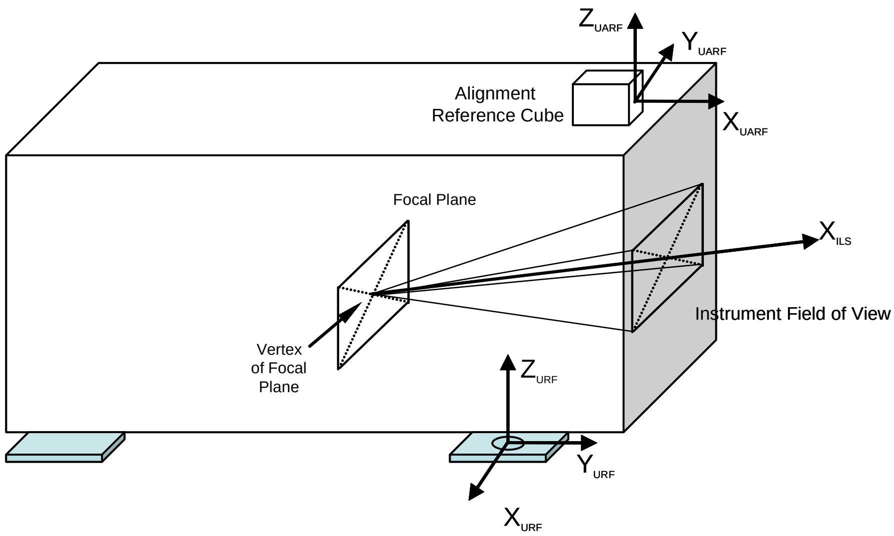


Figure 7 Example of Unit Alignment Reference Frame (UARF) and Instrument Line of Sight Reference Frame (ILS) visualization.

4.3 Alignment, Pointing and Straylight

4.3.1 *Instrument Alignment*

Note: chapter 4.3.1 in the EID-A has been derived from existing missions and should be considered only as a placeholder. It will require in the future adaptation for EChO

4.3.1.1 Definitions

The instrument **Vertex** is the theoretical centre of the Instrument Focal Plane, as shown in figure above

The instrument **Field of View (FoV)** is the angular opening of the instrument's viewing field used for scientific observations, measured from the Instrument Vertex, as shown in figure above

The instrument **Unobstructed Field of View (UFoV)** is 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 presentin flight configuration.

The instrument **Field of Regard (FoR)** is the e 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.

4.3.1.2 Instrument (Co)-Alignment Requirements

EIDA-R-0330. 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-R-0340. 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 tbd accuracy.

EIDA-R-0350. 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 tbd accuracy.

EIDA-R-0360. The PI shall ensure that the difference between the theoretical and actual angular offset for any of the three instrument coordinate frames shall be ≤ tbd arcsec, full cone

EIDA-R-0370. 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 ≤ tbd mm.

EIDA-R-0380. The PI shall mount alignment cube(s) on a solid part of the unit structure to ensure that alignment stability and repeatability is ≤ tbd arcsec .

EIDA-R-0390. 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-R-0400. 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-R-0410. 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-R-0420. The PI shall ensure that the optical cube(s) incorporate scribed crosshairs within its clear apertures or the visible faces.

EIDA-R-0430. The PI shall ensure that the optical cube(s) surfaces are orthogonal to within +/- 10 arcsec (TBC).

EIDA-R-0440. 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. The locations shall be documented in the instrument specific EID-B.

EIDA-R-0450. The PI shall complete all instrument internal alignment activities before integration of the instrument unit into the spacecraft.

EIDA-R-0460. The PI in case of active instrument unit alignment shall not introduce unacceptable tbd stresses in the instrument and in the spacecraft structure.

4.3.2 *Pointing and pointing knowledge*

Note: This chapter is already tailored for EChO

In accordance with standards ECSS-E-ST-60-10C, the following pointing terminology applies:

Absolute Performance Error (APE):
The absolute performance 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. The contributors to the APE are:

- Microvibrations
- Thermoelastic deformations
- Calibration errors
- Measurement noise transmission in the control loop

Relative Performance Error (RPE):
The relative performance 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 performance error is also known as pointing stability.

Performance Reproducibility Error (PRE)
The performance reproducibility error is the difference between the means of the performance error taken over two time intervals within different observation periods.

Performance Drift Error (PDE):
The performance drift error is defined as the difference between the means of the pointing error taken over two time intervals within a single observation period.

Absolute Knowledge Error (AKE):
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. The contributors to the AKE are:

- Residual bias errors between the pointing sensor (FGS/startracker) and the instrument
- Thermo-elastic deformations between the AOCS sensors and the instrument
- AOCS sensor errors and noises

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.

EIDA-R-0470. PI shall ensure that the instrument performances are compatible with the spacecraft performances given in Table 5:

Quantity	***Value***
Fine APE (with FGS in the loop)	600 mas (3σ) (TBC)
Course APE (without FGS)	5 arcsec (3σ) (TBC)
RPE	60 mas up to 90 sec (3σ) (TBC)
PRE	10 mas from 90 sec to 10 hrs (1σ) (TBC)

Table 5 Pointing performances of the EChO spacecraft

The coarse APE is achieved with the SVM AOCS actuators and sensors and allows to position the target star in the instrument and FGS FoV.

All the pointing angles defined above are half angles, and are applicable around $X_{E\text{-}TEL}$ and $Y_{E\text{-}TEL}$.

The acquisition rate of the FGS shall be ≥ 1Hz, with a centroïding performance <10 mas (5 mas TBC).

4.3.3 *Straylight*

Note: This chapter is already tailored for EChO

EIDA-R-0480. The PI shall ensure that a straylight analysis is performed

EIDA-R-0490. The PI shall define straylight requirements to the S/C
Note: This should include absolute straylight and straylight stability during one observation

4.4 Mechanical Interfaces and Design Requirements

Note: chapter 4.4 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO, except EIDA-R-0570 and chapter 4.4.11 which are already tailored for EChO

4.4.1 *Mechanical Interface Control Drawing*

EIDA-R-0500. The PI shall produce, deliver and keep up to date for each instrument unit a Mechanical Interface Control Drawing (MICD).

EIDA-R-0510. The PI shall ensure that each MICD contains, as a minimum, the following set of interface information:

- Drawing Identification Code and date of issue
- Dimensions and associated tolerances (at ambient temperatures), including feet, external connectors and their dedicated clearance
- Allocated dynamic volume, as provided by the Prime Contractor.
- Mobile parts in the different configurations.
- Identification of the Unit Physical Reference Frame (URF) and Reference Hole (RH)
- Identification of the thermal Unit Reference Point (URP)
- Identification of the Unit Alignment Reference Frame (UARF)
- Identification of the Instrument Line-of-Sight Reference Frame (ILS),
- Theoretical angular offset, if any, between URF, UARF and ILS)
- Linear offset, if any, between the origins of the (URF, UARF and ILS)
- Field of View (FoV)
- Unobstructed Field of View (UFOV)
- Field of Regard (FoR)
- Instrument Vertex
- Mounting hole pattern dimensions and hole patterns
- Dimensions of mounting feet and contact area (base-plate and mounting feet)
- Spot-faced area for seating of the mounting screw washers (if and where applicable)
- Dimensions and location of dowel pins (where applicable)
- Dimensions of volume below instrument unit for its mounting feet (if applicable)
- Mass and associated tolerances (precise if estimated, calculated or weighted)
- Location, naming, type and function of all connectors
- Location and dimensions of venting holes
- Connector key shape orientation, the identification of connector contact “1”, showing connector in front view and the connector centre line
- Information about connector fixation
- Identification and details of grounding studs and grounding straps
- Identification of non-flight items (i.e red tag items)
- Location of handling points (e.g. threaded bushes)
- Location of unit and connector identification labels
- 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
- Location of operational and non-operational heaters, and temperature sensors (for test and flight purpose)
- Location and routing of any harness interconnecting modules of a “stacked” box configuration
- Identification of free areas for harness fixation
- Centre of Gravity coordinates, calculated and specified wrt URF

- Moments of Inertia coordinates, calculated and specified wrt URF
- Location and type of interface for of transport/storage purging connections (if - applicable)
- Material of housing and surface finish
- Flatness and roughness of contact area
- Base plate material and surface treatment
- Surface coating (IR Emissivity and Solar absorptance if external location)
- Specific heat (J kg^{--1} K^{--1}) (calculated or measured)

4.4.2 *Mass*

From the initial instrument design up to launch, the PI will control the resources/budgets that were allocated to the instrument according to strict rules in order to show adequate margins, at each major instrument review milestones.

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, thermal (heating/cooling requirements).

Shortly after instrument selection an allocation for shielding mass will be made for each instrument. This mass shall then be included within the instrument's mass budget and shall be maintained and monitored by the PI.

EIDA-R-0520. The PI shall establish, keep up to date and provide the ESA EChO Project office with a mass budget for each instrument unit (including unit interconnecting harness(es).

EIDA-R-0530. The PI shall ensure that each unit mass budget include at least the following elements, as applicable:

- Structure, mechanisms and optics;
- electronics up to the interfaces with the spacecraft power and data systems;
- thermal control hardware, including any necessary thermal straps or heaters / thermistors, instrument blankets, cold fingers, cold straps defined by the instrument
- pigtail and interconnecting harness (if instrument consists of more than one unit)
- electrical connectors, but not the mating harness connector
- attachment hardware including instrument-delivered brackets or struts, but excluding standard fixation bolts to the spacecraft structure and washers
- potting compounds used in the units
- alignment references, e.g. mirrors, that are not removed before flight
- internal balance mass (applicable for periodically operating mechanisms)
- electrostatic screens and/or magnetic shielding
- in-flight covers, purge ports, purging pigtails
- shielding at component level (e.g spot shielding).

Note1: Shielding at unit level is presently not included in the mass allocation but shall be evaluated and communicated by the PI in the EID-B.

Note2: for harnesses between units when applicable, a minimum of 2 meters (TBC) shall be assumed at this stage if the exact configuration is not known.

EIDA-R-0540. The PI shall calculate, for each unit mass budget, the Basic Mass of each identified unit element.

Basic Mass is the engineering best estimate without any design margin due to any uncertainty at the time of the issuing of the mass budget.

EIDA-R-0550. The PI shall calculate, for each unit mass budget, the Nominal Mass of each identified unit element.

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

EIDA-R-0560. The total Instrument mass shall include an ESA instrument level mass margin of at least 20 % of the total instrument Nominal mass as specified specified in EIDA-R-0550

Note: *Evolution of the ESA instrument mass margin during the mission development will be defined at IPRR.*

EIDA-R-0570. Instrument shall be compliant with the following mass (including items listed in **EIDA-R-0530**) allocation:

Instrument part in EPLM	***Basic Mass[kg]***	***Design margin***	***Nominal Mass [kg]***
IOB including support			≤30
Science Instrument Boxes			≤30
Common Optics (including support)			≤10
FGS			≤6
Thermal Shielding, Instrument Radiators, coldfingers			≤15
Cooler elements on V-Grooves			≤10
Total (including Instrument design margin)			≤101
ESA Instrument level mass margin (20%)			≤20
Total Instrument allocated mass in EPLM			≤121

Table 6 EChO instrument mass allocation in EPLM. The instrument complement and/or mass indicated in this table are as extracted fromRD01 and may be subjected to change pending the outcome of the Payload review committee after the AO review. However the total mass of the complement will remain as a limit.

Instrument part in ESVM	***Basic Mass [kg]***	***Design margin***	***Nominal Mass [kg]***
Electronics			≤40
Cryocoolers			≤75
Total (including Instrument design margin)			≤115
ESA Instrument level mass margin (20%)			≤22
Total Instrument allocated mass in ESVM			≤137

Table 7 EChO instrument mass allocation in ESVM. The instrument complement and/or mass indicated in this table are as extracted fromRD01 and may be subjected to change pending the outcome of the Payload review committee after the AO review. However the total mass of the complement will remain as a limit.

EIDA-R-0580. The PI shall calculate and provide the instrument Design Maturity and ESA Instrument level Margin.

EIDA-R-0590. The PI shall apply the following design margin factors due to uncertainty and/or design maturity:

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

EIDA-R-0600. Instruments shall be required to adhere to the following mass margin philosophy:

- 20 % at ISRR
- 15 % at IPDR
- 10% at ICDR

Note: the margin is defined as the percentage of the total instrument nominal mass. Evolution of the mass margin during the mission development will be defined at IPRR.

EIDA-R-0610. The PI shall ensure that the difference between the measured mass of each STM, QM unit and FM unit with the respective nominal mass, specified in the relevant MICD, current at the time of the STM, QM and FM delivery, is less than 1%.

4.4.3 *Centre of Mass*

EIDA-R-0620. The PI shall calculate and document any variation of Centre of Mass (CoM) for each unit; variations could be due for example to consumables or appendages deployment.

EIDA-R-0630. 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-R-0640. 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 (TBC).

4.4.4 *Moments of Inertia*

EIDA-R-0650. The PI shall calculate and document any variation of the Moment of Inertia (MoI) for each unit, due for example to due to mechanisms movements or appendages deployment.

EIDA-R-0660. The PI shall ensure that the difference between the measured or calculated MoI of each STM, FM and FS unit and the MoI, current at the time of the STM, FM and FS delivery are less than 10%.

4.4.5 *Unit Dimensions*

EIDA-R-0670. 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
+ 1.0/-0.0 mm for d > 500 mm

All dimensions within 10 mm (TBR) of the allocated envelope shall be declared and tracked in a critical dimension list by the S/C Prime Contractor

4.4.6 *Mounting*

EIDA-R-0680. 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.
- Provision of sufficient accessibility to the position of the connectors and grounding studs to enable easy the mounting and removal of the unit.
- 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.

EIDA-R-0690. 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
- mounting feet surface roughness Rz < 1.6 um (TBC)
- effective contact area to the S/C interface surface approx 350mm^2 (typically for M5)

EIDA-R-0700. 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
- coplanarity between all mounting feet surfaces < 0.050 mm per 100 mm length
- mounting feet surface roughness Rz ~ 6.4 µm (TBC)
- additional (lateral) contact area for the attachment of thermal straps having the following typical characteristics:
- surface flatness < +/- 0.100 mm (TBC)
- surface roughness Rz < 1.6 µm(TBC)
- effective contact area approx TBD mm^2 per W

EIDA-R-0710. The PI shall ensure that the characteristics of the thermal attachment interface(s) on the instrument side are maintained under all operating conditions.

EIDA-R-0720. The PI shall ensure that any mechanical and thermal mounting contact area interface(s) is free of paint.

EIDA-R-0730. The PI shall provide isostatic mounts for units requiring APE and/or co-alignment to better than 0.1°.

EIDA-R-0740. 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 (TBC) in the following conditions:

- Maximum displacement of the instrument feet at the S/C interface as specified in the table below:
- instrument subjected to the specified in-orbit thermal environment

Foot	Maximum displacement	
Any	In-plane	Out-of-plane
	TBDmm	0mm

Table 8 Instrument foot prescribed displacement at S/C interface

EIDA-R-0750. The PI shall provide handles for units weighing more than 10kg . These handles used only during ground operation shall clearly be identified as a non-flight item If a handling jig is provided, than this shall be detailed in the EID-B and agreed together with the Prime Contractor.

EIDA-R-0760. The PI shall provide HW lifting interfaces (e.g eye-lids, spreaders, etc) to a single hook crane for units weighing more than 20kg; details design of the HW lifting interfaces shall be agreed with the Prime Contractor

EIDA-R-0770. 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.

4.4.7 *Aperture covers*

EIDA-R-0780. The PI shall identify any aperture covers not intended for flight and provide an associated design for this cover.

4.4.7.1 Removable covers

EIDA-R-0790. The PI shall identify any removable covers intended for in-flight and provide an associated design for this cover.

4.4.7.2 Deployable covers

EIDA-R-0800. the PI shall identify any deployable covers intended for in-flight and provide an associated design for this cover.

4.4.7.3 Accessibility

EIDA-R-0810. the PI shall provide design and procedures for accessing the instrument if covers and shutters are included in the instrument design.

4.4.8 *Structural Design*

4.4.8.1 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).
The **Qualification Test Level (QL)** corresponds to the maximum level expected to be encountered during the unit lifetime increased by qualification margins.
The **Acceptance Test Level (AL)** corresponds to the maximum level expected to be encountered during the unit lifetime increased by acceptance margins
The **Test Factors (KA and KQ)** are used to define respectively the acceptance and the qualification test levels.
The **Design Limit Load (DLL)** is the Limit Load multiplied by Coef A (see Table 9).
The **Design Yield Load (DYL)** is the Design Limit Load multiplied by Coef B (see Table 9).
The **Design Ultimate Load (DUL)** is the Design Limit Load multiplied by Coef C (see Table 9).
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).
The **Ultimate Strength**, is the maximum load or stress that a structure or material can withstand without incurring rupture or collapse.

EIDA-R-0820. The PI shall ensure that DLL, DYL and DUL, for the design of units, are calculated from the LL as specified in Figure 8 and Table 9.

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 K_M and K_P factors only.

KQ is equal to 1.25
KA is equal to 1.0

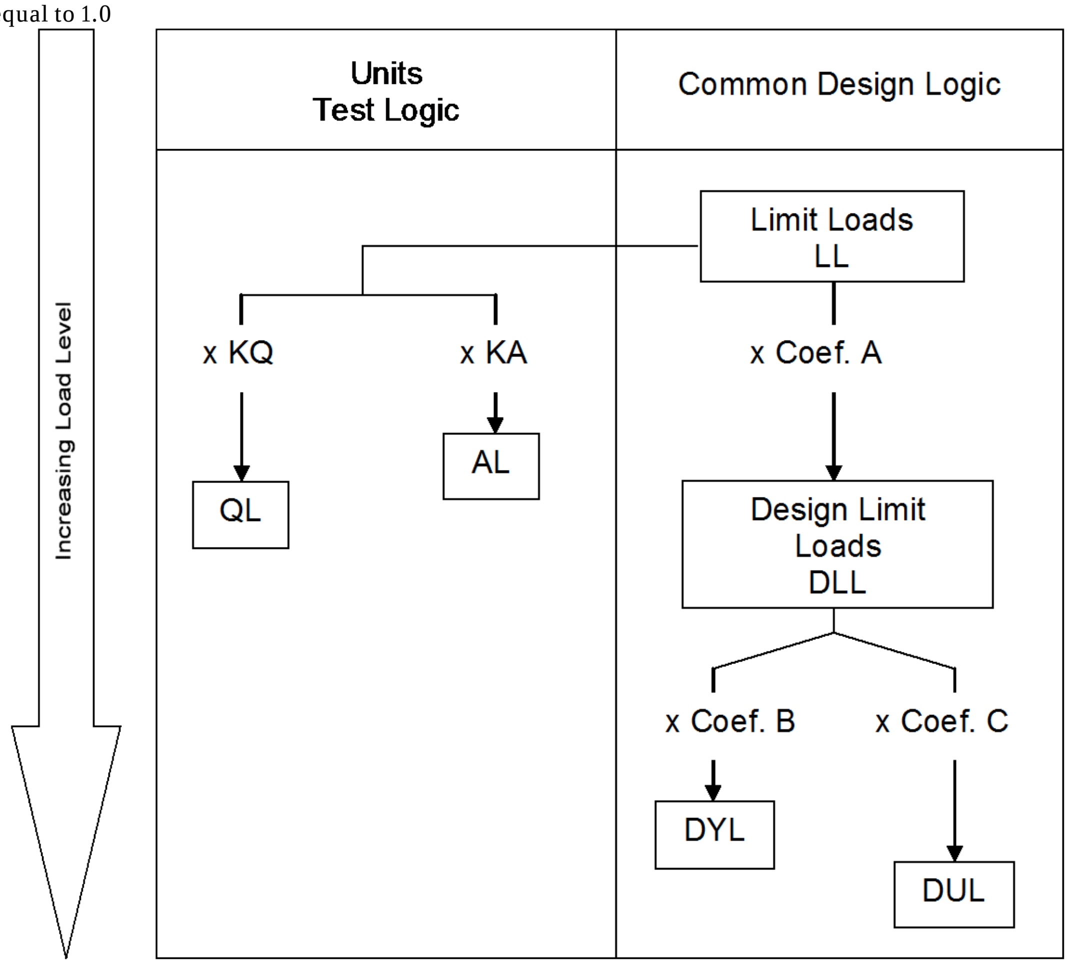


Figure 8 Definition of loads.

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 9 Relationship among (structural) factors of safety, design factors and additional factors.

EIDA-R-0830. The PI shall ensure 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-R-0840. The PI shall ensure 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

K_M will be agreed with ESA and the Prime Contractor

EIDA-R-0850. The PI shall ensure 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).

K_P will be agreed with ESA and the Prime Contractor

EIDA-R-0860. The PI shall ensure that K_P is equal to 1.0 in the case of non-protoflight approach and ≥ 1.1 in case of proto-flight approach.

K_P will be agreed with ESA and the Prime Contractor

EIDA-R-0870. The PI shall ensure that a Local Design Factor (K_{LD}) is applied when the sizing approach or local modelling are complex and is ≥ 1.0.

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

EIDA-R-0880. The PI shall apply the Factors of Safety (FOS) as defined in Table 10

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)]	TBD	1.25	TBD	2.0

a) If material and design requirements 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

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 dependent on the manufacturing process, the size of the part and of the surface quality. Therefore the stress/strength requirements 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

Table 10 Factors of safety

4.4.8.2 Design Loads

EIDA-R-0890. The PI shall apply the design loads to the instrument provided in Figure 9, factored by the corresponding safety factor(s), for the design of bolts, feet and adjacent structure(s).

This figure is to be used only for early design phases. For IPDR analysis and later stages, the PI shall use the set of loads specified in section 6.4.5.

Actual unit internal dynamic behaviour is not taken into account.

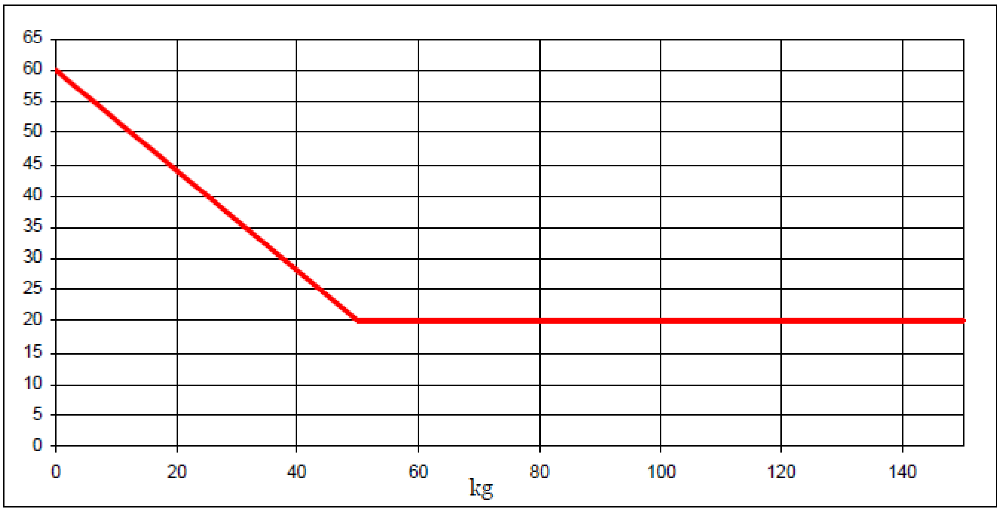


Figure 9 Quasi Static Loads (tbc)

The design load curve will be updated during the course of the project.

4.4.8.3 Stiffness Requirements

EIDA-R-0900. The PI shall ensure that each instrument unit have all fundamental resonance frequencies above 120 Hz (TBC).

EIDA-R-0910. The PI shall ensure that each PI provided deployable structure has the required stiffness to survive the highest thrust levels during the phase when the fuel tanks are close to empty (TBD).

4.4.8.4 Payload and S/C Generated Disturbances

4.4.8.4.1 Identification and description

EIDA-R-0920. The behaviour of the instrument that generates a dynamic disturbance to the spacecraft shall be identified and described, separating:

- the non-recurring transient events (deployments, unlocking device, etc...)
- the recurring transient events, the continuous behaviour.
- the continuous behaviour

EIDA-R-0930. The dynamics of the payload deployment shall be described including:

- shocks;
- duration of the total deployment and of intermediate steps if any
- disturbances (forces, torques) induced by the deployment.

EIDA-R-0940. The PI shall analyse and quantify the instrument generated disturbances (e.g. due to mechanisms movements) vs. frequency. The analysis will include the moving mass and the movement frequencies and characteristics. A complete analytical model shall be provided including the following items:

- geometrical description of the rotation/translation axes;
- description of mass and/or inertia motion;
- description of actuators disturbances or defects;
- description of the control laws for the mechanism;
- description of possible static unbalances (when the centre of mass of the rotating assembly is not aligned with the rotation axis);
- description of possible dynamic unbalances (when the products of inertia of the rotating assembly with respect to the rotation axis are not zero).

EIDA-R-0950. The disturbance analysis shall cover the frequency range [0-10 Hz] that can be partially compensated by the Attitude Control of the Spacecraft, and the high frequency range [10 - 1000 Hz] that concern micro-vibrations phenomena. For the micro-vibrations, the description of the disturbance (amplitude, frequencies) could replace a model.

4.4.8.4.2 Limitation

The disturbances induced by the instrument and subsystems will be assessed by the prime. If they result in unacceptable levels for sensitive parts of the instrument or subsystems, work-arounds will have to be agreed with ESA and the PI.

4.4.9 *Mechanisms*

4.4.9.1 General Requirements

Mechanisms' materials, parts and components will be selected according to the ESA approved qualification procedures and they will be compatible with the requirements specified in the relevant applicable documents. Their performance under long exposure to space environment must be specifically addressed and potential performance degradation over the ground life.

EIDA-R-0960. Mechanisms design shall comply with ECSS-E-ST-33-01C, but tailored to the specific needs of EChO subject to approval by ESA

EIDA-R-0970. Mechanisms shall be compatible with the EMC (see section 4.11) and cleanliness requirements (see section *4.12.2 and 4.13.3*) mentioned in this document.

EIDA-R-0980. Mechanisms shall include means to determine uniquely their position and status (e.g. on/off, latching) by telemetry.

4.4.9.2 Mechanism Envelope

EIDA-R-0990. The envelope of movement for each moving part shall be defined by the PI and agreed with the Prime contractor, reported in the MICD and the EID-B and demonstrate compliance by measurement for each instrument unit

4.4.9.3 Reliability and Redundancy

For all mechanisms, which are critical to mission success, conformance to the specified reliability figure shall be demonstrated according to the following methods:

- Electronic components: by parts count as a minimum or other methods approved by the customer;
- Mechanical parts: by stress analysis or other methods approved by the customer;
- Mechanical limited-life by life test approved by the customer.

[Origin: ECSS ECSS-E-ST-33-01C 4.2.5.1a]

EIDA-R-1000. Failure of one part or element in a mechanism shall not result in consequential damage to the equipment or other spacecraft components.

Note: In particular the mechanism redundant chain has to remain fully operational, the thermal loads have to remain acceptable to the systems thermal control system and no obstruction of any field of view should occur.
[Origin: ECSS ECSS-E-ST-33-01C 4.2.5.1c]

EIDA-R-1010. Unless redundancy is achieved by the provision of a complete redundant mechanism, active elements of mechanisms, such as sensors, motor windings, brushes, actuators, switches and electronics, shall be redundant.

[Origin: ECSS ECSS-E-ST-33-01C 4.2.5.2f]

EIDA-R-1020. Spring actuators shall be redundant unless it is

- Agreed by the Agency,
- Verified by analysis and test that the spring sizing and functional performance characteristics meet the specified reliability of the mission, and
- Verified that a spring failure can not cause any catastrophic, critical or major hazardous event as defined in section 7.3.3.

[Origin: ECSS ECSS-E-ST-33-01C 4.7.5.3.2f]

EIDA-R-1030. Unless monitored at spacecraft system level, the design of mechanisms shall include means to monitor the execution of its main functions.

[Origin: ECSS ECSS-E-ST-33-01C 4.7.5.3.2a]

4.4.9.4 Lifetime requirements

EIDA-R-1040. Limited-life components of mechanisms shall be identified.

[origin: ECSS ECSS-E-ST-33-01C 4.8.2.15a]

EIDA-R-1050. All mechanisms shall be designed for a lifetime of the number of operations during their predicted service life – including both in orbit and ground operations necessary for functional tests, system tests etc - multiplied by the safety factors listed in Section 6.4.6

[origin: ECSS ECSS-E-ST-33-01C 4.8.3.3.14]

4.4.10 *Mechanical environment*

4.4.10.1 AIV mechanical environment

EIDA-R-1060. During transportation and system integration the mechanical environment will be controlled so as to be significantly less severe than the environment during launch. For the handling points the following limit loads will not be exceeded:

Hoisting (nominal handling loads):
- vertical: ± 2.0 g
- horizontal: ± 1.5 g

The instrument shall be designed accordingly.

4.4.10.2 Ground transportation environment

EIDA-R-1070. The instrument transport container shall be designed to sustain the following environmental conditions during the transportation and storage periods.

Mechanical Environment:
- Vertical ± 3.0 g;
- Lateral ± 2.0 g;

Note 1: Temperature, Humidity, Pressure are defined in thermal chapter
Note 2: The instrument has to withstand what is specified above. The container (empty) however may see a more severe environment. Also, the container may have to protect the flight hardware (e.g. shock absorption) i.e. be such that the transportation environment (3.0g / 2.0g) does not induce loads greater than 2g/1.5g for the flight hardware.

4.4.10.3 Launch mechanical environment

The mechanical environment induced by the launcher is composed of high frequency loads and of quasi-static loads. For design purposes of the EChO spacecraft/ instrument interfaces the design loads defined in chapter4.4.8.2 (strength requirements) and 4.4.8.3 (stiffness requirements) are applicable. They envelope the launch loads.
For verification purposes the mechanical test levels are defined in chapter6.4.5. The unit random and acoustic test levels envelope the high frequency loads. The unit sinusoidal and static test loads envelope the quasistatic loads.
Shock test levels are defined in the following sections. They will be refined during the course of the project.

EIDA-R-1080. The instrument shall be designed to survive in their Launch mode (configuration) a pressure decrease within the fairing during ascent of typically less than 2000 Pa/s with a peak of 4500 Pa/s between 50 and 52 s after lift-off. Note: To be confirmed after Launcher ICD is established

EIDA-R-1090. The spacecraft is subjected to noticeable shocks during the following events:
The launch vehicle upper stage separation from the main cryogenic stage
The fairing jettisoning
The spacecraft separation
The shock generated by the upper stage separation and the fairing jettisoning are propagated from their source to the base of the spacecraft through the launch vehicle structures. The spacecraft separation shock is directly generated at the base of the spacecraft.
The corresponding expected shock levels are then:

Frequency range (Hz)	Shock level (g)
100-1000	20-1000 (linear variation)
1000-10000	1000

Table 11 Shock levels at spacecraft base (Soyuz). Values at Instrument I/F are TBC and depends on the exact location in the S/C.

4.4.10.4 Cruise and operation mechanical environment

The mechanical environment induced by thruster actuation is less severe than the environment during launch.

4.4.11 *Accommodation/Mechanical interfaces*

4.4.11.1 ESVM

EIDA-R-1100. The Pi shall ensure that the volume of the instrument units located in the ESVM shall be less than:

Unit	Number of boxes	Size
Instrument Control Unit	Tbd	300mmx300mmx180mm (TBC)
Cooler(elements)	tbd	600mmx400mmx300mm (tbc)
Cooler Drive electronics	tbd	250mm x 250mm x 250mm (tbc)
Other	tbd	Tbd

Table 12 Instrument volume in ESVM

EIDA-R-1110. The PI shall consider that the location of the instrument units located in the ESVM is tbd

EIDA-R-1120. The PI shall provide a cryo harness connecting the warm units located in the ESVM and cold units located in the EPLM with a length of >2000mm (tbc)

4.4.11.2 EPLM

EIDA-R-1130. The instrument part mounted in the EPLM shall fit inside the volume defined in Figure 10 (tbc), with the instrument detector radiator shown in red and an instrument volume extension (tbc) shown in yellow:

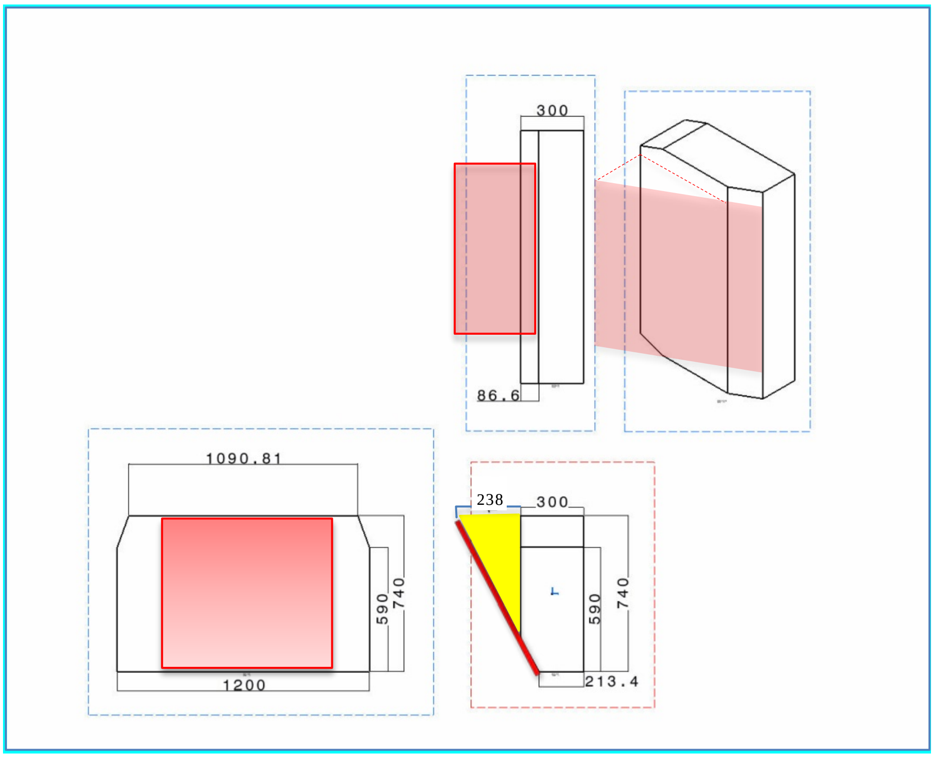


Figure 10 Allocated Instrument volume in EPLM

Note: A tbd volume is available on the V-Grooves for Cooler elements, thermal/mechanical I/F's and cryoharness

EIDA-R-1140. The instrument volume specified in Figure 10 shall be mounted behind the primary mirror on the TOB. The mounting plane is located at the position (in the telescope coordinate system):
[tbd,0,-300mm] TBC with the normal of the surface (toward the FPA) defined by the triplet [17.36,0,-100] TBC (i.e. an inclination of 10 deg)

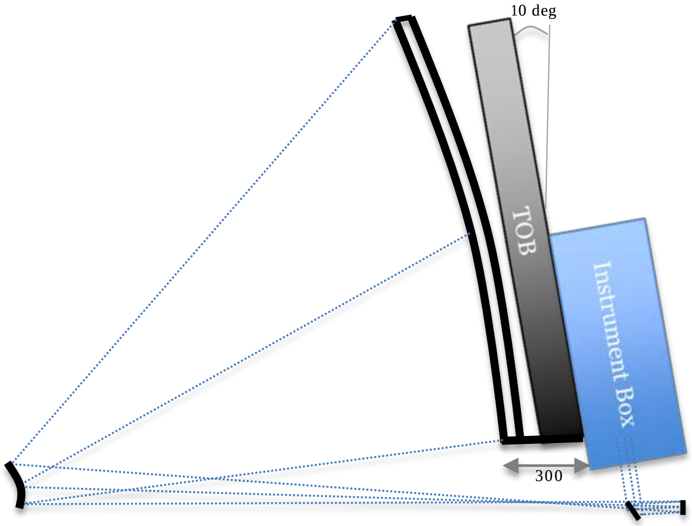


Figure 11 Instrument accommodation in EPLM

4.5 Optical Interfaces

Note: chapter 4.5 in the EID-A is already tailored to EchO

EIDA-R-1150. The instrument shall be compatible with the following Optical quality:
The telescope shall be within a FoV of ≥ 20”x 20” diffraction limited at wavelengths > 5 µm (tbc). At 1 µm, at the instrument focal plane, the tbd% encircled energy diameter of the monochromatic system PSF shall be smaller than the tbd% encircled energy diameter of a diffraction limited PSF

EIDA-R-1160. The Wavefront Error budget of the instrument is tbd

EIDA-R-1170. The instrument shall be compatible with a collimated beam with an exit pupil diameter of 36.6mm (tbc) ±tbd provided by the telescope. Position and direction at the entrance of the instrument volume is tbd
Note: Due to the ongoing work on the baseline telescope definition, the exit pupil diameter will change slightly in the future

EIDA-R-1180. The distance between exit pupil and first optical element of the instrument shall be less than 500mm (tbc)

EIDA-R-1190. Telescope Straylight tbd

EIDA-R-1200. During nominal operation the instrument shall be compatible with a temperature the Telescope Assembly T <45K (tbc)considering an emissivity of < 0.03 (tbc) for the mirrors

EIDA-R-1210. During nominal operation the instrument shall be compatible with a temperature stability of the Telescope Assembly of less than 200mK/10h (tbc)

EIDA-R-1220. The transmission of the telescope assembly shall be > 87 %(tbc) between 1 µm and 16µm and > 80% (tbc) between 0.55µm (goal 0.4µm) and 1µm

4.6 Fine Guidance Sensor

Note: chapter 4.6 in the EID-A is already tailored to EchO

The Fine Guidance Sensor is part of the AOCS system and will be provided by the Prime/ESA for integration into the instrument volume specified in 4.4.11.2.

EIDA-R-1250. The PI shall accommodate the FGS module with a size of less than 350mm x 100mm x 250mm (tbc), as shown in Figure 12

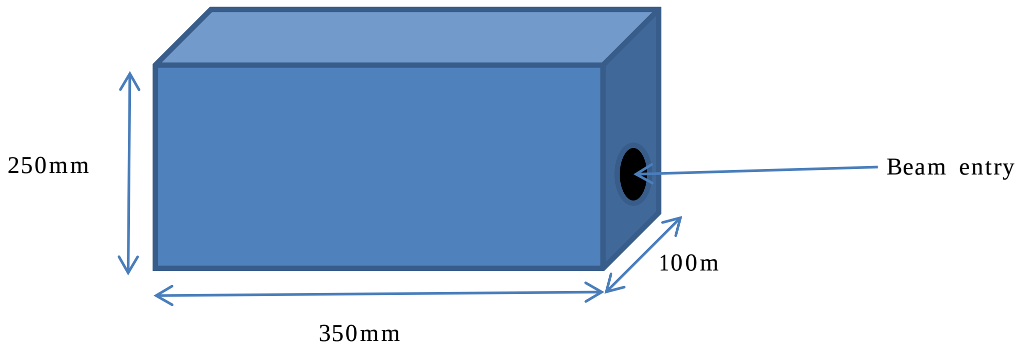


Figure 12 FGS dimensions

EIDA-R-1260. The PI shall consider a mass of the FGS module of less than 5kg (tbc) without margin

EIDA-R-1270. The PI shall consider a that the dissipation of the FGS inside the Instrument volume shall be less than 100mW at 55K (tbc)

EIDA-R-1280. The instrument shall provide a collimated beam to the FGS with an exit pupil diameter of 36.6mm ± tbd(tbc)

EIDA-R-1290. The PI shall distribute the light between the FGS and science instrument such that the average total throughput (all optical elements along the FGS channel's optical path, from primary telescope mirror down to optical interface including losses due to field stops) shall be ≥ 0.4 (tbc) in the wavelength band specified in EIDA-R-1300
Note: splitting the beam for the nominal and redundant FGS channel will be performed inside the FGS

EIDA-R-1300. The operational wavelength range of the FGS is tbd

4.7 Thermal Interface and Design Requirements

Note: chapter 4.7 in the EID-A is already tailored to EchO

4.7.1 *Definitions*

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.

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.

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

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

URP (Unit Reference Point): The URP is a physical point located on the instrument unit close to the mechanical interface to the spacecraft and defined in the unit MICD. Its temperature provides a simplified representation of the unit thermal behaviour and shall be given for the 3 following modes: at switch-on, when operating and when non operating.

Cold finger/ cold strap interface temperature
Temperature at which the heat is extracted by a cold finger/ cold strap

Radiative temperature
Virtual black body radiation temperature used to define the equivalent radiative thermal exchange with an instrument internally mounted

Calculated Temperature Range
This is the temperature range calculated for flight and/or test by means of thermal analyses.

Predicted Temperature Range
This is the temperature range predicted for flight and/or test. It shall be derived from the analytically calculated temperature range, at least extended on both ends by the temperature uncertainty.

Design Temperature Range
This is the maximum range of temperature experienced by a unit on ground and during the mission.

Acceptance Temperature Range
This is the temperature range to be achieved during the acceptance process that verifies the hardware workmanship under simulated conditions more severe than those defined by the design temperature range, at least by the acceptance margin.

Qualification Temperature Range
This is the temperature range to be achieved during the qualification process that verifies the compliance of all specified requirements under simulated conditions for acceptance extended by the qualification margin.

Design Temperature Margin
This is the remaining margin between the predicted temperatures and the design temperatures. Margins are positive, if the design temperatures are more severe than the predicted temperatures.

Acceptance Margin
Temperature offset between design temperatures and temperatures used for acceptance testing.

Qualification Margin
Temperature offset between acceptance temperatures and temperatures used for qualification testing.

Temperature Uncertainty
This is the aggregate inaccuracies of all parameters related to the computation of temperatures. It is calculated as the root sum square (RSS) of the environmental parameters, physical parameters and modelling parameters with variances specified by the ECSS and depending on project phase. Additionally a general modelling error has to be taken into account.

Switch-on Temperature
This is the lowest temperature at which a unit can safely be switched-on throughout the mission and during ground phases.

4.7.2 *Thermal Control Margins*

EIDA-R-1310. The PI shall ensure that the required **URP** temperature and margin are in line withFigure 13

EIDA-R-1320. The PI shall apply the acceptance and qualification margins given in the figure below during the unit thermal vacuum tests on all the instrument interfaces (radiative and conductive) and in all functional modes (operating, non-operating, switch-on)

EIDA-R-1330. The PI shall define in the EID-B, for thermally insulated units, the design temperature ranges shown in the figure below at the URP, including all the instrument margins and uncertainties due to the design and analysis maturity.

EIDA-R-1340. The PI shall assess the thermal uncertainties with a 99% (tbc) confidence level.

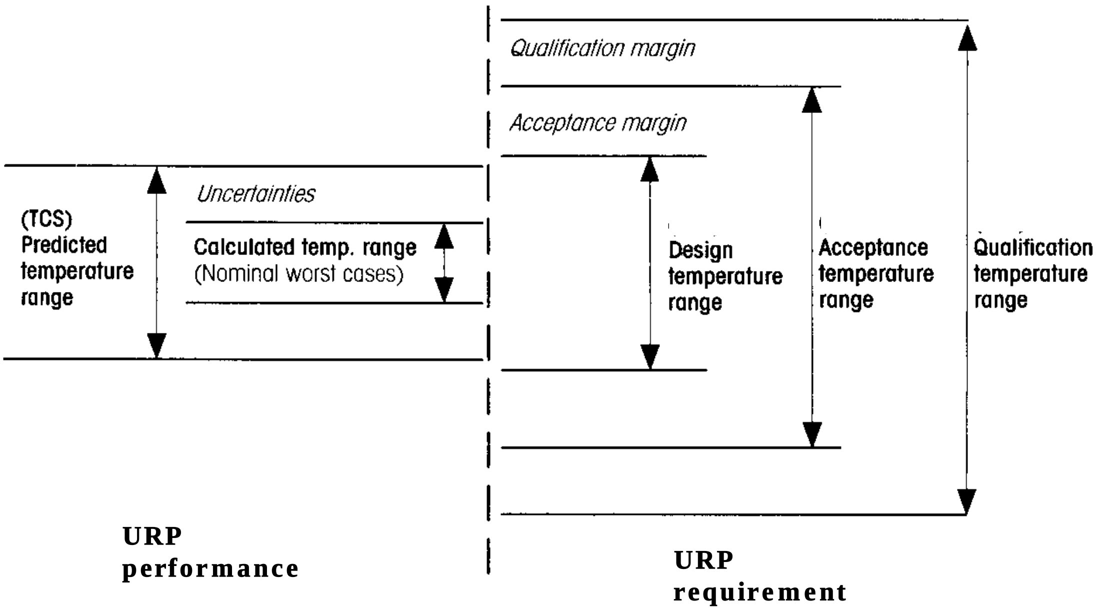


Figure 13 Temperatures and Margins requirements

EIDA-R-1350. For classical temperature range (-70C to +70C) the following is applicable:

- The acceptance margin is 5 °C in addition to the test temperature uncertainty
- The qualification margin is 5 °C in addition to the acceptance margin

EIDA-R-1360. For cryogenic temperatures (T < 200K), acceptance/qualification margins are tbd (based on the detailed design suitable margins in temperature and/or heat load need to be established)

4.7.3 *Thermal Control Responsibilities*

The Prime Contractor will :

- design the spacecraft TCS (ESVM and EPLM excluding Instrument box)
- maintain the URP temperature of thermally coupled instrument units within their design temperature limits at any time in the mission and during ground operations
- monitor the URP temperature
- define, procure and install the necessary thermal control H/W (heaters, thermostats, temperature sensors, heat-pipes) and control S/W (as far as necessary for control of the URP for thermally coupled units).
- provide data on the thermal environment of each payload unit demonstrating the performance of the TCS by analysis and test, including all uncertainties.
- provide the resources (monitoring and electrical power lines, control) for the external thermally insulated units survival heaters

The Instrument responsibilities will:

- Design the Instrument TCS located in the EPLM, covering :
  - the baffle/ thermal insulation, isolating the cold part of the instrument from the rest of the satellite
  - the cold finger/ cold strap (for FPAs, FEE, IOB cooling and active cryocooler pre-cooling),
  - active/passive cooling of the detectors below 50K

- Define and describe the unit internal thermal design with particular attention to:
  - the thermal control principles,
  - the hot/cold elements of the unit,
  - the thermal interfaces to the spacecraft.
- Define the URP location.
- Define the URP temperature and the temperature requirements of critical internal parts.
- Maintain the internal parts within their allowed temperature limits during:
  - the mission i.e. launch and flight,
  - ground phases,
  - unit level acceptance and qualification tests.
- Provide an Interface Geometric Mathematical Model (IGMM) and an Interface Thermal Mathematical Model (ITMM) for coupled thermal analysis with the spacecraft as specified in TBD section Thermal Mathematical Models.
- Procure the necessary instrument thermal H/W such as heaters, etc. to maintain the payload unit within the specified temperature limits.
- Provide the figures on the heat dissipated by the unit and report the interface heat flux in all relevant environments.
- Demonstrate the performance of the unit internal thermal design by analysis and test including uncertainties.

EIDA-R-1370. The PI shall define and describe the unit internal thermal design with attention to:

- the thermal control principles
- the baffle (if appropriate), the cold finger/ cold strap(if appropriate)
- the thermal interfaces with special attention to the cryogenic I/F's

EIDA-R-1380. 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,
- the ground phases,
- the unit level acceptance and qualification tests.

EIDA-R-1390. The PI shall procure and install the necessary instrument thermal H/W such as MLI, heaters, temperature sensors etc. to maintain the insulated units within the specified temperature limits.

EIDA-R-1400. The PI shall provide all data on the heat dissipated by the unit and report the interface heat flux in all relevant environments.

EIDA-R-1410. The PI shall demonstrate the performance of the unit internal thermal design by analysis and test including uncertainties.

4.7.4 *Thermal Design Requirements*

4.7.4.1 Generic requirements

EIDA-R-1420. The thermal design shall guarantee that the internal parts are maintained within their allowed limits at any time in the mission and during unit level acceptance and qualification tests.

EIDA-R-1430. The unit must be designed to remove its internally dissipated heat by conduction to thermal sinks provided by spacecraft (to be specified later), with the exception of active/passive detector cooling under the responsibility of the instrument.

EIDA-R-1440. The unit shall be in conductive contact with the thermal sinks provided by spacecraft (to be specified later) through a flat contact area. The contact area shall have roughness and planarity requirements specified in chapter 4.4.6.

EIDA-R-1450. The contact area shall be left unpainted.

EIDA-R-1460. Where cryogenic (active/passive) cooling of detector elements is required, the PI shall define the thermal design of the sensor and of its cooler in order to thermally insulate them from the rest of the unit.

4.7.4.2 Material and processes

EIDA-R-1470. Any material used for thermal control purpose shall be compatible with ECSS-Q-ST70-71 and with spacecraft prime contractor standards if more restrictive (will be detailed in this document if needed)

EIDA-R-1480. for which dismountability is required during integration and verification shall be removable without degradation of thermal characteristics

4.7.5 *Thermal Hardware Interfaces*

4.7.5.1 Temperature Sensor Interfaces

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

URP temperature sensors: Temperature sensor under the prime responsibility

EIDA-R-1490. The PI shall, for thermally insulated units, procure, install and test three (tbc) thermistors to be used for the control of survival heaters:.

Temperature values will be acquired by the spacecraft.

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

EIDA-R-1500. The PI shall, for thermally insulated units, acquire and provide the temperature in HK telemetry.

EIDA-R-1510. The PI shall route to external connector(s) the thermistors harness which shall be isolated from any other electronics within the unit.

4.7.5.2 Heaters Interfaces

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

EIDA-R-1520. The PI shall ensure that instrument heaters are redundant.

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.

EIDA-R-1530. 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. The PI shall define the power needed for survival heaters and include these numbers in a detailed instrument power budget.

EIDA-R-1540. The PI shall route to external connector(s) the survival heaters harness which shall be isolated from any other electronics within the unit

EIDA-R-1550. The PI shall define the operational temperature thresholds for the survival heaters, to be agreed on a case by case with the Prime Contractor.

The survival heaters will be operated by the S/C.

EIDA-R-1560. The PI shall ensure that the survival heaters can be operated by the 28 V (TBC) bus.

EIDA-R-1570. The PI shall ensure that the survival heater lines are sized for a minimum primary bus voltage of 26 V. (TBC).

EIDA-R-1580. The PI shall verify the correct sizing and operation of the survival heaters during the Instrument thermal Balance and Thermal Vacuum Test.

EIDA-R-1590. 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-R-1600. The PI shall ensure that, for the software controlled instrument heaters, the survival heaters' thresholds can be modified via telecommand.

4.7.6 *Thermal interface requirements*

Conductive interface - URP

EIDA-R-1610. 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-R-1620. The PI shall demonstrate by analysis that for coupled units, the URP temperature is representative of the unit average interface temperature.

EIDA-R-1630. 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-R-1640. The PI shall ensure that the I/F-attachment-points are at the instrument structure and mechanically coupled to the instrument.

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.

The Prime Contractor will be responsible for the thermal straps from the thermal interface points of an instrument to the radiators.

The Prime Contractor will be responsible for the thermal coupling across the interface between the thermal straps and the attachment points of the instrument.

EIDA-R-1650. 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 (TBC): this shall include all mechanical and thermal environments that the instrument is subjected to during AIV test and mission.

EIDA-R-1660. The PI shall assume a local force and torque generated by the thermal straps on the thermal interface attachment points of respectively 500 N (tbc) in any direction and 50 Nm (tbc) in any direction.

4.7.6.1 Cryogenic Conductive interface-V-Grooves

A cold strap interface to the V-Grooves can be taken into consideration to fulfil specific temperature requirements of the instrument.

EIDA-R-1670. The PI shall ensure that cryogenic thermal interface provide a single attachment point at the instrument side for a spacecraft-provided thermal strap that conductively links the instrument to the Cryogenic V-Groove thermal I/F.

EIDA-R-1680. The instrument requiring a cold strap I/F shall provide adequate mechanical interfaces, following the characteristics requirements ruled under section 4.4.6.

4.7.6.2 Radiative interface

EIDA-R-1690. For thermal analysis purposes of internally mounted units, the ESVM thermal environment shall be assumed as a black body cavity at a temperature equal to: Cold case: -20 Celsius (TBC), Hot case: +40 Celsius (TBC)

EIDA-R-1700. For thermal analysis purposes of internally mounted units, the EPLM thermal environment shall be assumed during nominal operation (excluding cooldown and bakeout) as a black body cavity at a temperature equal to:
V-Groove 3 and ECTA: Cold case: 35 Kelvin (TBC), Hot case: 55 Kelvin (TBC)
V-Groove 2: 90-110K (Tbc)
V-Groove 1: 140-150K (tbc)
Note: Elements routed through the V-grooves shall be considered as internally mounted units

EIDA-R-1710. For thermal analysis purposes of the cryogenically cold instrument box, the EPLM thermal environment shall be assumed as a black body at a temperature equal to as shown in the figure (tbc) below:
Cold case: 35 Kelvin (TBC), Hot case: 55 Kelvin (TBC) during nominal operation (excluding cooldown and bakeout)

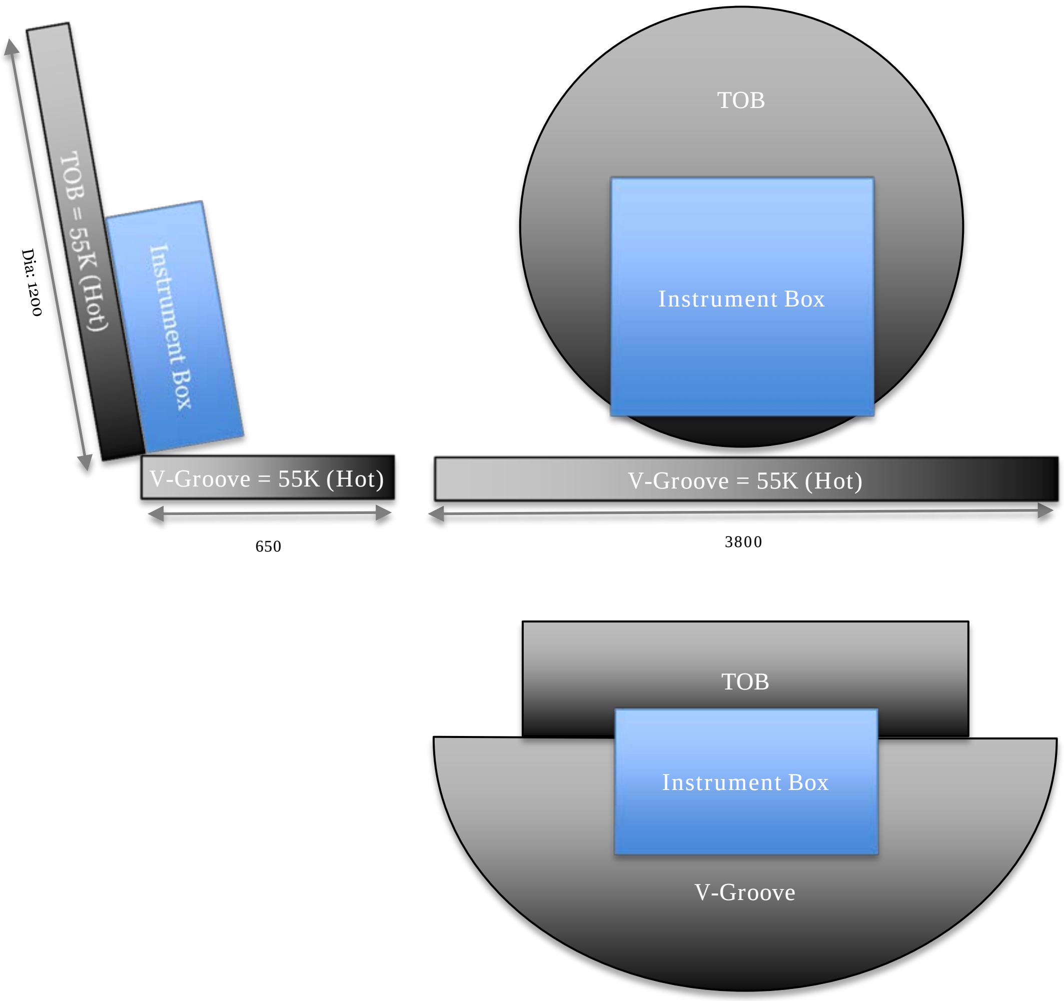


Figure 14 Radiative thermal environment EPLM

4.7.6.3 Conductive interface- Temperature range

EIDA-R-1720. For coupled units, the following temperature ranges shall be used for thermal design and analysis of the instrument and shall be understood as design temperatures:

Internal units ESVM:
Operational: -20 Celsius/+50 Celsius (TBC)
Non operational -30 Celsius/+60 Celsius (TBC)
Stability TBD

EPLM:
V-Groove 3 and ECTA: Cold case: 35 Kelvin (TBC), Hot case: 55 Kelvin (TBC)
V-Groove 2: 90-110K (Tbc)
V-Groove 1: 140-150K (tbc)
Stability tbd

The I/F temperature agreed by the Prime Contractor are TBD.

4.7.6.4 **Heat fluxes**

4.7.6.4.1 Environmental heat loads

EIDA-R-1730. The environmental heat loads on the instrument shall be calculated for the different phases of the mission as defined in EIDA-R-4710 on the basis of environmental constraints given in section 4.7.7. Maximum cases shall be evaluated as well as orbit average steady state for orbital phases. The values shall be reported in the EID-B.

4.7.6.4.2 Unit dissipated heat loads

EIDA-R-1740. The PI shall report in the EID-B the power dissipated by an instrument unit in the following conditions:

(1) Steady levels corresponding to the different instrument unit modes with BOL/EOL conditions.
(2) Timelines of variable power corresponding to the instrument unit modes with BOL/EOL conditions.

Applicability of 1 and 2 to various mission phases as defined in EIDA-R-4710

Definition of nodes where to input data (1) and (2) in the unit TMM (as defined in 6.3.3.2.)

4.7.6.4.3 Heat load budget

The heat load budget defines the amount of heat that can be transferred (conductively and radiatively) between the instrument and the spacecraft.

The conductive heat exchange budget applies at the interface between the instrument unit and the spacecraft and includes the conductive heat through the harness.

EIDA-R-1750. The heat load budget including margins within the ESVM shall be defined in each instrument EID-B.

EIDA-R-1760. The heat load budget including margins within the EPLM shall be lower than:

Thermal I/F	No Sorption cooler		Sorption cooler on VG3		Sorption cooler on VG1/2		Comment
	T [K]	Heatload	T [K]	Heatload	T [K]	Heatload	
Cryo I/F IOB to 3rd V-groove	45K	300mW (tbc)	55K	300mW (tbc)	55K	300mW (tbc)	IOB/telescope temperature dependent on applied heatload on V-Grooves 1/2/3
3rd V-Groove	45K	150mW (tbc)	55K	3150mW (tbc)	55K	150mW (tbc)	Additional I/F for thermalisation harness/ pipe/ sorption cooler etc.
2nd V-Groove	90K	100mW (tbc)	90K	100mW (tbc)	110K	3000mW (tbc)	
1st V-Groove	140K	100mW (tbc)	140K	100mW (tbc)	150K	5000mW (tbc)	

Table 13 EPLM instrument heat load budget

EIDA-R-1770. The margins on the heat load budget shall be derived from a sensitive analyses considering as a minimum the following uncertainties:
design:

- Electrical dissipation +/-30%
- Conductance of Kevlar, Composite or Plastic materials +/-30%
- Conductance of Metallic Material (except Harness) +/-15%
- Conductance of Harness +/-30%
- Multi Layer Insulation (MLI) efficiency +/-50%
- Contact Resistance +/-50%
- Uncertainties on Emissivities:
  - High Emissivity (>0.2): +/-0.03
  - Low Emissivity (<0.2): +/-0.02
- Uncertainties on Interface Temperatures:
  - Above 270K: +/-5K
  - Between 80K and 270K +/- 3K
  - Between 20K and 80K +/- 1K
  - Between 10 and 20K +/- 0.5K
- Uncertainties on aging effects: if aging effects are identified (e.g. know
  - contamination), +/-10% shall be applied on the effect of the aging (e.g. if a cooler provides 10mW less cooling power in EOL than in BOL, the aging uncertainty is +/-1mW).

4.7.6.4.4 *Active/passive detector cooling*

EIDA-R-1780. For temperatures between 35K and 45K required by the instrument (e.g. detector cooling), an instrument provided radiator mounted on the IOB shall be considered with an area of less than $0.6m^2$, viewing deep space.

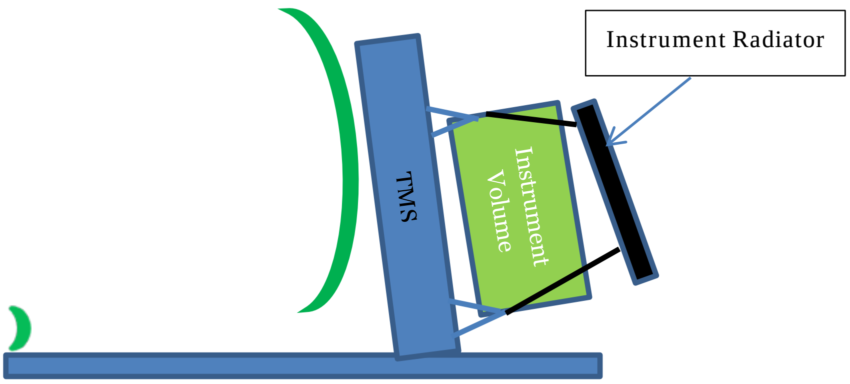


Figure 15 Example of Instrument Radiator accommodation

EIDA-R-1790. The different focal plane detectors and intermediate temperature levels that are actively cooled by a common cryo-cooler shall be connected to a common I/F on the IOB (i.e. the cryo-cooler cold finger) by thermal straps, and cannot be separated by more than 500 mm from each other and shall be located on the IOB.

EIDA-R-1800. The following System level margin for active/passive cooling systems shall be applied by the PI:
- Passive cooling: +15% on Radiator Surfaces to be considered for accommodation.
- Active cooling: the design of the Cryogenics Subsystem shall demonstrate 15% margin on the available cooling power

4.7.7 *Environment Requirements*

4.7.7.1 Launch Thermal Environment

EIDA-R-1810. The PI shall design each unit to cope with the thermal fluxes given below, during launch and ascent.

Under fairing
Duration: 3 min (TBC)
Direction on any surface of the satellite
Flux < 1000 W/m²
After fairing jettison (aerothermal)
Direction: perpendicular to velocity vector
Duration 20 s (TBC)
Flux < 1135 W/m²

4.7.7.2 On-orbit Thermal Environment

EIDA-R-1820. The PI shall analyse the environmental heat loads and heat exchanged with the spacecraft surfaces by considering the following inputs:

Deep space temperature -270°C
Solar intensity at 1 AU SC=1366 ± 3 W/m²
Sun collimation

Half-cone angle = $\tan^{-1}\dfrac{R_S}{d_S}$

with R_s: radius of the Sun and d_s distance to the Sun

EIDA-R-1830. The PI shall define clearly any required avoidance angles, such as instrument apertures, which are sensitive to exposure to direct sunlight.

4.8 Electrical Interface and Design Requirements

Note: chapter 4. 8 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO, except EIDA-R-1920 already tailored for EChO

4.8.1 *Power Generation and Distribution Architecture*

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.

Independently of the mission phase instrument units will receive regulated (TBC) 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 tbd types of power interfaces normally in cold redundancy.

4.8.2 *Instrument Power Supply*

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.

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.

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.

EIDA-R-1840. The PI shall calculate average power value per power line for all operating modes.

EIDA-R-1850. The PI shall calculate long and short peak power values per power line and the time needed for those peak power values.

EIDA-R-1860. The PI shall provide a power profile for units that operate in cycles of longer than 1 second.

EIDA-R-1870. The PI shall develop, keep up to date and provide the EChO 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-R-1880. The PI shall specify, for each unit power budget, the Basic Power.

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

EIDA-R-1890. The PI shall specify, for each unit power budget, the Nominal Power.

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.

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

EIDA-R-1910. The PI shall specify, for each unit power budget, the power margin

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

EIDA-R-1920. Instrument shall be compliant with the following power allocation:

Instrument	Standby power (W)	Survival heater power (W)	Peak power (W)	Average power (W)
ICU	Tbd	Tbd	Tbd	100
Cooler including Drive Electronics	Tbd	Tbd	Tbd	250
Others	Tbd	Tbd	Tbd	Tbd

Table 14EChO instrument power allocation. The instrument complement indicated in this table is as extracted from RD01and may be subjected to change pending the outcome of the Payload review committee after the AO review.

EIDA-R-1930. Instrument shall implement the following power margin philosophy:

- 20 % at SRR
- 15 % at PDR
- 10% at CDR

EIDA-R-1940. The PI shall ensure that the instrument switches-on by receiving the regulated voltage input plus a dedicated HVC-HPC telecommand which acts on an Instrument internal switch.

EIDA-R-1950. Instrument shall remain off at LCL switch on and until commanded by the pulse command to switch on.

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

EIDA-R-1960. The PI shall ensure that the instrument operate with nominal performance within the following steady state voltage limits provided by the PCDU:

- Power Bus Voltage = 28 V:
- Min: 26 V
- Max: 29 V

This applies for both Main and Redundant Lines.

EIDA-R-1970. The PI shall ensure that each unit safely survive any standing or fluctuating voltage in the full range 0 V to TBD V of the power lines.

EIDA-R-1980. 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 (TBC).

EIDA-R-1990. The PI, in case of power off/on cycling, shall ensure that instrument computers reset and restart operations in line with TBD.

4.8.3 *Power Interface Requirements*

EIDA-R-2000. The PI shall design the instrument power interfaces assuming that the spacecraft will provide two independent power lines routed via two dedicated connectors.

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

EIDA-R-2010. 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-R-2020. The PI shall ensure that the instrument survives an instantaneous short circuit occurring on the external power line.

EIDA-R-2030. 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-R-2040. The PI shall ensure that the initial electrical status (directly after powering up) of each payload unit is safe (i.e. no degradation of nominal performance, caused if this initial electrical status is kept for an unlimited time) .

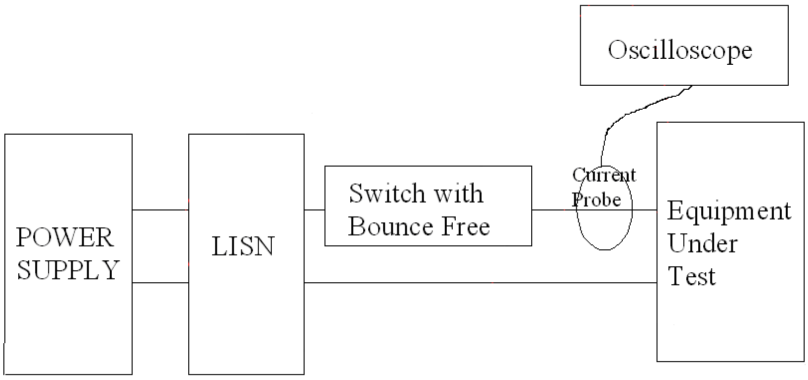
EIDA-R-2050. The PI shall measure the Ipeak, the dI/dt and inrush current considering the maximum and the minimum bus voltage to the loads

EIDA-R-2060. The PI shall measure the inrush current according to the following set-up

- positive power line of each user connected to LCL.
- current probe connected near the load
- load connections with a limited length.
- voltage measure performed near the LISN outlet; performed for engineering analysis / investigation.

EIDA-R-2070. The PI shall ensure that the unit are powered by using the Line Impedance Stabilisation Network (LISN) when switching it ON 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 below.

The Prime Contractor will specify the LISN characteristics. The LISN will be provided by the PI.



In-rush Current Test Setup

EIDA-R-2080. The use of current limiters shall be avoided . Use of current limiters shall be subject to approval by the EChO project office.

All power lines are protected by LCLs. Current limiters at this interface should be avoided in order to prevent oscillations.

EIDA-R-2090. If current limiters are used with a payload unit the PI shall:

- verify the stability of current limiters by analysis under worst case conditions
- test the stability of current limiters under a TBD set of cases.
- 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.

EIDA-R-2100. The PI shall ensure that the cross-over of the 0 dB line in open loop measurement is in one single point only.

The Prime Contractor will 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.

The Prime Contractor will ensure that the power distribution system does not generate spike with peak greater than ±3Vp.

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

EIDA-R-2110. The PI shall ensure that for all conducted emission and susceptibility tests on subsystem and unit level a LISN is used, simulating the EChO primary power bus impedance.

EIDA-R-2120. The PI shall ensure that the isolation between primary and secondary power lines in the instrument is ≥ 1 MOhm.

EIDA-R-2130. The PI shall take provisions , for equipment supplying secondary power to sensor units, that this unit can be powered without the presence of the sensor units.

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

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

4.9 Data Management Interface and Design Requirements

Note: chapter 4. 9 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO, except EIDA-R-2140 already tailored for EChO

4.9.1 *General*

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

- Mission control (including Mission Timeline, FDIR, OBCPs)
- Receiving and Dispatching Telecommands (from both Ground and onboard sources)
- Platform S/Ss management (including power, thermal and TTC)
- Collecting, storing and transmitting to Ground all telemetry data (i.e. science data and non-science data originated both from the Platform and the Instrument).
- Time Management, including onboard time distribution

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).

The DMS consists of the On-Board Computer (OBC), the Solid State Mass Memory (SSMM) and the Spacewire point-to-point network and potential other data/control lines.

EIDA-R-2140. The average instrument data budget transmitted to the S/C shall not exceed 35Gbit/week (tbc)

EIDA-R-2150. 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 (TBC) according to-[RD20].
It is under discussion whether for efficiency reasons science data shall be stored as files directly in the SSMM by the instruments.

EIDA-R-2160. The PI shall ensure that the instrument comply to the associated TM-/ TC-Packet Services specified as mandatory for the payload in TBD.

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 EChO spacecraft are given TBD.
The mandatory services are as follows:

- Service 1: Telecommand Verification Service
- Service 3: Housekeeping and Diagnostic Data Reporting Service
- Service 5: Event Reporting Service
- Service 6: Memory Management Service
- Service 9: Time Management Service
- Service 17: Test Service
- Service 20: Information Distribution Service
- Service 21: Science Data Transfer

EIDA-R-2170. The PI shall be in general compliant to and implement the specific physical interface between the DMS and the instrument using SpaceWire links (SpaceWire - Links, nodes, routers and networks) or1553 (TBC)

EIDA-R-2180. The PI shall be compliant to the 'CCSDS packet transfer protocol'

EIDA-R-2190. The PI shall provide the possibility for 'file transfer' of science data to the spacecraft telecom subsystem (tbc)
Note: This possibility has not yet been assessed for EChO. When addressing this issue the following point should be considered:
- *file management may need extension of PUS services (with implications on board and at ESOC/ESAC and potentially for the instruments)*
- *file structure should be in line with post processing needs (at ESAC).*

- Common approach to science data file structure with other ESA future science missions.

- addition of metadata to the files to reduce the management overhead for later processing.

EIDA-R-2200. The PI shall implement own computing functions, without relying on any spacecraft OBC support for all required functionality not covered by the services stated in TBD.

4.9.2 *Instrument Commanding*

EIDA-R-2210. The PI shall comply with the requirements regarding commanding as specified in TBD.

The Prime Contractor will 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.

EIDA-R-2220. The PI shall ensure that the instrument can fulfil its scientific objective with Telecommand rate of TBD Telecommand / week.

EIDA-R-2230. The PI shall ensure that the instrument can accept 2 telecommands separated by a minimum delay of TBD seconds.

EIDA-R-2240. The PI shall manage and perform their nominal mode-transitions without needing more than one telecommand.

EIDA-R-2250. The PI shall implement the execution of vital instrument functions and non-reversible functions by 2 separate commands (i.e. arm and fire).

Vital instrument functions are those functions that, if not executed or wrongly executed, could cause permanent degradation.

EIDA-R-2260. The PI shall ensure that telecommand are available in order to command all instrument units, functions and devices under all nominal and foreseen contingency conditions.

EIDA-R-2270. The PI shall ensure that each telecommand packet contain one and only one telecommand function, as specified in [RD20].

EIDA-R-2280. The PI shall ensure that the on-board reception, processing and execution of telecommand does not affect other independent instrument processes.

EIDA-R-2290. The PI shall ensure that if a telecommand is found to be invalid, the Instrument generate an error report in the form of a Service 1 packet, in line with the specifications in [RD20].

EIDA-R-2300. The PI shall ensure 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 affect the complete Safe configuration of that instrument, including individual units and subassemblies.

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

EIDA-R-2310. The PI shall implement **c**ommand counters for accepted and rejected telecommands. The value of these counters will be reported in tbd

EIDA-R-2320. The PI shall ensure that the execution of every telecommand is verifiable through a resulting change in the value of a Telemetry parameter."

4.9.3 *Instrument Telemetry*

EIDA-R-2330. The PI shall comply with the requirements regarding telemetry as specified in the section 2.1.4.3 and section 3 of the [RD20].

EIDA-R-2340. The PI shall ensure that telemetry is routed from the instrument as Telemetry Source Packets according to ECSS-E-70-41A, [RD20].
Note: File management could be an option

EIDA-R-2350. The PI instrument shall generate, during initialisation and during Stand-by / Safe mode, periodic HK TM-packets at a rate of 50 bps maximum (TBC)

EIDA-R-2360. The PI instrument shall generate, in any mode different from initialisation and Stand-by / Safe mode, periodic HK TM-packets at a rate of tbd bps maximum (TBC).

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

EIDA-R-2370. The PI shall ensure that no science telemetry is transmitted to the spacecraft during initialisation and during Stand-by / Safe mode

EIDA-R-2380. The PI shall support the generation of periodic HK-telemetry at any time any unit of the instrument is switched on.

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

EIDA-R-2390. The instrument shall provide ground with the instrument housekeeping 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-R-2400. 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-R-2410. The instrument 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-R-2420. Any compression or other on-board processing of instrument telemetry data shall be performed by the instrument prior to transmission to the spacecraft for storage / download.

EIDA-R-2430. 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:

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

The spacecraft on-board computer is not responsible for processing or compression of payload data.

EIDA-R-2440. 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-R-2450. The PI shall provide unit(s) status information in telemetry from direct unit(s) measurements, rather than from secondary effects.

EIDA-R-2460. The PI shall ensure that the values of telemetry parameters are self-contained.

EIDA-R-2470. The PI shall transmit the value of a telemetry parameter in contiguous bits within one packet.

EIDA-R-2480. The PI shall ensure that, if compression is applied, all data also in raw format can be transmitted to the spacecraft data management system (e.g. for diagnostic purposes).

EIDA-R-2490. The PI shall ensure that if compression can be applied, it can be switched- off

EIDA-R-2500. Instrument shall be compliant with the following telemetry allocation:

Instrument subsystem	Acronym	TM [kbps] Max
ICU	ICU	Tbd

Table 15EChO instrument telemetry allocation. Subjected to change pending the outcome of the Payload review committee after the AO review.

4.9.4 *Onboard Time Distribution*

EIDA-R-2510. The instrument shall comply with the requirements regarding Timing as specified in TBD

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

EIDA-R-2520. If SpaceWire is used, the PI shall ensure the instrument synchronises its local time with the spacecraft in accordance with the SpaceWire standard.

The Prime Contractor will distribute the system time, CTR, with an accuracy of 100 µs (TBC)

EIDA-R-2530. The instrument shall increment its local time autonomously.

EIDA-R-2540. The instrument shall report, on request, the instrument local time.

4.9.5 *Solid State Mass Memory*

The S/C will store all the scientific data generated by the instrument, as well as the housekeeping data and non-periodic report-data in a Mass Memory for their downloading.

EIDA-R-2550. The PI shall ensure that the instrument design complies with the data storage volume of TBD.

EIDA-R-2560. The PI shall provide information if a direct link from instrument to the SSMM of the spacecraft is needed.

EIDA-R-2570. The PI shall provide for a ‘file management’ capability when transferring data from the instrument to the spacecraft SSMM.

4.9.6 *Electrical Interfaces and Redundancy*

EIDA-R-2580. The PI shall support, for redundancy, two independent communication (e.g. SpaceWire) lines addressed and routed separately from/ to the spacecraft (e.g. DMS).

Only one of the two communication links will be active at a given time.

4.9.7 *SpaceWire Interface*

EIDA-R-2590. The PI shall comply with the electrical specifications of a SpaceWire Link Interface as defined by the ECSS-E-ST-50-12C [RD18] for:

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

EIDA-R-2600. The PI shall ensure that the spacewire drivers and receivers use a nominal supply voltage of 3.3V.

EIDA-R-2610. 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-R-2620. The PI shall implement transmission buffers compatible with:

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

EIDA-R-2630. The PI shall establish a connection on the S/C SpaceWire link after power ON.

EIDA-R-2640. The PI shall establish a connection on both prime and redundant SpaceWire/communication link, both SpaceWire/communication links shall be supported (prime and redundant) regardless of the power I/F being used (i.e. internally non-redundant units, or internally cross-coupled units).

EIDA-R-2650. The PI shall try to establish a connection on both prime and redundant SpaceWire/communication links, both SpaceWire/communication links shall be supported (prime and redundant) regardless of the power I/F being used, if a persistent SpaceWire/communication link error happens (e.g. preventing the instrument to transmit TM packets).

EIDA-R-2660. 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.

The Prime Contractor will 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.

This applies as well for routing of any TC- or TM-data to a test-interface during spacecraft AIVD: Packets stored in the SSMM may be subject to on-board latencies of up to 10s.

4.9.8 *1553 Bus*

The use of the 1553 bus can be considered by the instrument teams.

4.9.9 *Discrete Signals*

EIDA-R-2670. The PI shall implement all standardized discrete electrical signals, as listed below, according to ECSS-E-ST-50-14C, Spacecraft discrete interfaces [RD19]

EIDA-R-2680. 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 [RD19]

These commands will be used to switch ON/OFF the main power of the Instrument.
Pulse lengths will be in the range of 32 - 64 ms.

EIDA-R-2690. 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 [RD19]

Bi-level Switch Monitor interfaces will be used to report the status of the above commands (status ON/OFF).

4.10 Software Design and Interface Requirements

Note: chapter 4. 10 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO

EIDA-R-2700. The PI shall comply with the requirements regarding Onboard Processors, Software and Memory Management as specified in [TBW].

4.10.1 *Software Design Requirements*

EIDA-R-2710. The PI shall ensure that all instrument on-board software comply with the software standard ECSS-E-40C [RD17].

EIDA-R-2720. The PI shall assign functionally distinct areas of memory to:

- code;
- fixed constants;
- variable parameters.

Needed in view of the in-flight software maintenance

EIDA-R-2730. The PI shall ensure that minimum boot software reside in PROM.

EIDA-R-2740. The PI shall ensure that the instrument system and application software reside in non-volatile memories.

EIDA-R-2750. The PI shall ensure that all instrument functions are accessible from the minimum boot state including EEPROM updates, or any direct hardware test functions.

EIDA-R-2760. 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-R-2770. 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-R-2780. The PI shall ensure that the instrument software do not cause erroneous operation creating a safety hazard.

EIDA-R-2790. 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-R-2800. 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.

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).

EIDA-R-2810. The PI shall provide the capability to check that on-board software has been correctly uploaded before enabling it.

The PI will ensure that enabling of on-board software is carried out by a single telecommand.

EIDA-R-2820. 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-R-2830. 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-R-2840. The PI shall generate an event report whenever a processor overload condition is detected,

EIDA-R-2850. The PI shall generate an event report whenever an unexpected arithmetic overflow condition is detected.

EIDA-R-2860. The PI shall generate an event report whenever an illegal program instruction is encountered during execution of a program code.

EIDA-R-2870. The PI shall generate an event report whenever a data bus error is detected by software.

EIDA-R-2880. The PI shall generate an event report whenever a memory corruption is detected by an error detection and correction mechanism.

EIDA-R-2890. The PI shall generate an event report whenever a checksum error is detected. .

EIDA-R-2900. The PI shall ensure that the software is structured in modules.

EIDA-R-2910. The PI shall ensure that the software can load and check redundant memory prior to operational utilization.

EIDA-R-2920. 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.

4.10.2 *Software Implementation Requirements*

EIDA-R-2930. The PI shall ensure that the SpaceWire Link implementation up to the packet & network levels is compliant with the relevant SpaceWire ECSSs, [RD17, RD18].

EIDA-R-2940. The PI shall develop the on-board software using a high level language. ('C' or 'ADA' languages are recommended).

The PI shall ensure that the Software Development Environment used to develop the on-board software is properly identified and documented for each software delivery.

4.10.3 *Instrument Autonomy and FDIR*

4.10.3.1 Instrument operation modes

EIDA-R-2950. Instrument Operations shall be defined in terms of clearly identifiable operating modes. A distinct logical operating mode shall be defined if any of the following conditions apply to the instrument actual mode of operation:

- Mode results in a significant change in demand on spacecraft resources (e.g. power; data rate)
- Mode requires a specific spacecraft operational status (e.g. thermal environment; pointing; specific DMS functions)
- Mode results in a functionally distinct operating mode of the unit (e.g. calibration function; standby; software maintenance)

An operational mode represents an operationally well- defined and, within certain limitations, a stable configuration as concerns mechanical, thermal, electrical and functional conditions.
Modes are defined on an appropriate level and form operational entities, which are defined by a list of conditions.

It is recommended to use the following modes nomenclature and definitions, in order to allow a common approach:
OFF:
This mode is defined by power consumption equal zero

Stand-by Mode
After switch-on the software shall be initialized and enter a safe state which allows to verify the health of the instrument, with the software running in RAM after being transferred from PROM (where applicable)

Safe Mode
This mode shall always be automatically entered when an instrument or a system failure case occurs. The instrument shall be able to survive in this mode indefinite time before ground intervention has to occur

Configuration Mode
This mode is defined by the actions connected to it, i.e. configuration from ground / timeline or by retrieval of context information

Diagnostic Mode:
This mode is an engineering mode, in which the instrument is put in a safe operational mode allowing investigations and diagnostic, both for software and hardware problem solution.

Science Modes (one or more)
One or more scientific modes shall be identified according to instrument needs. Within a scientific mode only one scientific Software task shall be scheduled.

Memory / Software maintenance Mode
Memory Load is a critical event in the operational scenario and shall be carefully evaluated. Note: The total number of modes should be minimised if possible. The mode concept should be such that operation is as simple as possible.

EIDA-R-2960. The instrument modes shall be clearly identified in terms of both hardware and software.

EIDA-R-2970. The instrument telemetry shall provide unambiguous identification of the modes and mode transitions.

EIDA-R-2980. After being powered-up, each instrument shall have a safe and well-defined initial mode that is fully reproducible.

EIDA-R-2990. Initialisation of an instrument mode shall include configuration of the necessary hardware, activation of a default periodic telemetry configuration, and all the automatic processes required to achieve the objectives of the mode.

EIDA-R-3000. The instrument logic shall ensure that forbidden mode transitions are not possible.

EIDA-R-3010. It shall be possible to command the instrument into each of its pre-defined operation modes by means of a single telecommand. This shall be only true for allowed mode transitions.

4.10.3.2 Generic requirements

EIDA-R-3020. 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-R-3030. The PI shall implement a connection test service (Service 17) according to the specifications given in [TBW].

EIDA-R-3040. The PI shall ensure that the Instrument provides the capability to perform self-checks on command and at power on.

EIDA-R-3050. The PI shall ensure that entering a test mode does not require (or imply) disabling of fault management functions.

EIDA-R-3060. 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.

It is recommended that all parameters used for Instrument autonomous operations are updateable by dedicated telecommand and available in Instrument HK telemetry.

EIDA-R-3070. 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)
- Mode requires a specific spacecraft operational status (e.g. thermal environment; pointing; specific DMS functions)
- Mode results in a functionally distinct operating mode of the unit (e.g. calibration function; standby; software maintenance)

An operational mode represents an operationally well-defined and, within certain limitations, a stable configuration as concerns mechanical, thermal, electrical and functional conditions.

EIDA-R-3080. The PI shall provide for each defined mode, the corresponding average and/or peak power consumption and nominal/average science data rate.

EIDA-R-3090. The PI shall provide the peak data rate and typical / peak duration in case science data are generated in burst.

EIDA-R-3100. The PI shall ensure that telemetry provides unambiguous identification of the modes in periodic HK telemetry and mode transitions in event telemetry.

EIDA-R-3110. The PI shall ensure that after power-up, each instrument have a safe and well-defined initial mode that is fully reproducible.

EIDA-R-3120. 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
- description of the hierarchical structure of the autonomous fault management functions
- identification of the autonomy functions implemented in the instrument and of those for which spacecraft autonomy support is required.
- justification of the above selection
- identification of mission-phase related autonomy functions and their relation with ground control

EIDA-R-3130. The PI shall ensure that the instrument is ready to accept command within 1 second after the boot event has been generated.

The time between instrument switch-on and completion of booting initialisation may last several seconds.

EIDA-R-3140. The PI shall ensure that each unit enables the generation of its default housekeeping report, after successful boot-up and time synchronization

EIDA-R-3150. 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 (tbc).

EIDA-R-3160. The PI instrument shall report successful boot up via an event packet.

EIDA-R-3170. The PI shall detail the relevant anomaly contingency procedures in the instrument user manual.

4.10.3.3 Instrument FDIR at Equipment Level

EIDA-R-3180. The PI instrument shall provide autonomous fault detection and recovery capabilities for all failures which can be managed internally at unit/equipment level by the HW/SW.

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.

EIDA-R-3190. The PI instrument shall report in event packets anomalies and autonomous actions taken to recover from them.

EIDA-R-3200. The PI instrument shall report in instrument HK telemetry all the mode transitions and reason of them

EIDA-R-3210. The PI shall ensure that the conditions leading to the generation of an event, can be reconstruct from HK telemetry.

EIDA-R-3220. The PI shall ensure that each individual Instrument fault management function can be enabled / disabled from ground.

EIDA-R-3230. The PI instrument shall report in periodic HK telemetry the current status of each individual instrument fault management function.

EIDA-R-3240. 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-R-3250. The PI shall ensure that telecommands can enable/disable autonomous entry and can force manual entry into Standby Mode (or Safe Mode).

EIDA-R-3260. The PI shall ensure that autonomous entry to Standby (or Safe) mode is enabled by default at power on.

EIDA-R-3270. The PI shall ensure that instrument Fault management functions are not trigger by one single sample of a parameter.

EIDA-R-3280. 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-R-3290. The PI shall ensure that no fault management function is triggered on test data generated while running in diagnostic/test mode.

4.10.3.4 **Instrument FDIR at System Level**

EIDA-R-3300. 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 2 hours.

EIDA-R-3310. The PI shall identify unambiguously situations in non-science telemetry in which the ground is expected to react within 24 hours, without the need for complex processing on ground.

EIDA-R-3320. The PI shall define (if any) the set of events to be monitored by the on board computer autonomously, together with the associated reactions.

Both events and reactions will be documented in the EID-B.

EIDA-R-3330. The PI shall define (if any) the set of events to be monitored by the Mission Operations Centre.

EIDA-R-3340. 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-R-3350. The PI shall define the basic instrument safety requirements related to unexpected interruption of nominal operations due to spacecraft entering safe mode.

The basic instrument safety requirements should 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.

4.10.3.5 **Autonomy**

EIDA-R-3360. The PI shall ensure that the instrument is able to operate safely (standby mode or non-science operation such as diagnostic mode as defined in section 4.10.3.1) for a minimum of 11 days (tbc) without ground intervention.

EIDA-R-3370. The PI shall ensure that the instrument is able to operate in science mode for at least 7 days without ground intervention.

4.11 Electromagnetic Design and Interface Requirements

Note: chapter 4. 11 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO

4.11.1 *General Concept*

The EMC requirements are levied to guarantee the system performances and the required electromagnetic environment at payload level.

Generic EMC requirements are described in the following paragraphs

4.11.2 *General EMC requirements*

The requirements herein specified are a baseline, not necessarily comprehensive at this stage, which should be used as a starting point to tailor the EMC specification.

EIDA-R-3380. The PI shall develop an instrument EMC Control Plan according to ECSS-E-ST-20C, [RD09].

EIDA-R-3390. The Prime Contractor will ensure that a controlled grounding and isolation concept is defined for the spacecraft prior to initial release of the EMC control plan.

EIDA-R-3400. The PI shall be compliant with the grounding and isolation concept defined by the prime contractor

EIDA-R-3410. The PI shall implement electromagnetic interference safety margins as specified in ECSS-E-ST-20C [RD09] for all critical signals, pyrotechnics, and power circuits under all operating conditions.

The minimum acceptable safety margins shall be 6 dB for power and signal circuits and 20 dB for pyrotechnic circuits.

EIDA-R-3420. 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-R-3430. The PI shall ensure that bonding provisions are compatible with other requirements imposed on the spacecraft for corrosion control.

EIDA-R-3440. 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, [RD09].

4.11.2.1 Spacecraft charging

The Prime Contractor will exercise control on spacecraft charging according to paragraph 4.2.4 of ECSS-E-ST-20-07C [RD11] which calls application of ECSS-E-ST-20C [RD09] and ECSS-E-ST-20-06 [RD10].

4.11.2.2 Spacecraft dc magnetic emission

EIDA-R-3450. The PI shall comply with the relevant requirements, as defined in paragraph 4.11.2.1 and paragraph 4.2.5 of ECSS-E-ST-20-07C [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in paragraph 4.11.2.1 and paragraph 4.2.5 of ECSS-E-ST-20-07C [RD11].

4.11.2.3 Radio Frequency compatibility

EIDA-R-3460. The PI shall comply with the relevant requirements, as defined in paragraph 4.2.6 of ECSS-E-ST-20-07C [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in paragraph 4.2.6 of ECSS-E-ST-20-07C [RD11].

The Prime Contractor will prepare an RFC analysis as part of the EMC control plan, identifying risk frequencies.

EIDA-R-3470. **T**he PI shall provide relevant inputs, in order to allow the Prime Contractor to prepare an RFC analysis as part of the EMC control plan,.

The Prime Contractor will verify the absence of intermodulation interference by a combination of analysis and test.

4.11.2.4 EMC with ground support equipment

EIDA-R-3480. The PI shall comply with the relevant requirements, as defined in paragraph 4.2.9 of ECSS-E-ST-20-07C [RD11].

The prime contractor will comply with the relevant requirements, as defined in paragraph 4.2.9 of ECSS-E-ST-20-07C [RD11].

4.11.2.5 Grounding and Isolation

EIDA-R-3490. The PI shall comply with the relevant requirements, as defined in paragraph 4.2.10 in ECSS-E-ST-20-07C [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in paragraph 4.2.10 in ECSS-E-ST-20-07C [RD11].

EIDA-R-3500. The PI shall ensure that each electrical equipment chassis can be bonded to structure with a resistance of less than 5mOhm.

4.11.2.6 Electrical Bonding and Case shielding

EIDA-R-3510. The PI shall comply with the relevant requirements, as defined in paragraph 4.2.11 of ECSS-E-ST-20-07C [RD11] and Paragraph 6.3 of ECSS-E-ST-20-06C [RD10] and.

EIDA-R-3520. The Prime Contractor will comply with the relevant requirements, as defined in paragraph 4.2.11 of ECSS-E-ST-20-07C[RD11] and Paragraph 6.3 of ECSS-E-ST-20-06C [RD10].

EIDA-R-3530. 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.

EIDA-R-3540. 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-R-3550. The PI shall ensure that exposed, insulating dielectrics are avoided. Higher surface resistivity is acceptable only if it can be demonstrated that the differential charge of the surface when exposed to space plasma is less than 1 V (TBC).

EIDA-R-3560. The PI shall ensure that no harness dielectric is directly exposed to space plasma environment.

4.11.2.7 Cable Shielding and Separation

EIDA-R-3570. 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 [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in paragraphs 4.2.12 and 4.2.13 in ECSS-E-ST-20-07C [RD11].

4.11.2.8 Launch environment

EIDA-R-3580. The PI shall ensure the instrument is compatible with the Soyuz electromagnetic environment during launch. Specific requirements will be defined at a later stage

4.11.3 *Unit EMC Requirements*

4.11.3.1 General

EIDA-R-3590. The PI shall meet the requirements specified in the following paragraph in any operating mode of the instrument.

Intentional signal emissions are not subject of the emission requirements below.

EIDA-R-3600. 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-R-3610. For units using permanent magnets, the PI shall provide to ESA a sample of the magnet for evaluation.

EIDA-R-3620. The PI shall conduct demagnetisation 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-R-3630. 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 TBD W over a 4 hour period (to minimise current loop variations over 1 hour periods).

EIDA-R-3640. The PI shall design the instrument such, that both primary and secondary power supplies have a switching frequency greater than 100kHz (TBC) and lower than 200 kHz (TBC)

EIDA-R-3650. 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 +/- 5ppm over a period of 60 minutes.

The Prime Contractor will specify and tailor, but not necessarily be limited to the following generic EMC requirements on spacecraft units.

EIDA-R-3660. The PI shall ensure that maximum magnetic moment at the location of each instrument unit on the spacecraft complies with TBD

4.11.3.2 Conducted emissions on power lines, differential mode, frequency domain

EIDA-R-3670. The PI shall comply with the relevant requirements, as defined in Annex A, paragraph A.2 of ECSS-E-ST-20-07C [RD11]

The Prime Contractor will comply with the relevant requirements, as defined in Annex A, paragraph A.2 of ECSS-E-ST-20-07C [RD11]

4.11.3.3 Conducted emissions on power and signal lines, common mode, frequency domain

EIDA-R-3680. The PI shall comply with the relevant requirements, as defined in Annex A, paragraph A.4 with limit in fig. A-2 and not A-3 of ECSS-E-ST-20-07C, [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in Annex A, paragraph A.4 with limit in fig. A-2 and not A-3 of ECSS-E-ST-20-07C, [RD11].

4.11.3.4 Conducted emissions on power lines, differential mode, time domain

EIDA-R-3690. The PI 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.

The Prime Contractor will 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-R-3700. The PI 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.

The Prime Contractor will 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.

4.11.3.5 Conducted emissions on power lines, common mode, time domain

EIDA-R-3710. The PI shall ensure that current ripple and spikes are ≤ 5 mApp when measured with at least 50 MHz bandwidth.

The Prime Contractor will ensure that current ripple and spikes are ≤ 5 mApp when measured with at least 50 MHz bandwidth.

4.11.3.6 Conducted emissions on power lines, inrush current

EIDA-R-3720. The PI shall comply with the relevant requirements, as defined in Annex A, paragraph A.3 of ECSS-E-ST-20-07C, [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in Annex A, paragraph A.3 of ECSS-E-ST-20-07C, [RD11].

4.11.3.7 Conducted emissions on antenna ports

EIDA-R-3730. The PI shall comply with the relevant requirements, as defined in Annex A, paragraph A.5 ECSS-E-ST-20-07C [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in Annex A, paragraph A.5 ECSS-E-ST-20-07C [RD11].

4.11.3.8 Conducted susceptibility on power lines, differential mode, frequency domain

EIDA-R-3740. The PI 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 [RD11].

The Prime Contractor will 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 [RD11].

4.11.3.9 Conducted susceptibility on power lines, common mode, frequency domain

EIDA-R-3750. The PI shall comply with the relevant requirements, as defined in Annex A, paragraph A.11 of ECSS-E-ST-20-07C [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in Annex A, paragraph A.11 of ECSS-E-ST-20-07C RD11].

4.11.3.10 Conducted susceptibility on power lines, differential mode, transient

EIDA-R-3760. The PI shall comply with the relevant requirements, as defined in Annex A, paragraph A.12 of ECSS-E-ST-20-07C [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in Annex A, paragraph A.12 of ECSS-E-ST-20-07C [RD11].

4.11.3.11 Conducted susceptibility on signal lines, common mode

EIDA-R-3770. The PI shall ensure that receiver circuits meet test requirements according to paragraph 5.2.10 in ECSS-E-ST-20-07C [RD11]

The Prime Contractor will ensure that receiver circuits meet test requirements according to paragraph 5.2.10 in ECSS-E-ST-20-07C [RD11]

4.11.3.12 Radiated emissions, electric field

EIDA-R-3780. The radiated emission – electric field requirement(s) for frequencies ≥ 30MHz as given in ECSS-E-ST-20-07C, paragraph 5.4.6 [RD11] are TBD.

The radiated emission – electric field requirement is driven by the Payload Specific EMC requirement for frequencies ≤ 10MHz.

4.11.3.13 Radiated emissions, ac magnetic field (f >10÷100Hz up to 1MHz)

EIDA-R-3790. The radiated emission – electric field requirement(s) for frequencies f >10÷100Hz up to 1MHz are TBD.

4.11.3.14 Radiated susceptibility, electric field

EIDA-R-3800. The PI shall comply with the relevant requirements, as defined in Annex A, paragraph A.14 of ECSS-E-ST-20-07C [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in Annex A, paragraph A.14 of ECSS-E-ST-20-07C [RD11].

4.11.3.15 Radiated susceptibility, magnetic field

EIDA-R-3810. The PI shall comply with the relevant requirements, as defined in Annex A, paragraph A.13 of ECSS-E-ST-20-07C [RD11].

The PI will comply with the relevant requirements, as defined in Annex A, paragraph A.13 of ECSS-E-ST-20-07C [RD11].

4.11.3.16 Magnetic emissions, dc and low frequency ac (f < 10÷100Hz)

TBD

4.11.3.17 ESD susceptibility, radiated

EIDA-R-3820. The PI shall comply with the relevant requirements, as defined in Annex A, paragraph A.15 of ECSS-E-ST-20-07C [RD11].

The Prime Contractor will comply with the relevant requirements, as defined in Annex A, paragraph A.15 of ECSS-E-ST-20-07C [RD11].

4.11.3.18 ESD susceptibility, conducted

EIDA-R-3830. The PI 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. (TBC)

The Prime Contractor will 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. (TBC)

4.11.4 *Magnetic cleanliness*

EIDA-R-3840. Magnetic cleanliness TBD

4.12 Instrument Handling Requirements

Note: chapter 4. 12 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO

4.12.1 *Transport Container*

EIDA-R-3850. 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
- Relative humidity 55 % ± 10%
- The design load curve will be updated during the course of the project.
- Pressure atmospheric conditions
- Cleanliness see section 4.12.2

EIDA-R-3860. The PI shall design each unit to be compatible with the following transport container environmental conditions:

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

EIDA-R-3870. The PI shall identify those units which are sensitive to operating on ground above ambient temperature.

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

4.12.2 *Cleanliness*

EIDA-R-3880. 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.

The Prime Contractor will maintain the required external cleanliness levels at the instrument aperture after handover of the instrument to the spacecraft for integration by

- Maintain an ISO 5 clean room (TBC)
- Supply a cleanliness purging system to the instrument
- 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.
- 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.

Class	maximum particles/m³						FED STD 209E equivalent
	≥0.1 µm	≥0.2 µm	≥0.3 µm	≥0.5 µm	≥1 µm	≥5 µm	
ISO 1	10	2					
ISO 2	100	24	10	4			
ISO 3	1,000	237	102	35	8		Class 1
ISO 4	10,000	2,370	1,020	352	83		Class 10
ISO 5	100,000	23,700	10,200	3,520	832	29	Class 100
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293	Class 1000
ISO 7				352,000	83,200	2,930	Class 10,000
ISO 8				3,520,000	832,000	29,300	Class 100,000
ISO 9				35,200,000	8,320,000	293,000	Room air

Table 16 ISO 14644-1 clean room standards.

The Prime Contractor will 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.

EIDA-R-3890. The cleanliness levels are tbd

EIDA-R-3900. 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.

4.12.2.1 Purging

EIDA-R-3910. The PI shall specify the purging requirements for the each instrument unit during spacecraft integration and testing, transportation and the launch campaign.

EIDA-R-3920. The PIs shall specify individual purge rates for each unit.

The Prime Contractor will provide flow-controlled purging for the relevant instrument units for use from physical delivery to lift off.

4.12.2.2 Particulate and Molecular Cleanliness Requirements

EIDA-R-3930. The PI shall ensure that the instrument design is compatible with the contamination level as indicated in Table 17

Phase	Molecular contamination (mg/m²/week)	Particulate contamination (ppm)
After AIT	TBD	TBD
Launch preparation campaign	TBD	TBD

Table 17 Molecular and particulate contamination level requirements until launch preparation.

4.12.3 *Physical Handling*

EIDA-R-3940. The PI shall define the handling requirements of each unit in the document “Instrument and Ground Support Equipment Packaging, Storing, Transport and Handling Procedures”

This document is part of the Instrument End-Item Data Package.

4.13 Mission Environment Requirements

Note: chapter 4. 13 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO

4.13.1 *Radiation Environment*

EIDA-R-4000. The PI shall ensure that the instrument withstand the environment defined in the EChO Environmental Specification [AD01], predicted for the worst case full nominal mission duration with no detriment on its performances

The EChO Environmental Specification [AD01] 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 0.7 AU.

EIDA-R-4010. The PI shall ensure that electronic equipment design is based on components and sensors which have been proven to withstand the expected radiation environment.

See section 7.7 for radiation hardness for EEE components.

EIDA-R-4020. The PI shall analyse the radiation effects on the instrument according to the standard ECSS-E-10-12C [RD08].

EIDA-R-4030. The PI shall perform the radiation modelling based on the environment and methods described in [AD01]and documents the results in the Instrument Radiation Effect Modelling Report.

EIDA-R-4040. 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 tbd mm equivalent Al.

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.

EIDA-R-4050. The PI shall provide the resources (manpower and software) to assist in the 3D ray tracing analysis by the Prime Contractor by delivering at specified dates the latest 3D radiation model of the instrument.

4.13.2 *Charging*

EIDA-R-4060. The PI shall ensure that the instrument withstand the surface and deep charging environment described in[AD01].

4.13.3 *Cleanliness*

EIDA-R-4070. The PI shall ensure that the instrument design is compatible with the contamination level as indicated in Table 18

Phase	Molecular contamination (mg/m^2)	Particulate contamination (ppm)
Launcher outgassing (during ascent)	TBD	TBD
Thruster plume	TBD	TBD
Spacecraft outgassing	TBD	TBD

Table 18 Molecular and particulate contamination level requirements after launch preparation.

4.13.4 *Micrometeorite Environment*

EIDA-R-4080. The PI shall ensure that the instrument withstands the micro-meteorite environment defined in the EChO Environmental Specification [AD01].

5 GROUND SEGMENT & MISSION OPERATIONS

Note: chapter 5 in the EID-A has already been tailored to EChO

This chapter describes synthetically the following elements and aspects related to the EChO mission: ground segment, mission operations, mission products, system operation testing & simulation and finally instrument documentation.

This chapter specifies the mission operation requirements, applicable to the PIs. Once the Science Implementation Requirement Document (SIRD) is issued, the related requirements presently given in the EID-A will be removed.

5.1 Ground Segment

The EChO Ground Segment will provide all the capabilities for the monitoring and for the 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 Operations Ground Segment and the Science Ground Segment.

5.1.1 *Operations Ground Segment*

The Operations Ground Segment will include:

1. A Ground Station and Communication Network performing telemetry, telecommand and tracking operations within the X-band frequencies. EchO mission shall be compatible with the network of ESA ground stations. The ground station will be a 35m ESA deep space station, to be augmented by additional ground stations during critical mission phases. The choice for the main ground station is still TBD
2. The EChO Mission Operations Centre (MOC) , which will be:
   - responsible for provision of flight dynamics support including determination and control of the satellite's orbit and attitude, and for intervention in case of anomalies.
   - collects raw telemetry and ancillary data and provides the raw science data for transmission to the SOC.
   - performs all communications with the EchO satellite through the ground stations.
   - Provides skeleton planning files to the SOC and converts SOC delivered final planning files into expanded telecommands files (timelines)

   Further details will be described in the Mission Assumption Document (MAD)

   The responsibility for the design, implementation, and operation of the MOC rests with ESA-ESOC.

The MOC located at ESOC (Darmstadt, Germany) will perform the operation and control of the spacecraft during all mission phases, described in paragraph 5.2.2.

In case of a catastrophic event at the MOC, preventing spacecraft control over periods beyond the maximum survival capabilities of the EChO spacecraft, a Back-Up Control Centre (BUCC) will be available in another location, currently baselined to be the TBD 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*

The principle components of the EChO Science Ground Segment (ESGS) are the Science Operations Centre (SOC, located at ESAC) and the Instrument Operations and Science Data Centre (IOSDC).

The responsibility for the design, implementation, and operation of the SOC rests with ESA-ESAC; further details will be given in the Science Operations Assumptions Document (SOAD).

1. The EChO Science Operations Centre (SOC):
    - is the nominal point of contact to the MOC for providing detailed operational requests during routine operations
    - responsible for the development and validation of the EChO payload mission planning system
    - generates the final plans, schedules, timelines and commands for the EchO (scientific) payload activities, working together with the science and schedule planning working groups
    - provides the final planning files to MOC for conversion into expanded telecommand files (timelines)
    - responsible for the development and maintenance of the EchO mission archive, including the science archive and the telemetry database (including other TBD mission type information, e.g. command logs)
    - hosts the EchO archive to support the exchange of data with the IOSDCs during operations and to distribute the data products to the Community
    - responsible for the software archiving, software quality assurance and software change request management system (including operational and processing software)
    - responsible for provision of the data processing infrastructure needed for Level 0, 1 and 2 data product generation
    - responsible for development of the Level 0 pipeline, with software modules requiring instrument knowledge (eg. Decompression) to be provided by the IOSDC
    - responsible for running the data processing pipelines to generate all products up to Level 2 with bulk reprocessing to be done following a major upgrade of the data processing pipelines by the IOSDCs
    - responsible for populating the EchO archive with pipeline products up to and including Level 2
    - responsible for quality control of science data up to and including Level 2 data using critical metrics/parameters to be defined by the IOSDCs
    - manages any call for observing proposals relating to open time (to include helpdesk, outreach activities, documentation plus time allocation management) with help and inputs provided by IOSDC
    - responsible for providing interface software (a la 'HSPOT' or 'expert HSPOT') that allows users and experts from IOSDC to access and use observation templates (provided by IOSDC) for the mission planning
    - during the commissioning phase, responsible for the reconstruction of EchO spacecraft pointing information, using the necessary data provided by the MOC flight dynamics team and working closely together with Industry. IOSDCs are invited to participate in this task (TBC); during normal operations, responsible for the reconstruction of EchO spacecraft pointing information, using the necessary data provided by the MOC flight dynamics team and working closely together with IOSDCs (TBC).

2. The IOSDC (Instrument Operations & Science Data Centre) is responsible for:
    - the monitoring of the instrument operations and maintenance of instrument health
    - the provision of standard observation templates
    - ensuring that members of the instrument teams will be located at the MOC in order to monitor the (near) real time contact and commanding during commissioning phase.
    - instrument calibration, i.e. to provide to SOC a calibration plan (including calibration requests) and a description of calibration constituents for the general instrument calibration as well as for those specific to individual observations.
    - maintenance of on-board S/W, instrument command scripts for special situations, raising of instrument anomalies and support of their investigation together with MOC and SOC
    - the development, validation, updating and delivery to SOC of instrument specific software modules and processing blocks needed for all science data processing in the Level 0 (eg. Decompression algorithms) and Level 1 pipelines, as well as Level 2 pipelines specific to the processing of exoplanet observations
    - providing support to the SOC in the development of the EChO payload mission planning tools;
    - providing support to the SOC and the science planning working group in scheduling activities, details TBC
    - as a goal (TBD), for delivery to SOC of the final data analysis pipeline to produce exoplanet spectra by the end of the mission
    - provision of updated calibration tables/products at appropriate intervals for the data processing pipelines, and delivery to the SOC

- o definition of critical parameters in the data processing pipelines to be used as a "quality control" to establish quality of Level 1 science data by the SOC.
- o (not mandatory) support of activities relating to pointing reconstruction
- o provides support to the SOC in their role of supporting open time observers (documentation, HelpDesk etc.)
- o development and operation of quick-look-analysis tools that will be used during commissioning phase (near real time at the MOC) and at the IOSDC.

Note: In practise the EchO waveband will divided over a series of spectrometers (referred to individually as a spectral channel), each covering a fraction of the waveband and defined by its own detector chain. Each detector technology will likely require an individual approach to calibration and possibly also to some aspects of detrending, and as such will require dedicated software modules. During operations, all EchO channels will be used simultaneously, however and thus conceptually and from an operational perspective, EchO should be considered as a single spectrometer. It should be noted cross-calibration of the different spectral channels will be essential, and detrending of data taken in one channel may require knowledge of data taken in other channels.

EIDA-R-4100. The PI shall make available the necessary resources to support the science operations conducted from the SOC.

EIDA-R-4110. The PI shall be responsible for the development and delivery to the SOC of all instrument-specific software modules and processing blocks, calibration files and algorithms needed to process telemetry and to generate level 1 data products, and level 2 (TBC) data products specific to exoplanet observations.

EIDA-R-4120. The PI shall ensure that Level 1 and the Level 2 processing SW comply with the requirements specified in [RD17], "Software".

EIDA-R-4130. The PI shall identify a single point of contact for instrument planning activities and to support the science planning working group (TBC)

EIDA-R-4140. The PI shall support the SOC in the definition of level 0 products that are needed to start the scientific data processing and generation of higher level products

EIDA-R-4150. The PI shall make available the necessary resources to support the installation and the maintenance of any relevant software at the SOC.

The support period presently envisaged is of the order of several months.

EIDA-R-4160. The PI shall provide inputs, in a TBD format, for the instrument modelling at the SOC.

EIDA-R-4170. The PI shall perform the instrument monitoring

EIDA-R-4180. The PI shall perform the in-flight calibration

5.2 Mission Operations

5.2.1 *Basic Principals*

5.2.1.1 General

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).

The MOC will switch-off any instrument which is deemed to be interfering with or endangering the mission safety and/or objectives, using agreed and validated contingency procedures.

Science TM packets will not be processed at the MOC. 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.

EIDA-R-4190. The PI shall ensure that the instrument non-science TM packets follow the requirements specified in the EChO Operation Requirements Document (TBW).

EIDA-R-4200. The PI shall provide in the instrument User Manual and the instrument Database detailed information to enable the processing of payload non-science TM packets at the MOC.

5.2.1.2 Off-Line Operations

The mission operations concept is based on strictly preplanned 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.

Telemetry evaluation will be mainly off-line with limited possibility of quasi real-time intervention in selected critical phases and in major contingency cases.

Autonomy requirements are given in section 4.10.3.

The spacecraft will be able to continue nominal operations (and generation of mission products) without ground contact during a period of 7 days (tbc).

Anomalies will only be detected by the MOC with a delay, typically at the next ground station pass.. Reaction to on-board failures from the MOC will require unambiguous identification of the failure in telemetry, and the related contingency procedures being contained in the instrument user manual (and translated into the FOP).
During commissioning the same principle of preplanned operations is applied, albeit with the possibility to adapt plans within a short time by the support of the on-site presence of the PI team and to take advantage of extended daily coverage.

FDIR requirements are given in section 4.10.3.

EIDA-R-4210. The PI shall support the investigation and resolution of Instrument-related anomalies in-flight. This may include provision of technical consultancy and presence of PI team technical experts at the MOC if required.

5.2.1.3 **Ground Contact**

The contacts between the MOC 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 (during LEOP/Commissioning) and up to two/three times per week (during nominal Science Operation Phase), depending on the mission phase.

5.2.1.4 **Reporting**

The MOC will regularly report on the mission and spacecraft status with a frequency depending on the criticality of the mission operation; namely:

a. During LEOP operations reports will be issued daily.
b. For critical event operations report will be issued ad-hoc.
c. During routine phases operations reports will be issued weekly to monthly depending on the level of activity.

Contents and distribution lists of these reports will be agreed with the Mission Manager.

The MOC 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, MOC will report such anomalies to the Project Scientist, to the SOC and to the affected PI.

EIDA-R-4220. The PI shall issue instrument operations reports to MOC, SOC and the EChO Project scientist after each in-flight phase as defined in Table 19.

5.2.2 *Mission Phases*

The definition and the mission phases and the PI related support is summarized in the following table:

Mission Phase	Operations Support
Pre-launch Phase	• Support Simulations
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 MGA.*	• 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 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.
Commissioning Phase (CP) including Transfer Phase ***CP definition:*** *The CP extends from end of LEOP until the end of the initial check out of the Spacecraft.*	• 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 the instrument will be activated. • The control centre operations will be carried out from the Dedicated Control Room (DCR) with the support of the PSR. • The TBD 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. • EPLM cooldown including telescope de-contamination Phase • Telescope re-focussing and final performance verification of AOCS system with operational FGS • Transfer to final orbit at L2 • Duration: about 2-3 months spacecraft commissioning
Instrument Performance and science demonstration Phase	• Verification of Instrument performance • science demonstration • duration 3 months
Nominal Science Operations Phase (NSOP) ***NSOP definition:*** *The NSOP is the nominal time period during which mission products are generated and returned from the operational orbit.*	• Full science operations are performed with the entire payload complement through the normal mission planning cycle. • TBD is used 2 times/week (tbc) for a pass duration sufficient to provide 3 hours of science data downlink.
Extended Science Operations Phase (ESOP) ***ESOP definition:*** *The Extended Mission Phase, if approved, will start after NSOP and continue until tbd*	• As for NSOP
Decomissioning Phase	• Tbd

Table 19 Mission phases definition.

5.2.3 *Payload Operations Support*

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.
At top level, ESA will capture requirements and monitor their implementation through the Science Implementation Requirements Document (SIRD) to be answered by the Science (operation) Implementation Plans (SIPs) of the SOC and each PI team, for their respective areas of responsibility.

5.2.3.1 **Nominal & Extended Science Phase Operations**

In the Nominal Mission Phase the instrument on board the spacecraft will perform scientific measurements.

The science operations strategic planning will be defined by the EChO SWT, in coordination with the SOC. The SOC will be responsible for planning all payload operations, while the MOC will remain responsible for the overall mission planning and mission operations.

The SOC will be responsible for submitting consolidated payload operations requests to the MOC at the level of command sequences. The MOC will convert the submitted operations requests into commands and will ensure timely uplink to the spacecraft for execution. The interface between MOC and SOC will include a list of command sequences authorized for scheduling by the SOC.

During NSOP 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 SOC will be checked by the FCT at the MOC against the mission rules and constraints and the available spacecraft and environmental resources, iterated if necessary with the SOC/PI and finally implemented in the mission timeline to be uplinked to the spacecraft.

5.2.3.2 **Payload On-Board Software Maintenance**

EIDA-R-4230. The PI shall comply with the requirements specified in the EChO Operation Requirements Document [TBW] for On-board Processors and Software, Memory Management Service and referenced documents therein.

EIDA-R-4240. The PI shall maintain the instrument on-board software throughout the mission.

The MOC 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.

EIDA-R-4250. The PI shall define in the instrument User Manual a generic software maintenance procedure, which contains the detailed steps to configure the instrument in its maintenance mode and the constraints related to any in-flight software maintenance activity.

EIDA-R-4260. The PI shall submit SW modifications including memory maintenance requests in form of text files in a TBD format.

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.

The MOC will be responsible for converting the text files input into Memory Maintenance commands.

The MOC 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.

EIDA-R-4270. 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 MOC.

If requested by the PI, telemetry generated by the maintenance commands (dump / check) can be compared by the MOC against the contents expected by the PI. These telemetry packets will also be available to the PI via the TBD.

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 MOC ground software will be determined and, if required, modifications shall be initiated by the SOM.

The MOC will support system-level operational validation of instrument software updates upon PI request, provided that a representative instrument model is used with the AVM (TBC).

5.2.3.3 **Mission Planning**

The payload operations will be governed by the rules and guidelines established and periodically discussed by the SWT. While in the LEOP 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.

EIDA-R-4280. The PI shall support the preparation of the EChO Mission Planning, including exchange of files between the SOC and MOC in line with the requirements set out in the SOC to MOC ICD (TBW)

The Mission Planning approach for all the routine science operations phases will be built on the experience of previous missions including Herschel, JWST etc

EIDA-R-4290. The PI shall provide inputs to the SOC for the requested science operations for integration in the mission planning products.

The SOC will pass a consolidated request to the MOC which will check the requests against mission, environmental and resource constraints.

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. This takes into account orbit events as defined by Flight Dynamics and freezes spacecraft resources, like pointing, as early as possible, to give SOC and MOC enough time to evaluate the requests at plan level and resolve conflicts if needed. Nevertheless, more modern integrated planning should be discussed/evaluated.

The set of constraints applicable to the payload operations during NSOP and ESOP implies that a baseline science plan will have to be established long before the SOC submits the final science operations requests to the MOC.

5.3 Mission Products

Mission products will be made available to the SOC and to the PIs in parallel, and will include all spacecraft and instrument raw telemetry data plus auxiliary data as defined in this section.

5.3.1 *Telemetry Processing at MOC*

5.3.1.1 Generic

All telemetry packets received at the MOC will be stored as raw data and made available to all mission users. Upon retrieval of raw data by 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.

Decompression of data compressed by the instrument itself is not supported by the MOC. These packets will be delivered as received by the on-board data handling system.

Non-science telemetry packets will be further processed by the MOC in near real time for 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.

The MOC will not perform any processing of science telemetry packets beyond archiving, neither for calibration nor for instrument monitoring purposes. For this reason, it is essential that any information required at the MOC for health and safety monitoring is included in the instrument non-science telemetry.

5.3.1.2 Auxiliary Data

Auxiliary data are non-telemetry data required to support mission planning and science data 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 attitude prediction/reconstitution.
b. Event files.
c. Command history data.
d. Time correlation history (OBT/UTC).
e. Mission planning information.

Auxiliary data will be provided in a format and within coordinate systems jointly defined between ESA and the PIs through the relevant SWT.

5.3.2 *Data Disposition System*

The TBD is the part of the MOC system that provides access to the mission telemetry and auxiliary data described above.

5.3.2.1 **Long Term Raw Data Archiving**

Raw telemetry and auxiliary data will be kept by the MOC throughout all post launch mission phases on the Long Term Archive (LTA). This archive will be accessible remotely via the TBD throughout the mission, up to 3 to 6 months after end of the ESOP. The MOC will ensure completeness and integrity of the LTA during its active lifetime.

There will be no delivery of data on Raw Data Media during or after the mission.

Processed scientific and auxiliary data will be archived by SOC following the SIRD requirements and according to the SOC SIP.

5.3.2.2 **Delivery Formats**

Each data delivery request to the TBD will result in a transfer of a block of data containing three main areas:

1. An acknowledgment, including request details and status.
2. A catalogue entry giving identification details of the requested data actually supplied (e.g. experiment, date, time).
3. The requested data itself.

5.3.2.3 **Command Request Handling**

In addition to the data access capability, the TBD will allow for transfer of consolidated command requests to the MOC as inputs to the mission planning system. The MOC will support approval, authentication and authorisation of command requests. After validation the MOC 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.

5.4 Testing, Training and Simulation

5.4.1 *General*

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.

5.4.2 *System Validation Tests*

Main objective of the System Validation Tests (SVTs) is:

- the verification of end-to end communication links between spacecraft and MOC,
- the verification of databases needed in support of spacecraft operations,
- the development and verification of Flight Procedures and Contingency Procedures for all spacecraft subsystems and instrument.

The SVTs are performed with the actual satellite linked to the MOC via a communications network for TM, TC and voice connections.

EIDA-R-4300. 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.

The Project will provide on-line access to the EChO Flight Model for closed loop TM/TC testing (System Validation Test) with the ground segment and the flight control software.

The SVTs will comprise:

a. Spacecraft commanding from the MOC
b. Telemetry flow between satellite and MOC. Real time non-science TM data processing in the MOC in parallel to the (simulated) science TM processing in the Instrument Stations.

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.

EIDA-R-4310. The PI shall provide instrument test procedure inputs for the relevant part of the SVTs.

EIDA-R-4320. The PI shall review and approve instrument procedures defined by the MOC for the relevant part of the SVTs.

EIDA-R-4330. The PI shall make available the necessary resources for real-time support at test site and/or at the MOC during SVT execution.

EIDA-R-4340. The PI shall support the evaluation of the relevant part of the SVT results.

EIDA-R-4350. The PI shall support instrument anomaly investigation and resolution for the relevant part of the SVTs.

5.4.3 *System Operations Validation Test (SOVT)*

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 deferred to the post launch phases. Details about the overall system testing activities will be defined in the Ground Segment System Test Plan.

5.4.4 *Data Disposition System (DDS) Interface Tests*

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.

Note that the DDS interfaces will have to be tested both in remote configuration and with the payload support systems installed at the MOC in the configuration required for critical operations.

EIDA-R-4360. The PI shall make available the necessary resources to support the procedure definition, the procedure approval, the text execution, the results analysis and the anomaly investigation/resolution for the Data Disposition System Interface Test (DDSIT).

5.4.5 *MOC/SGS End-to-End Test*

The objective of the MOC-/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.

EIDA-R-4370. 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 MOC-SSGS End-to-End Test as well as test execution.

5.4.6 *Pre-Launch Operations*

Pre-launch operations support will start approximately 6 months before the launch. During this period the MOC 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.

EIDA-R-4380. 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*

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.

These documents, listed in 8.6, are:

1- Instrument On-board Software ICD: This document is the formal ICD between the instrument software and the S/C system on-board software. It is an essential input to operations since it describes in detail the services provided by the on-board central software to the instrument, including operationally relevant aspects like data transfer and autonomy functions.

2- Instrument User Manual.

EIDA-R-4390. The PI shall ensure that the instrument User Manual complies with the requirements specified in the EChO Operation Requirements Document TBD.

ESA will propose a common, coherent Table of Content for the instrument User Manual based on the tailoring of the User Manual definition in ECSS-E-70.

EIDA-R-4400. The PI shall review and approve the FOP for the aspects/sections relevant to instrument operations.

5.5.2 *Instrument Database*

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. This will ensure compatibility of the spacecraft database required by the multi-mission control system which is part of the MOC infrastructure.

The MOC 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.

The MOC will contribute to the population work pre-launch with direct inputs in areas agreed with the Project, such as payload TM/TC, displays, etc.

Responsibility for database maintenance will be transferred to the MOC at the Flight Acceptance Review.

EIDA-R-4410. The PI shall establish, maintain, validate and deliver an Instrument Data Base (IDB) to the ESA EChO Project Office.

The IDB will become part of the Mission Information Base (MIB).
The format of the IDB will be agreed with by the PI with ESA and the Prime Contractor.

EIDA-R-4420. 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-R-4430. The PI shall ensure that the IDB comply to the detailed format, population rules and conventions defined & documented by the Prime Contractor

This is not currently documented, although will be provided and maintained under configuration control by the Prime Contractor.
Data to be provided as input to the SRDB (System Requirement DataBase), the list is not exhaustive:

- For TM: Mnemonic, description, addressing, coding, calibration, validity conditions, monitoring limits.
- For TC: Mnemonic, description, addressing, coding, calibration, execution conditions, execution checking.
- Model (e.g. EQM, FM), SW version (where applicable) and TM/TC ICD document reference
- Change log defining changes in data above from previous version (inserts, deletions and updates).

6 VERIFICATION REQUIREMENTS

Note: chapter 6 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO, except chapter 6.7 already including a cryogenic tests at system level

This chapter addresses the following aspects of the instrument verification: definitions, concept, analyses, acceptance and qualification test programmes, models and test philosophy, responsibilities.

6.1 Definitions

Acceptance Verification: Verification intended to demonstrate that hardware is acceptable for flight.

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.

Electromagnetic Compatibility (EMC): The prevailing condition when various electronic devices are performing their functions according to design in a common electromagnetic environment.

Electromagnetic Interference (EMI): Electromagnetic energy which interrupts, obstructs, or otherwise degrades or limits the effective performance of electrical equipment.

Electromagnetic Susceptibility: Undesired response by a component, instrument or system to conducted or radiated electromagnetic emissions.

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.

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.

Incoming / Receiving Inspection: Inspection and / or functional tests to declare that the item is ready for integration on the spacecraft.

Modal Survey Test: A series of mechanical investigations to determine the natural frequencies and associated modes of a structure.

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.

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.

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.

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.

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.

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.

Shock Tests: A test conducted to verify the soundness of the design under the transport, spacecraft and launcher induced shocks.

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.

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).

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.

Analysis: Verification method (e.g. structural, thermal analyses), achieved by performing theoretical or empirical evaluation by accepted techniques.

Inspection: Verification method achieved by visual determination of physical characteristics (such as construction features, hardware conformance to document drawing or workmanship requirements).

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.

6.1.1 *Documentation*

EIDA-R-4500. The PI shall provide an Instrument Assembly, Integration and Test plan.

EIDA-R-4510. 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-R-4520. The PI shall provide a step-by-step procedure for each test defined in the Instrument Assembly, Integration and Test Plan.

EIDA-R-4530. 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-R-4540. The PI shall seek agreement with ESA before the start of any unit level test campaign.

6.2 Verification Concept and Methods

The main instrument verification objectives are as follows: to qualify the design
to ensure that the is free from workmanship defects and acceptable for use in its spacecraft environment; to verify that the instrument is able to fulfil mission and science requirements;

EIDA-R-4550. The PI shall apply one or more of the verification methods defined below to meet the above instrument verification objectives:
- test
- analysis
- review of design/similarities
- inspection

Note: Verification by test is the preferred method.

6.3 Analyses and Mathematical Models

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.

6.3.1 *Structural analysis*

EIDA-R-4560. 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
- A description of the mathematical finite element model and/or of the assumptions taken to verify the structure
- A description of all possible loading cases and an identification of the design driving load cases or load combinations
- A description of the most loaded elements listed with relevant stresses, and the loading cases that generated them
- A list of the materials and structural components with characteristics data sheets (including long-life effects under space environment)
- 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.

EIDA-R-4570. The PI shall provide a Structural Mathematical Model (SMM) for each unit

The SMM will be used to calculate the mechanical characteristics and performances of each instrument unit.

EIDA-R-4580. 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-R-4590. 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-R-4600. The PI shall ensure that the SMM fulfils the requirements of the Design Verification Requirements, when compared to test results.

EIDA-R-4610. 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).

For mechanisms, two or more models (stowed, deployed; general position), may be required.

EIDA-R-4620. The PI shall ensure that all mathematical models are maintained in current configuration.

EIDA-R-4630. The PI shall perform a structural dynamic analysis and include at least:

- A description of the configuration analysed with reference to interface controlled drawings
- A description of the mathematical finite element model and/or of the assumptions/reductions introduced in the analysis
- A description of the checks performed on the model to verify its quality (e.g. rigid body modes, residual forces)
- A list of eigen-frequencies with relevant mode type and associated modal effective

EIDA-R-4640. The PI shall deliver a 3D CAD Model for each unit, in support of the accommodation of the instrument in the spacecraft and related structural design .

EIDA-R-4650. The PI shall compile a 3D CAD model for each unit, in accordance with the check list described in Annex A1.

Additional details for the compilation of the 3D CAD Model can be found in Annex A of ECSS-E-ST-32C [RD13]

EIDA-R-4660. 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
- A detailed description of the operating modes with reference to ground and orbital activations
- 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)
- A Failure Modes, Effects and Analysis (FMEA) defining the failure modes and the functional margins of safety against each of them
- A performance description of the control system that the mechanisms form a part of.

6.3.2 *Radiation analyses*

EIDA-R-4670. The PI shall perform the necessary radiation analyses of the instrument design to ensure that the instrument will work as expected in the radiation environment given inAD01]

EIDA-R-4680. The PI shall create a radiation model which can be easily integrated into the spacecraft overall radiation model and shall update the radiation model of the instrument at each review.

6.3.3 *Thermal Analysis*

EIDA-R-4690. The PI shall perform a thermal analysis of each instrument unit.

The objectives of the thermal analysis are as follows:

- Verify that internal parts and materials are within allowed temperature range during flight conditions and acceptance/qualification testing;
- Verify the ability of the unit thermal design to maintain the instrument specified internal temperatures and internal heat flow pattern that ensure performance requirements;

6.3.3.1 Thermal Design Cases

EIDA-R-4700. 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-R-4710. The PI shall define and analyse the worst thermal sizing cases.

EIDA-R-4720. 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.

6.3.3.2 Thermal Mathematical Models

EIDA-R-4730. 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-R-4740. 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-R-4750. The PI shall ensure, in order to exchange 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).

For unit detailed thermal analysis, the following codes are recommended:

- Thermal network solver: ESATAN-TMS/Thermal (formerly called ESATAN) Version Release R2 or higher;
- Radiation coupling computation& Geometrical Model: ESATAN-TMS/Radiative (formerly called ESARAD) Version Release R2 or higher.

EIDA-R-4760. The PI shall provide a RTMM / RGMM representative of the updated DTMM / DGMM after correlation with the results of the instrument thermal balance test.

6.3.4 *Optical analysis*

EIDA-R-4770. The PI shall maintain an optical model to be delivered to the Agency upon request. This model (Zemax/Code V) shall be delivered with a text file containing the description of the optics in line with the optical prescription format described in AD05.

EIDA-R-4780. The PI shall analyse the optical performances of the instrument including the manufacturing and integration tolerances which shall be part of the optical model.

EIDA-R-4790. The instrument provider shall analyse the optical performances of the instrument including the stability tolerances in-flight over the mission lifetime which shall be part of the optical model.

6.4 Testing

6.4.1 *General*

6.4.1.1 General Test Approach

EIDA-R-4800. The PI shall define a model philosophy for the instrument to be agreed by the EChO project office.

EIDA-R-4810. 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-R-4820. The PI shall specify and detail in the Assembly, Integration and Test Plan the qualification and acceptance test programmes the Instrument HW will undergo

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.

It is strongly recommended that the vibration/acoustic test precede the thermal vacuum test unless there is an overriding reason to reverse that sequence.

EIDA-R-4830. 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-R-4840. The PI shall incorporate the following tests as part of the qualification programme.

The actual tests and sequence of tests can be agreed on a case by case basis between the EChO Project Office and the PI, based on a formal RFD/RFW.

- Visual Inspection
- Dimensions Verification
- Physical Properties
- Functional Test
- Shock test
- Sine Vibration test
- Functional Test
- Random Vibration test
- Functional Test test
- Acoustic Noise test
- Functional Test .
- Thermal Vacuum/ Thermal Balance test
- Mechanism(s) lifetime testing.
- Functional Test .
- Bonding test
- Isolation test
- Grounding test and conductivity test of space exposed surfaces
- EMC Conducted Emission / Susceptibility test
- EMC Radiated Emission / Susceptibility test
- ESD susceptibility tests
- DC Magnetic Properties test
- Purging Rate Verification test
- Functional Test .
- Visual Inspection

EIDA-R-4850. The PI shall demonstrate and justify via the defined acceptance test programme that the hardware is acceptable for flight.

EIDA-R-4860. The PI shall incorporate the following tests as part of the acceptance programme

The actual tests and sequence of tests can be agreed on a case by case basis between the EChO Project Office and the PI, based on a formal RFD/RFW.

- Visual Inspection
- Dimensions Verification
- Physical Properties
- Functional Test
- Sine Vibration test
- Functional Test test
- Random Vibration test
- Functional Test test
- Acoustic Noise test
- Functional Test
- Thermal Vacuum/ Thermal Balance test
- Functional Test
- 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
- Purging Rate Verification test
- Functional Test .
- Visual Inspection

EIDA-R-4870. 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

As a guideline the following sequence of tests is recommended:

- Functional Test
- Random Vibration - 1 axis
- Functional Test
- Thermal Vacuum (2 cycles)
- Functional Test
- Grounding / Bonding / Isolation
- EMC Conducted Emission / Susceptibility
- DC Magnetic Properties
- Visual Inspection

6.4.1.3 Test Level & Measurement Tolerances

EIDA-R-4880. The PI shall respect the following test tolerances, unless otherwise specified:

Temperature:
Tmax: 0 to +3°C,
Tmin: 0 to -3°C
Within the temperature range: -55°C ÷ +150°C

Environmental heat fluxes:
infrared fluxes: +/- 3% (from the SC)

NOTE: The percentage figures in the following table reflects a Sun distance of 1AU. EChO specific figures will be provided at a later date.

Solar intensity distribution in reference plane		±4 % (TBC)
Solar intensity distribution in reference volume		±6 % (TBC)
Solar intensity stability		±1 % (TBC)
Solar intensity stability (absolute)		±3 % (TBC)
Type	Wavelength (Angstrom)	Percent of total energy
Far Ultraviolet	1 to 2000	0.008 (TBC)
Near Ultraviolet	2000 to 3800	6.995 (TBC)
Visible	3800 to 7000	39.88 ±TBD% (TBC)
Near Infrared	7000 to 10000	22.59 (TBC)
Infrared	10000 to 20000	24.02 (TBC)
Far Infrared	20000 to 100000	6.45 (TBC)

Table 20 Solar intensity wavelength distribution

Values are presently TBC

Pressure:
- Equal or above 0.1 mbar 10%
- Below 0.1 mbar 50%

Relative humidity: ± 5%

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

Random vibration:
- Power spectrum density (50 Hz or narrower)
  20 to 500 Hz ± 1.5 dB
  500 to 2000 Hz ± 3.0 dB
- Overall g rms ± 1.5 dB

Static force: ± 5.0%

Acoustic: ± 1 dB

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

Mass Properties

- Weight: ± 1 %
- Centre of Gravity: ± 5 mm
- Moments of Inertia: ± 10%

6.4.2 *Test Requirements at Instrument level*

6.4.2.1 Full Performance Test

EIDA-R-4890. 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-R-4900. 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.

The PI is in charge of structuring or decomposing this test as adequate for the instrument.

EIDA-R-4910. The PI shall demonstrate and document that the FFPT, is carried out in the representative environmental conditions and fulfil at least the following:

- be completed within, typically eight hours.
- Verification of the proper operations of all nominal and redundant circuitry.
- Instrument performances are meeting the instrument performance requirements in all operational modes.
- When provided with appropriate stimuli, instrument performances are according to expectations and outputs are within allowed limits.

6.4.2.2 Short and Abbreviated Functional Tests

EIDA-R-4920. The PI shall establish a Short Functional Test (SFT) and an Abbreviated Functional Test (AFT)

EIDA-R-4930. The PI shall ensure that as a minimum the SFTs and the AFTs

- focus on verification of instrument overall integrity and functionality
- be completed within, typically one hour.

AFT and SFT are 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. AFT and SFT should test both the nominal and redundant branches.
The AFT and/ or SFT may also be used in cases where FFT is unwarranted or impracticable.

6.4.3 *Instrument Functional Test at Spacecraft Level*

EIDA-R-4940. The PI shall define an instrument Full Functional Test (FFT), demonstrating that the hardware and software meet their functional requirements.

The initial FFT will serve as a baseline against which the results of all later FFTs can be readily compared.
Only SFTs will be performed as a diagnostic after major test steps. They will serve for verifying the command and telemetry paths during overall spacecraft functional tests.

Full instrument functional tests (FFT) are foreseen at least once at the start of the spacecraft-level 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.

EIDA-R-4950. 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.

The instrument FFTs, SFTs will be conducted in normal cleanroom conditions, as foreseen during 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).

Potential constraints on what can be done within these tests might depend on the SC AIT 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*

The Prime Contractor will prepare a system-level Control and Verification based on tailoring of ECSS-E-ST-20-07C [RD11].

The Prime Contractor will prepare Control and Verification Report based on tailoring of ECSS-E-ST-20-07C [RD11].

The Prime Contractor will establish a verification matrix showing all combinations of individual equipment/subsystems under test in order to verify overall intra-system compatibility.

The Prime Contractor will 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.

The Prime Contractor will use time domain methods for safety margin demonstration of a time domain circuit. (includes EEDs)

The Prime Contractor will verify by test bonding of discharge elements, thermal blankets, or metallic items removed from structure and requiring a bond for static potential equalisation.

The Prime Contractor will verify by test immunity to electrostatic discharge for equipment under Prime Contractor responsibility.
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**

The following general EMC testing requirements both at instrument and unit-level apply.

EIDA-R-4960. 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 section 4.11..

Included in the ambient level are also emissions from test equipment, including unit-testers (EGSE) with its harness.

EIDA-R-4970. The PI shall ensure that, if a shielded room is used, then the ground plane is bonded to the room with low inductive bonds separated by less than 0.5 metre.

EIDA-R-4980. The PI shall ensure that this low inductive bond is verified by a resistance test.

This connection of the ground plane is very important when the EGSE has to be located outside the shielded room because of emission or susceptibility excess.

EIDA-R-4990. 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-R-5000. The PI shall not take the interface wires to ground if not done in the actual/final installation in the spacecraft.

EIDA-R-5010. The PI shall ensure that the power sources used for the tests have well defined impedance below 10 MHz.

EIDA-R-5020. The PI shall ensure that the test harnesses are flight representative.

EIDA-R-5030. The PI shall ensure that the grounding of interfaces is in accordance with flight installation.

EIDA-R-5040. The PI shall ensure that bonding of units, unit tester, etc to the ground plane are verified by a bonding test.

EIDA-R-5050. The PI shall ensure that the unit bonds are similar to that specified for the actual installation.

EIDA-R-5060. The PI shall ensure that all equipment used for emission and susceptibility tests are calibrated.

EIDA-R-5070. The PI shall ensure that passive equipment, such as antennae, current probes etc. have calibration curves from the manufacturer.

6.4.4.2 Conducted emissions on power lines, differential mode, frequency domain

EIDA-R-5080. The PI shall abide by paragraph 5.4.2 of ECSS-E-ST-20-07C [RD11].

6.4.4.3 Conducted emissions on power and signal lines, common mode, frequency domain

EIDA-R-5090. The PI shall abide by paragraph 5.4.3 of ECSS-E-ST-20-07C, [RD11].

6.4.4.4 Conducted emissions on power lines, differential mode, time domain

EIDA-R-5100. The PI shall measure current ripple and spikes according to the test set-up in fig. 5-8 of ECSS-E-ST-20-07C, [RD11] with current probe and oscilloscope with the required bandwidth.

EIDA-R-5110. 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, [RD11] 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-R-5120. 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, [RD11]

6.4.4.6 Conducted emissions on power lines, inrush current

EIDA-R-5130. The PI shall abide by paragraph 5.4.4 of ECSS-E-ST-20-07C, [RD11].

6.4.4.7 Conducted emissions on antenna ports

EIDA-R-5140. The PI shall abide by MIL-STD 461F, CE106

6.4.4.8 Conducted susceptibility on power lines, differential mode, frequency domain

EIDA-R-5150. The PI shall abide by paragraph 5.4.7 of ECSS-E-ST-20-07C, [RD11]

EIDA-R-5160. The PI shall use, above 50 kHz, the test set-up and the calibration set-up shown in the figures below.

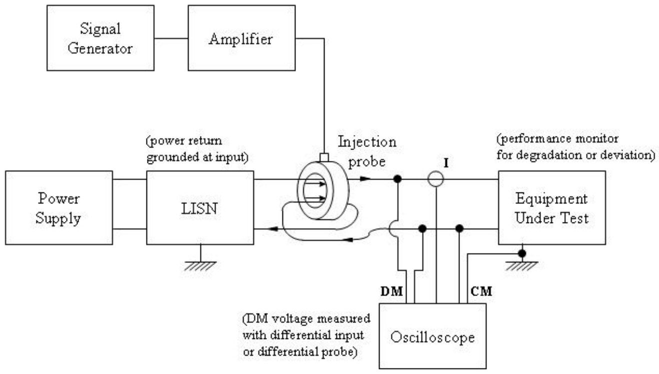


Figure 16 Conducted Susceptibility on power lines, differential mode, frequency domain.

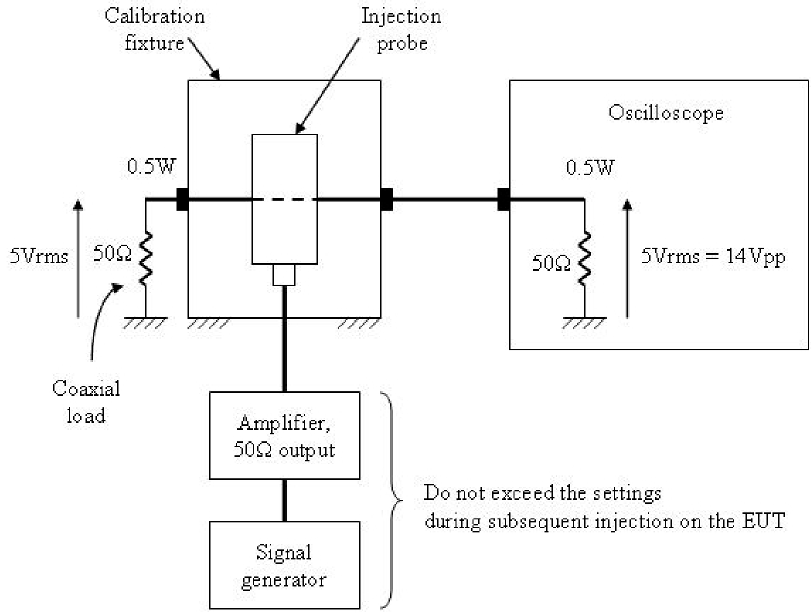


Figure 17 Conducted Susceptibility on power lines, differential mode, frequency domain, calibration set-up.

6.4.4.9 Conducted susceptibility on power lines, common mode, frequency domain

EIDA-R-5170. The PI shall abide by paragraph 5.4.8 of ECSS-E-ST-20-07C, [RD11]

6.4.4.10 Conducted susceptibility on power lines, differential mode, transient

EIDA-R-5180. The PI shall abide by paragraph 5.4.9 of ECSS-E-ST-20-07C, [RD11]

6.4.4.11 **Conducted susceptibility on signal lines, common mode**

EIDA-R-5190. The PI shall abide by paragraph 5.4.8 of ECSS-E-ST-20-07C, [RD11]

6.4.4.12 **Radiated emissions, electric field**

EIDA-R-5200. The PI shall abide by paragraph 5.4.6 of ECSS-E-ST-20-07C, [RD11] for frequencies above 30MHz.

Dealing with the low frequencies 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.

The figure below shows some of the precautions that can be taken to limit parasitic resonances to ± 1dB (instead of ± 10-15 dB without precaution). The absorbers are not represented as they do not play any role below 30 MHz.

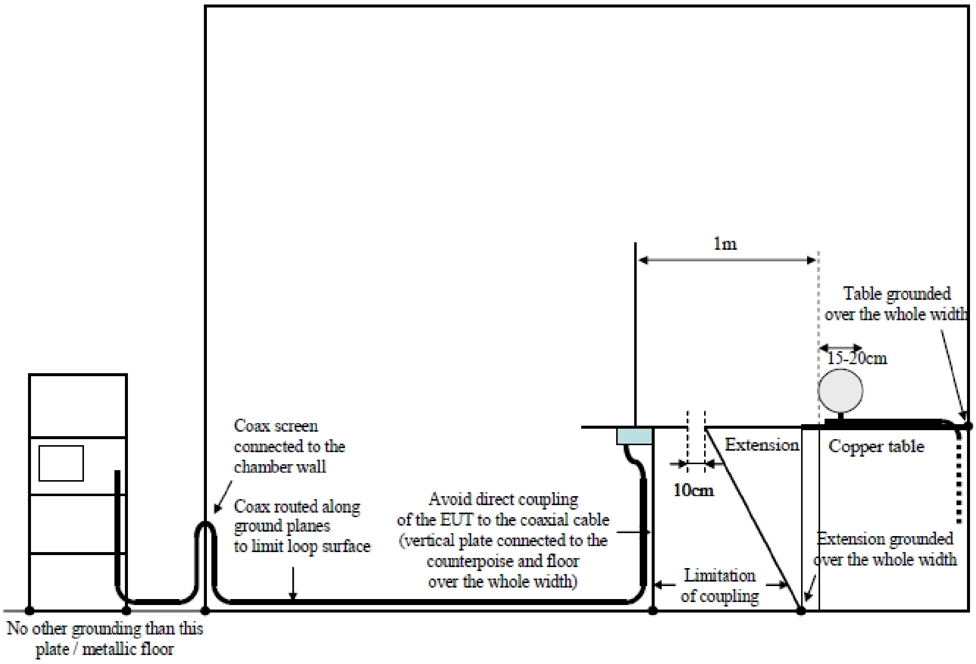


Figure Radiated emissions calibration at low frequencies.

The electrostatic field from a canonical object such as a sphere can be calculated and compared to the field measured by the rod antenna. With some precautions it is accurate within 1 or 2 dB over the whole 14 kHz – 30 MHz frequency range.

EIDA-R-5210. The PI shall ensure that the active rod antenna is battery powered.

The table extension is optional since the improved accuracy is within 2dB.
One way of checking the correctness of the set-up is to excite the test object (a sphere in the example) with constant voltage amplitude: the field measured by the rod antenna should be flat over the frequency range and exempt of resonances.

6.4.4.13 **Radiated emissions, ac magnetic field (f >10÷100Hz up to 1MHz)**

This activity is TBD. 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.

6.4.4.14 **Radiated susceptibility, electric field**

EIDA-R-5220. The PI shall abide by paragraph 5.4.11 of ECSS-E-ST-20-07C, [RD11]

6.4.4.15 **Radiated susceptibility, magnetic field**

EIDA-R-5230. The PI shall abide by paragraph 5.4.10 of ECSS-E-ST-20-07C, [RD11]

6.4.4.16 **Magnetic emissions, dc and low frequency ac (f <10÷100Hz)**

This activity is TBD. 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.

6.4.4.17 **ESD susceptibility**

EIDA-R-5240. 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-R-5250. The PI shall abide by paragraph 5.4.12 of ECSS-E-ST-20-07C, [RD11]

6.4.4.19 **ESD susceptibility, conducted**

EIDA-R-5260. The PI shall follow the set-up as shown in to the figure below.

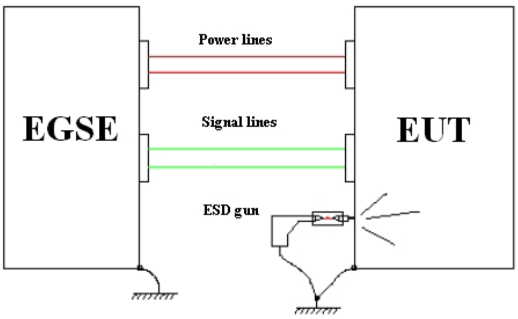


Figure 18 Conducted ESD test set-up.

6.4.5 ***Structural Test Requirements***

6.4.5.1 **Structural Test Setup**

EIDA-R-5270. The PI shall ensure that the instrument units are tested in launch configuration.

Launch configuration refers to units status / mode at launch from an electrical, SW, mechanisms, thermal point of view. Actual units orientation with respect to the SC is not relevant.

EIDA-R-5280. The PI shall ensure that test adaptors and / or non-flight items are removed before test.

EIDA-R-5290. The PI shall provide any special test adapter required for the test.

EIDA-R-5300. The PI shall vibrate the instrument in hard mounted configuration through the designated S/C interface points.

EIDA-R-5310. The PI shall ensure that the adapter shall have a first resonance frequency above 2 kHz in order not to influence the test.

EIDA-R-5320. The PI shall ensure that any amplifications 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-R-5330. The PI shall ensure that units mounted on the spacecraft panels are designed to withstand without degradation the sinusoidal environment as defined in table below at unit / structure interface (all values are TBC).

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

Table 21Qualification and Acceptance Levels for Sine Vibration Tests.

6.4.5.3 Random Vibration Test Levels

EIDA-R-5340. The PI shall ensure that each unit is designed to withstand without degradation the random environment as defined in the table below at unit/structure interface. All values are TBC.

Axis	Frequency (Hz)	Qualification	Acceptance
Out of plane	20 - 100	+3 dB/Oct	Qualification /2 (PSD)
	100 - 300	0.03 x[(M+30)/(M+1)]^1.5 M is the mass unit (kg)	
	300 - 2000	-6 dB/oct	
In plane	20 - 100	+3 dB/Oct	Qualification /2 (PSD)
	100 - 300	$(2/3)^2$ *0.03 x[(M*30)/(M+1)]^1.5 M is the mass unit (kg)	
	300 - 2000	- 6 dB/oct	

Table 22 General Qualification and Acceptance Levels for Random Vibration Tests.

EIDA-R-5350. The PI shall apply the random qualification level for the duration of 2 minutes

EIDA-R-5360. The PI shall apply the random acceptance level for the duration of 1 minute

6.4.5.4 Acoustic Test Levels

EIDA-R-5370. The PI shall ensure that each unit is designed to withstand without degradation the acoustic environment as defined in the table below.

Octave center frequency (Hz)	Flight limit level (dB) (reference: 0 dB = 2 x 10^{-5} Pa)
31.5	128
63	131
125	136
250	133
500	129
1000	123
2000	116
OASPL (20 – 2828 Hz)	139.5

OASPL: Overall Acoustic Sound pressure level

Acceptance test level duration is 1 minute with values as indicated above
Qualification test level duration is 2 minutes with values as indicatedabove + 3dB.

Table 23 Acoustic Test Levels.

6.4.5.5 Shock Test Levels

EIDA-R-5380. The PI shall ensure that each unit is designed and qualified to withstand without degradation the shock levels specified in section 4.4.10.

EIDA-R-5390. 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

Due to the risk of latent defects, FMs or PFMs will not undergo shock testing.
Component level shock testing may be considered for shock sensitive items to retire risk early prior to higher level testing.

6.4.5.6 Thermo-elastic loads

EIDA-R-5400. Thermo-elastic loads TBD

6.4.5.7 Pressurized Items Test Requirements

EIDA-R-5410. The PI shall abide by the guidelines and requirements define in ECSS-E-ST-32C [RD13].

6.4.6 *Mechanism Test requirements*

6.4.6.1 General

EIDA-R-5420. 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.

The aim of testing can be either, development, qualification or acceptance.
The test(s) will also verify the predicted deployment kinematics do not exceeded the allocated volume.

EIDA-R-5430. 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-R-5440. The PI shall carry out development test(s) on bread-board models to test specific aspects agreed by the Agency.

EIDA-R-5450. 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.
- vibration and thermal tests.
- tribological lifetime test on life critical components.

6.4.6.3 **Qualification tests**

EIDA-R-5460. 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-R-5470. 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 [RD16]

6.4.6.4 **Acceptance tests**

EIDA-R-5480. 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-R-5490. 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.) [RD16].

6.4.6.5 **Mechanism Lifetime Tests**

EIDA-R-5500. 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-R-5510. 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	
Ground Testing	x4
• number of on-ground test cycles	
(the minimum number to be used is 10)	
In-orbit predicted cycles:	
• 1 to 10 actuations	x10
• 11 to 1,000 actuations	x4
• 1001 to 100,000 actuations	x2
• > 100,000 actuations	x1.25

As actuation, a full output cycle or full revolution of the mechanism is defined.

EIDA-R-5520. 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 Tests Requirements***

6.4.7.1 **Thermal Design Verification**

EIDA-R-5530. 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:
- thermal balance (TB) test(s) at STM level and at FM level
- thermal vacuum (TV) cycling test at FM level

EIDA-R-5540. The PI shall carry out for internal electronic units only TV test(s).

EIDA-R-5550. The PI shall carry out for external electronic units both TV test(s) and TB test(s)

EIDA-R-5560. 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

The objectives of the thermal balance test will be to:
- Provide data for the verification of the thermal mathematical model
- Demonstrate the ability of the unit thermal control to maintain temperatures inside the specified limits
- Verify the performance of the thermal control hardware
- Verify that the unit performs correctly under vacuum and thermal conditions expected to be encountered during the mission
- Provide data about sensitivity of the unit thermal design with respect to parameter changes (e.g. heat dissipation, pointing

EIDA-R-5570. 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)

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

The PI shall ensure that the TB test(s) consist of at least a hot and a cold steady-state phase and transient phases that simulate boundary conditions experienced during the mission, including actual Sun exposure (when applicable)

EIDA-R-5580. 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).

EIDA-R-5590. 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-R-5600. The PI shall assume that for temperatures above 200K each steady state phase is reached when the temperatures of the unit does not vary by more than 1 C/ 3 hour

EIDA-R-5610. The PI shall for the cryogenic temperature range (T< 200K) define and justify stability criteria to define when steady state is reached.

6.4.7.3 Thermal Vacuum Cycling Test

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.

EIDA-R-5620. The PI shall ensure apply the acceptance and qualification margins, specified in para 4.7.2.

EIDA-R-5630. The PI shall qualify the cryogenic cooled units for tbd deep cryogenic cycles (1 orbit cooldown + 2 cooldowns at Satellite system tests + tbd cooldowns at instrument level)

6.4.7.4 Test Methods for Thermal Vacuum Cycling Test

EIDA-R-5640. 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.

EIDA-R-5650. The PI shall ensure that the test item experiences actual temperatures equal to or beyond the minimum and maximum qualification/acceptance temperatures.

EIDA-R-5660. The PI shall apply to the **non-optical and optical units internally mounted** the tbd test methods and requirements.

EIDA-R-5670. The PI shall apply to the **units externally mounted** the following tbd test methods and requirements.

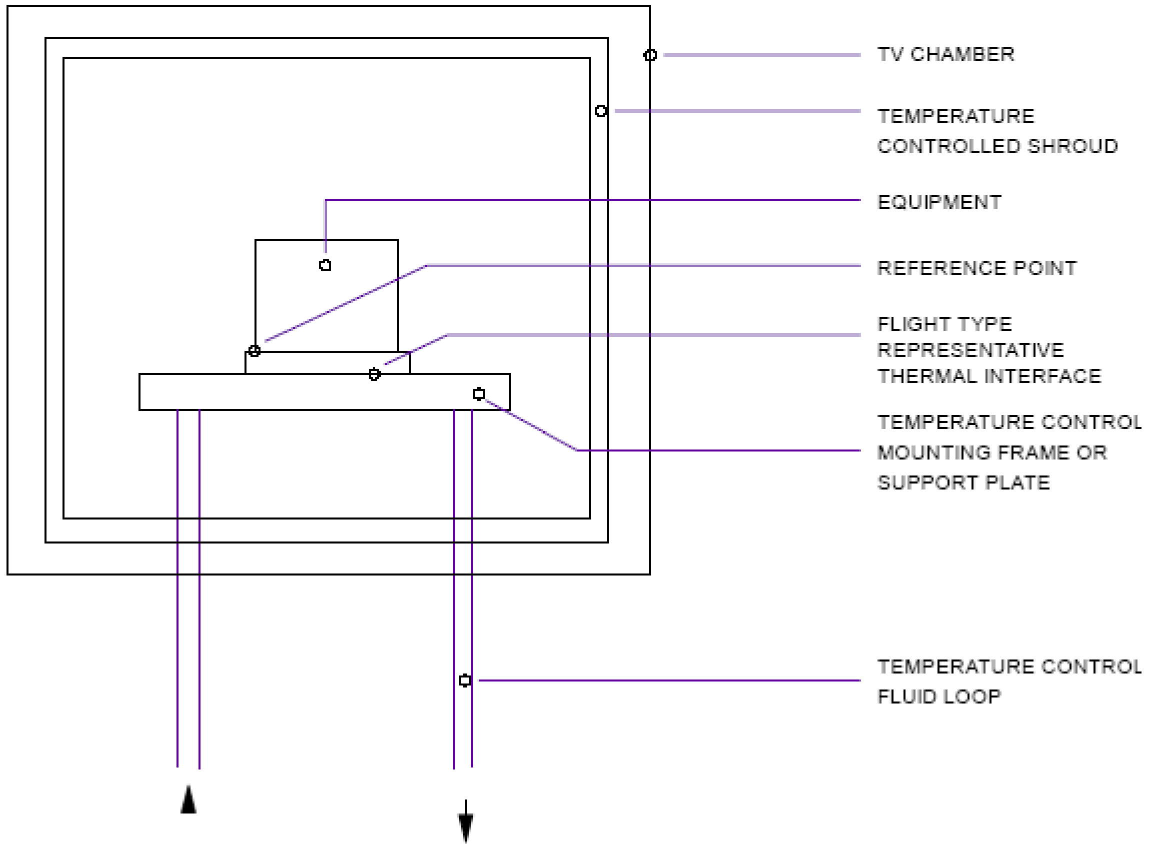


Figure 19 Unit Thermal Vacuum Cycling Test set-up.

EIDA-R-5680. The PI shall test each non-cryogenic unit in the combined thermal vacuum and thermal balance test in line with the following sequence, shown in the Figure 19.

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.

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).

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.

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).
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.

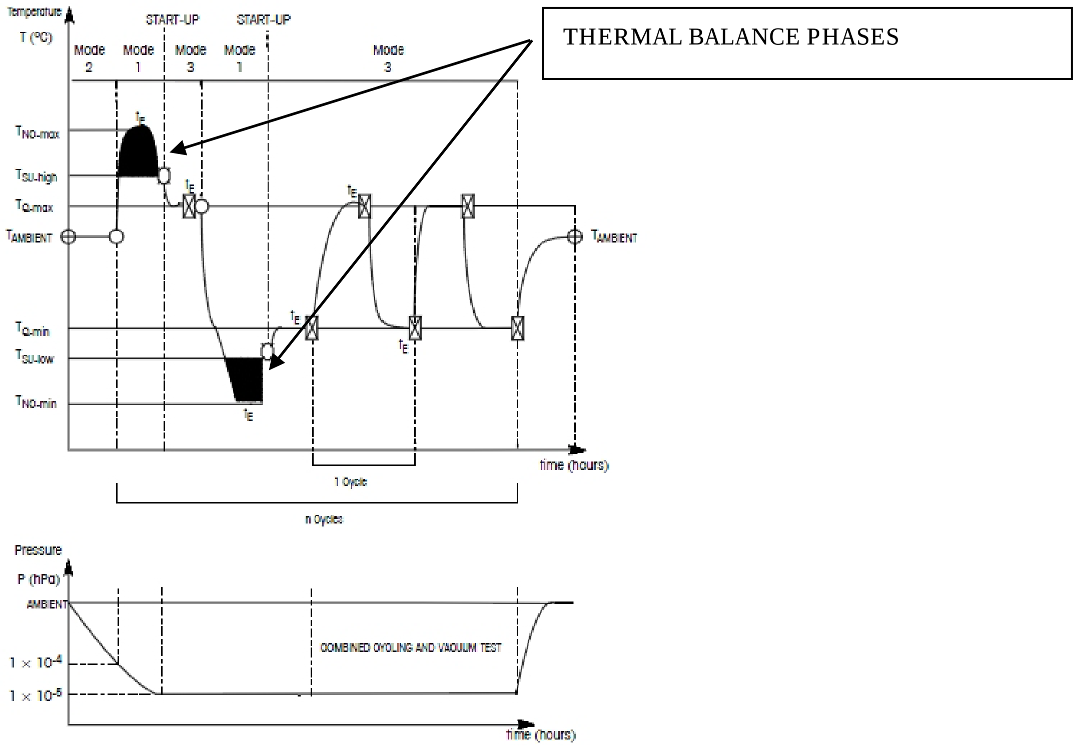


Figure 20 Unit Thermal Vacuum Cycling and Thermal Balance Combined Test Sequence (see Table 24 for nomenclature).

Symbol	Description
T	Test item temperature
$T_{AMBIENT}$	Ambient temperature
$T_{NO\text{-}max}$	Maximum non-operating temperature (highest design temperature for the equipment to survive not powered)
$T_{NO\text{-}min}$	Minimum non-operating temperature (lowest design temperature for the equipment to survive not powered)
$T_{SU\text{-}high}$	Maximum start-up temperature (highest design temperature of the equipment, at which the equipment can be switched on)
$T_{SU\text{-}low}$	Minimum start-up temperature (lowest design temperature of the equipment, at which the equipment can be switched on)
$T_{Q\text{-}max}$	Maximum qualification temperature (highest design temperature at which the equipment demonstrates full design ability)
$T_{Q\text{-}min}$	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.
$\oplus$	Initial and final "functional and performance test"
$\boxtimes$	Intermediate reduced functional and performance test
t_E	Dwell time
	Switch-on (Start-up)
○	Switch-off

Table 24Thermal balance test nomenclature.

EIDA-R-5690. The PI shall apply the values specified in the table below for non-cryogenic units:

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 = 5 ... 20°C/min
Dwell time	$t_E \geq 2$ h
Stabilisation criterion	$\Delta T / dt \leq 1$°C/h
Number of cycles	n = 8 for qualification n = 4 for acceptance n = 4 for recertification

Table Test Parameters Values for Thermal Vacuum Test.

EIDA-R-5700. The PI shall test each cryogenic unit in the combined thermal vacuum and thermal balance test performing tbd thermal cycles.

EIDA-R-5710. The cryogenic units shall be compatible with a temperature rate of change of tbd K/hour.

6.5 HW Inspections

EIDA-R-5720. 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
- Identification of hardware
- Connectors
- Grounding Points
- Attachment Surfaces
- Thermal Surfaces (any visible changes)
- Inspection of transport conditions
- Inspection for damage
- Inspection of Interfaces
- Visual inspection for contamination assessment
- Completeness of documentation

EIDA-R-5730. The PI shall measure the mass, the CoG and the Momentum of Inertia of each unit

6.6 Final Acceptance

The acceptance process will demonstrate that the Instrument has been fully verified in terms of:

- scientific performances (including calibration and characterization)
- behaviour versus environmental conditions (including EMC)
- all functional interfaces

The ESA EChO 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

6.7 System Level AIT

6.7.1 *Model Philosophy*

6.7.1.1 Satellite Model and Test Philosophy

The presently foreseen satellite model philosophy consists as a minimum of:

- STM: Structural Thermal Model;
- AVM: Avionic Validation Model
- PFM: Proto Flight Model

The following preliminary test programme is for information only

Test	STM	AVM	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	(+)		(+)
• Alignment	(+)		(+)
• Pressure / leak	(+)		(+)
• Thermal Balance	(+)		(+)
• Cryogenic Performance test at EPLM	(+)		(+)
• Thermal Vacuum Cycling			(+)
• Electrical Interfaces		(+)	(+)
• HW/SW Compatibility		(+)	(+)
• Conducted EMC		(+)	(+)
• Radiated EMC			(+)
• RF compatibility			TBD
• Ground Segment Compatibility			(+)

6.7.1.2 Instrument Model and Test Philosophy

EIDA-R-5740. The PI shall follow the following instrument Model Philosophy

- STM: Structural Thermal Model suitable for cryogenic performance tests (tbc)
- EM: Engineering Model (supporting the AVM test campaign tbd)
- PFM: Proto Flight Model

In support of instrument qualification (before delivery of PFM 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.

EIDA-R-5750. The PI shall propose, justify and seek agreement with the ESA EChO Project Office in case he/she does not intend to follow the baselined instrument model philosophy (e.g Proto-Flight model philosophy)

EIDA-R-5760. 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-R-5770. The PI shall ensure that the instrument STM units have the following build standard:

- structure flight representative, including, where applicable, alignment cubes with flight representative mountings and locations.
- mechanisms flight representative (TBC)
- thermal control hardware flight representative
- representative for mass, CoG, first eigen-frequency, interface mounting pattern, internal power dissipation.
- representative for key thermo-optical interfaces / properties, to be agreed with ESA.
- harness flight representative for mass, shape, heat load with flight representative connectors
- coolers
- 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

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

EIDA-R-5780. The PI shall ensure that the instrument EM units have the following minimum build standard:

- electronics flight standard except for parts quality
- commercial parts have to be of same technology, same supplier as FM parts
- mechanisms flight representative for electrical actuators
- structure flight representative for mounting and shape
- electrically representative as needed for conducted EMC tests (emissions and susceptibility).
- software flight standard as needed for all command/ control/ data interactions with the spacecraft.
- harness flight representative

In order to save cost the EM hardware contents may be reduced by reducing redundancy
Use of EQM if sufficiently representative electrically and functionally.
The EM units will remain at the Prime Contractor's and/or ESA premises following delivery.

EIDA-R-5790. The PI shall ensure that the instrument FS units have full flight standard verified by formal acceptance tests.

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.

EIDA-R-5800. 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.

In order to save cost the FS units

- may be derived from refurbished qualification units if full flight worthiness can be demonstrated
- 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.

6.7.1.3 **Spares Philosophy**

EIDA-R-5810. The PI shall propose a spares philosophy, to be agreed with the ESA Project Office.

7 PRODUCT ASSURANCE REQUIREMENTS

Note: chapter 7 in the EID-A has been derived from existing missions and might require some tailoring in the future for EChO

7.1 Introduction

All space products procured in the frame of a programme of the European Space Agency are required to conform to the Agency's Product Assurance (PA) requirements as laid down in the ESA-ECSS series of documents.
The ECSS-Q standards define the Product Assurance (PA) policy, objectives, principles and rules for the establishment and implementation of PA programmes for projects covering the mission definition, design, development, production and operations of space products including disposal. They shall be considered reference documents and as guidelines unless especially made applicable through this document.
Safety requirements imposed on ESA by the respective Launcher Authorities are mandatory on all flight hardware and software and hence the relevant requirements are applicable for the instrument.
N**ote:** Despite the fact that ESA and the selected Prime will act as formal interface to the Launcher Authorities this does not release the PI from the commitment to provide adequate inputs to ESA in order to comply with the applicable Launcher Authority Safety Requirements.
The prime objectives of the PA requirements are:

- to establish confidence in the design;
- to enhance the overall mission integrity;
- to assure the safety of the system and its operations;
- to assure that failures in one element do not have detrimental effects on other elements.

While the first two topics intend to assure a successful functioning and performance of an instrument, the latter two aim to assure the safety and integrity of the interface of the instrument with the spacecraft and the launcher.
Following these two different objectives the PA requirements defined in this document as derived from applicable ECSS set of documents will be:

- fully applicable to the interface of the instrument with the spacecraft (and the launcher)
- partially applicable to the overall instrument to assure the success of the programme

The interface between an instrument and the spacecraft must be understood in a wider sense than simply mechanical, electrical or thermal, e.g.:

Additional to the “physical” interfaces:

mechanical/dynamic:
elements that contribute to the mounting, fixation, position of an instrument, a subassembly a device or part of them and which can by its failure or faulty operation damage or render the capabilities of other elements of the platform

electrical
elements (harness or electronic equipment) which can be a source of any over voltage, under voltage, over current, under current (versus nominal design) or any unpredicted variation of an electrical signal of the interface circuit, capable to create any degradation to the electrical circuit characteristics or to the operational performance of the platform or any other instrument

thermal
elements which can cause any unexpected change in temperature or heat flux capable to generate major disturbance in the thermal balance of the platform

radiative electromagnetic

elements which can cause any disturbance of the platform by electromagnetic effect

<u>optical</u>
elements which can cause disturbance of the platform by generation of reflexion, absorption, biasing or modification (straylight) of the optical flux to a sensor, detector or from a source

<u>contamination</u>
outgassing of materials that can contaminate other parts of the S/C or lead to degradation of surface coatings that can influence the thermal control of the instrument and the spacecraft control of materials and processes that can affect the structural integrity of the instrument and hence the spacecraft, and even the launch vehicle; the following needs to be considered as interface relevant:

- qualification and acceptance testing of the instrument alone and after integration in the system;
- control of nonconformances to avoid effects on other subsystems and schedule delays during integration;
- configuration control on documentation, hardware and software to make possible to build and to operate a complex integrated system.

Specific PA rules defined herein are aimed at controlling the phenomena that may propagate beyond the interface of the instrument to other parts of the spacecraft. With the help of a Failure Modes, Effects and Criticality Analysis early in the design phase, the critical interfacing elements of an instrument will be determined and agreed between the Principal Investigator (PI) and the ESA selected Prime.
The PA Requirements and Guidelines defined here have been established to prevent potential problems, and past experience has shown that they are cost-effective and provide long term benefits to all parties participating in the programme.

If specific rules or procedures are considered irrelevant, impracticable or inefficient for implementation on a particular instrument, the Principal Investigator may propose alternative procedures to achieve the same objectives. These procedures are subject to agreement with ESA and the ESA selected Prime on a case-by-case basis.

Taking above said into account the PA requirements and guidelines defined hereafter are derived from the entire set of applicable documentation, and have been tailored and limited to be relevant to the items contributed by the PI. In General:

EIDA-R-5900. All products procured in the frame of the EChO programme of the European Space Agency, independently whether they will be procured under direct ESA industrial contract, direct PI responsibility or under responsibility of partner agencies, shall be conform to the "tailored" ECSS standards, as described in the following chapters.

EIDA-R-5910. The PI shall further apply launch site and launch vehicle safety requirements and regulations as defined in these programme requirements.

7.2 Product Assurance Management

7.2.1 *General*

EIDA-R-5920. The Principal Investigator (PI) shall establish and implement an effective PA programme in accordance with the RD22 to support the PA activities at programme level. The programme shall provide for the assessment and control of risks, and that acceptability of the residual ones is evaluated. This shall by:

- the prevention or early detection of actual and potential deficiencies,
- the identification of system incompatibilities,
- the identification of aspects, which could affect project requirements having major impacts on safety, mission success and the related cost and schedule consequences.

The basic implementation principles are to:

- ensure the allocation and availability of adequate resources, personnel and facilities to carry out the required PA tasks, (see ch. 7.2.2)
- define, in a Product Assurance Plan all PA activities consistent with the Project objectives, requirements, criticalities and constraints, (see ch. 7.2.3)
- ensure that lower level contractors / suppliers perform proper PA monitoring and control
- ensure proper progress monitoring, reporting and visibility of all PA matters, in particular those related to alerts, critical items, non-conformances, changes, deviations, waivers, actions and/or recommendations resulting from reviews, inspection and audits, qualification, verification and acceptance.

EIDA-R-5930. The PI shall report on a regular basis as specified in chapter 8.3 and8.5 of this EID-A the status of the product assurance programme implementation as part of the regular progress reporting.

7.2.2 *Organisation*

EIDA-R-5940. The PI shall establish an effective PA organisation tailored to the size and complexity of the programme.

Note: This requirement applies also to eventual supplier / contractors

EIDA-R-5950. The PI shall assign an instrument PA manager from the PA line organisation:

- reporting functionally to the instrument manager and
- having unimpeded access to higher management, to the PA structures within the Prime Contractor Organisation and ESA, who will manage the PA activities within the instrument collaboration and will coordinate these activities with the ESA designated Prime.

EIDA-R-5960. The appointed instrument PA manager shall have sufficient organisational authority and independence to propose and maintain a product assurance programme in accordance to the EChO product assurance requirements

EIDA-R-5970. The PI shall identify PA resource requirements and shall provide adequate resources to perform the required PA tasks. Trained personnel shall be assigned to the various PA activities.

In case the PI has no suitable facilities or experienced personnel, adequate measures shall be undertaken (including applying for additional funds) to grant the use of external facilities and / or ensure the training of personnel.
The use of National Agency resources, consultants and contractors should be considered for specific tasks for which in-house expertise is not available and where the investment may not be possible.

7.2.3 *Product Assurance Plan*

EIDA-R-5980. The PI shall prepare and implement a project product assurance plan as part of the management documentation to be submitted in responses to the AO to ESA for approval.

EIDA-R-5990. The PI shall maintain the PA plan throughout the project life cycle. The PA plan may refer to clauses of the PI Organisation Quality Manual and to in-house procedures.

Note: The PA plan shall be kept always up to date.

EIDA-R-6000. The PA plan shall describe the PA responsibilities within the instrument collaboration and eventually be extended to outside facilities and external personnel used during the project lifetime.

EIDA-R-6010. The PA plan shall describe in a structured manner the implementation phase addressing explicitly critical areas pertinent to the instrument development, such as magnetic, optical cleanliness, deployable items, safety items etc.

7.2.4 *ESA / Prime Contractor Right of Access*

EIDA-R-6020

EIDA-R-6020. For the purpose of product assurance and technical coordination ESA and / or its selected Prime have the right to perform or participate to, together with the Investigator, audits, surveys, source inspections, test reviews, mandatory inspections, etc., at the facilities of the PI and his contractors and suppliers.

EIDA-R-6030. ESA or its Prime contractor's participation shall not in any way replace or relieve the PI of his responsibility; it will be rather aimed at contributing to the identification of problem areas and assessing satisfactory progress.

EIDA-R-6040. Arrangements shall be made to permit designated ESA / Prime contractor personnel free access to all technical and programmatic documentation, areas and operations within the facilities of the PI and his contractors and suppliers in which work related to the EChO Programme is being performed.

Proprietary rights of the PI and third parties will be fully respected.

7.2.5 *Contractor and Supplier Surveillance*

EIDA-R-6050. In case the PI procures equipment or services from contractors or suppliers, he shall impose on them a set of product assurance requirements derived from the requirements listed herein, and tailored to the criticality of the products or services being provided.

EIDA-R-6060. The delegation of product assurance tasks by the PI to another lower tier supplier shall be done in a documented and controlled way. The PI retains the responsibility towards ESA and its selected Prime.

It is therefore mandatory that the PI carries out an effective surveillance of the activities carried out by contractors and suppliers. Status/problem reporting shall be included in the regular progress reports.

7.2.6 *Reviews and Audits*

EIDA-R-6070. A status review and the results of the PA programme shall regularly be included in the project reviews. (see chapter 7 management requirements on reporting)

EIDA-R-6080. A programme of internal and external audits shall be defined and implemented on inside and outside organisations:

- as planned activities at key points of the programme addressing specific points agreed with ESA and / or its selected Prime;
- as separate activities on subjects or organisations which are or become cause of particular concern;

EIDA-R-6090. Audits shall be documented by the PI in audit reports, which shall be made available to ESA or its Prime upon requests.

EIDA-R-6100. Follow-up audits shall be made to verify that the required corrective actions have been implemented effectively.

ESA and the Prime contractor shall be invited to participate in audits carried out by the Principal Investigator.

7.2.7 *Critical Items Identification and Control*

EIDA-R-6110. The QA function shall contribute to the overall risk management activities by:

- Supporting the identification and risk evaluation of critical items for which major difficulties or uncertainties are expected in:
  - demonstration of design performances
  - development and qualification of new product, processes and technologies
  - procurement, manufacturing, assembly, inspection, test, handling,
  - storage and transportation, which may lead to major degradation in the scientific performance of the instrument
- Contributing to the risk reduction plan by identifying the QA activities accompanying the individual risk reduction measures.
- Monitoring and documenting the achievement of the specified risk reduction implementation and the corresponding verification measures throughout all project phases.
- Identifying single-point failures with a failure consequence severity classified as catastrophic, critical or major (Reliability Critical Items)
- Identifying items or procedures that do not comply with the applicable safety requirements, or which cannot be verified as complying with those requirements (Safety Critical Items).
- Identifying products that cannot be checked and tested after integration, limited-life products, products that do not meet - or cannot be verified as meeting - applicable maintainability requirements (Maintainability Critical Items)
- Identifying items whose structural failure may cause catastrophic or critical consequences (Fracture Critical Items)

EIDA-R-6120. A Critical Items List (CIL) shall be prepared as a summary of data from the different disciplines in accordance with RD42.

An item shall be classified as critical if it meets the criteria above.

EIDA-R-6130. The complete CIL shall be updated to the main reviews. The Critical Items shall be maintained permanently and changes shall be reported as part of the progress report and during the progress meetings.

7.3 Quality Assurance Management

7.3.1 *General Requirements*

EIDA-R-6140. The PI shall establish a detailed **Quality Assurance (QA) Programme Plan** as part of the PA plan following the generic guidelines given in [RD22].

EIDA-R-6150. If the PI institute / organisation does not already provide a proven self-standing PA/QA organisation, the PI shall establish a QA system covering the following tasks:

- Documentation and Data Control including Quality Records and Stamp Control;
- Traceability and Logbook (see 7.3.2);
- Metrology and Calibration (see 7.3.3);
- Non-Conformance Control System (see 7.3.4);
- Alert System (see 7.3.5);
- Handling, Storage and Preservation (see 7.3.6)
- Statistical Quality Control and Analysis

EIDA-R-6160. The QA requirements shall be made applicable to:

- flight models and spares;
- manufacturing, assembly and integration facilities and tools / equipment interfacing directly with flight hardware (partially applicable)
- hardware subjected to or participating in design verification / qualification testing with respect to the properties relevant for those tests;
- portions of the GSE which interface directly with flight hardware or which can have an impact on safety (e.g. lifting devices).

EIDA-R-6170. The PI shall provide evidence that QA personnel and other personnel, whose performance affects the instrument quality, have followed adequate training programmes according to national or international standards. Especially those personnel performing critical processes or controlling critical processes shall be trained and certified according to the ESA accepted standards.

EIDA-R-6180. The QA management is an integral part of the configuration management. As such the QA function shall ensure that:

- the as designed status is defined prior to manufacturing the as-built documentation is properly defined, identified and maintained in order to reflect approved modifications;
- items to be delivered comply with the as-built documentation.

7.3.2 *Traceability and Logbook*

EIDA-R-6190. Each part, material or product shall be identified by a unique and permanent part or type number.

Note: To assure a full traceability the following controls shall be established:

- Identification numbers are assigned in a systematic and consecutive manner.
- Identification numbers of scrapped or destroyed items are not used again.
- Identification numbers, once allocated, are not changed, unless the change is authorised by the ESA or the selected Prime.

EIDA-R-6200. The logbooks shall contain historical and quality data and information which is significant for operation of the item, including non-conformances, deviations and open tasks.

EIDA-R-6210. The PI shall prepare and maintain system, subsystem and equipment logbooks (in accordance with annex B of [RD-PA-01]) for all operations and tests performed on he item during the period to be covered by the logbook.

EIDA-R-6220. Equipment logbooks shall start with the first qualification or acceptance test after assembly.

EIDA-R-6230. The log books shall accompany the hardware whenever it is placed under the custody of another organisation. The log books will form part of the End Item Data Packages which are to be delivered for every item at the time of acceptance.

7.3.3 *Metrology and Calibration*

EIDA-R-6240. The PI shall identify the measurements to be made and the accuracy required and shall select the appropriate inspection, measuring and test equipment.

EIDA-R-6250. The PI shall identify, calibrate and adjust all inspection, measuring and test equipment and devices that can affect product quality at prescribed intervals, or prior to use, against certified equipment having a known valid relationship to nationally recognised standards; where no such standards exist, the bases used for calibration shall be documented.

EIDA-R-6260. The PI shall establish, document and maintain calibration procedures.

EIDA-R-6270. The PI shall identify inspection, measuring and test equipment with a suitable indicator or approved identification record to show the calibration status.

EIDA-R-6280. All measurements shall take into account the total error in the measurement process attributable to the cumulative error from the calibration chain, measuring equipment and, as appropriate, those contributed by personnel, procedures and the environment. The basis for the calculation of the cumulative error shall be recorded.

EIDA-R-6290. Corrective action shall be taken when the total error is such as to compromise significantly the ability to make measurements within the required accuracy and precision. (e.g. 10%)

7.3.4 *Non-Conformance Control*

EIDA-R-6300. A Non-Conformance Report (NCR) is required when a discrepancy is observed between a characteristic of deliverable hardware or software and the relevant specification, including drawings and test procedures.

EIDA-R-6310. The PI and their contractors and suppliers shall establish and maintain a non-conformance control system.

EIDA-R-6320. Non-conformances shall be reviewed and dispositioned by a formal Non-Conformance Review Board (NRB). The originator's PA shall ensure that:

- responsibilities and authorities for the disposition of non-conformances are properly defined
- the NRB includes at least representatives from the PA and Engineering organisations
  the Board to review non-conformances is chaired by the Product Assurance Management function;
- all relevant Product Assurance experts are involved in the review, investigation and disposition of non-conformances;
- all knowledge acquired from non-conformances results in preventive actions in all relevant engineering, manufacturing and Product Assurance fields.

7.3.4.1 **Non-Conformance Classification**

EIDA-R-6330. Those non-conformances shall be classified as MAJOR which may have an impact on the next higher level requirements in the following areas:

- safety of people or equipment;
- operational, functional or contractual requirements;
- reliability, maintainability, availability;
- lifetime;
- functional or dimensional interchangeability;
- interfaces with hardware and/or software of different contractual responsibility.

EIDA-R-6340. Additionally, any non-conformances shall be classified as major in the cases of:

- changes to or deviations from approved qualification or acceptance test procedures;
- project specific items which are proposed to be scrapped;
- for EEE components, in case of:
- (a) lot/batch rejection during manufacturing, screening or testing at the manufacturer™s facilities, if the purchaser proposes:
  - to use as-is the rejected lot/batch, or
  - to continue processing, rework or testing, although the lot/batch does not comply with the specified requirements.
- (b) non-conformances detected after delivery from the manufacturer.

EIDA-R-6350. **Minor** non-conformances are those which by definition cannot be classified as major. The following EEE discrepancies after delivery from the manufacturer may be classified as Minor:

- random failures, where no risk for a lot-related reliability or quality problem exists;
- if the form, fit or function are not affected;
- minor inconsistencies in the accompanying documentation.

EIDA-R-6360. In case of doubt, non-conformances shall be classified as major.

EIDA-R-6370. The consequences of several different minor non-conformances on the same item shall be evaluated for proper classification.

7.3.4.2 Non-conformance Reporting

EIDA-R-6380. The next higher contractual level (regarding ESA and/or its selected Prime and the PI as contractually linked) are to be informed of MAJOR NCRs within 48 hours of their discrepancy, notified of the date of a proposed NRB.

EIDA-R-6390. The approval of the NCR closure is required of the higher level. It is the responsibility of the PI to involve any higher level, including ESA and Spacecraft Prime contractor if the NCR affects any of the interfaces as stated above.

EIDA-R-6400. The NCR shall be reported using the ESA provided NCTS tool

EIDA-R-6410. Subsequent reports should add pages numbered sequentially to previous reports, each page reflecting the original identification number. The final report should confirm that all actions are completed and that closure has been agreed by the relevant parties.

EIDA-R-6420. Reports between PIs, ESA, the Prime Contractor, Parts Agency and Spacecraft AIV and Test Houses shall be in the English language.

EIDA-R-6430. Minor NCRs must be reported to the next higher contractual level at least by means of a monthly report and shall be reviewed at regular progress meetings.

EIDA-R-6440. MAJOR NCRs will be treated at levels other than the originator, and to avoid confusion, the originator's number must be in line with the project documentation reference system.

7.3.5 *Alert System*

ESA operates an Alert system [RD45] to inform all affected ESA projects of technical problems of general nature concerning safety, parts, materials and processes (e.g. a serious deficiency discovered with the sealing of IC-packages by a specific manufacturer).

The notification of problems from any source will be screened by the Project Office for a first assessment of potential applicability to EChO. If it is suspected or if it cannot be excluded that an instrument may be affected, the alert will be forwarded to the Principal Investigators with a request to evaluate the alert, to assess the relevance to the instrument and to take corrective actions as necessary to assure that the reported problem is avoided or eliminated on the instrument.

EIDA-R-6450. The PI shall assess incoming Alerts for applicability to the instrument and a response shall be provided to the ESA Project Office within 15 days after receipt of a formal Alert, either indicating its non-applicability or the appropriate actions (to be) taken.

7.3.6 *Handling, Storage and Preservation*

EIDA-R-6460. Procedures and instructions shall be made available and be used for handling, storage, packaging and transportation which ensure that the integrity of the item and tolerable environmental conditions including cleanliness, humidity, pressure, temperature, vibration and shock will be maintained to prevent deterioration and damage. This can be implemented by adequate

- protection of items during handling (e.g. red tags);
- handling devices;
- procedures and instructions (e.g. purging procedures).
- Transport Container
- Effective implementation of applicable procedures and instructions shall be verified by the quality assurance activity.
- Appropriate marking and labelling for packaging storage, and transport shall be applied including the following:
- nomenclature of the item and serial number
- cleanliness level and decals or labels to permit ready detection of loss of packaging integrity or exceeding of environmental limits which could (have) deteriorated the item
- applicable caution/warning notes for handling, transportation and unpacking
- applicable caution/warning notes for dangerous or toxic contents
- life expiration dates
- package orientation arrows, weight and centre of gravity, handling and lifting points
- conditions and instructions for handling and unpacking
- name, address, phone number of sender and recipient for transport and shipment and shipping documents.

Compliance to the requirements shall be verified by the responsible quality assurance organisation before and after transport or shipment.

Note: Procedures and instructions shall ensure that the integrity of the item and the tolerable environmental conditions (including cleanliness, humidity, pressure, temperature, electrostatic discharge, vibration and shock) will be maintained avoiding so any possible deterioration and damage.

Note: The standard high purity nitrogen typically used during ground operations has the following specifications: Oxygen < 5 ppm; Water < 5 ppm; Hydrogen < 5 ppm; Argon < 1000 ppm; Hydrocarbon < 1 ppm. This corresponds to N2 type N48 or MIL-P-27401C Grade C type, "U" in France, White Spot in UK)

EIDA-R-6470. Records shall be maintained to ensure that all stored items are within the usable life limits and adequately controlled and retested, and to provide traceability within the storage area.

EIDA-R-6480. Appropriate marking and labelling for packaging storage, and transport shall be applied including the following:

- nomenclature of the item, part number and serial number;
- cleanliness level and decals or labels to permit ready detection of loss of packaging integrity or exceeding of environmental limits which could (have) deteriorate(d) the item;
- applicable caution/warning notes for handling, transportation and unpacking;
- applicable caution/warning notes for dangerous or toxic contents;
- life expiration dates;
- package orientation arrows, weight and centre of gravity, handling and lifting points;
- conditions and instructions for handling and unpacking;

- name, address, phone number of sender and recipient for transport and shipment and shipping documents.

7.3.7 *QA Requirements for Design and Verification*

EIDA-R-6490. The PI shall ensure that the design rules and guidelines are implemented to ensure:

- design simplification and standardization, reduction in part types and part number
- guidelines for selection of preferred parts, materials and processes are followed
- the product is designed such, that it can be easily and efficiently inspected and tested under representative conditions, for production, AIV and operational environment.

EIDA-R-6500. The Qualification Philosophy shall be conform to the model philosophy prescribed

7.3.8 *QA Requirements for Procurement*

7.3.8.1 Selection of Procurement Sources

EIDA-R-6510. For the procurement of equipment, components, parts, materials and services the PI shall evaluate and select manufacturers, suppliers or contractors who have a demonstrated capability of supplying the items with the required properties and the necessary quality levels. the demonstration of capabilities shall be based on the successful supply of items or services similar to those to be procured.

7.3.8.2 Procurement Documents

EIDA-R-6520. The Supplier shall ensure that supplies are precisely identified and that all applicable requirements are properly defined in the procurement documents. It shall be possible to demonstrate traceability from Customer requirements to those contained in lower tier procurement documents.

EIDA-R-6530. The procurement documents shall contain, by statement or reference:

- Comprehensive technical descriptions of the items and services to be procured.
- Details of the applicable requirements, such as requirements for preservation, packaging, marking, shipping, accompanying documentation and provisions for limited-life items.
- Details of QA activities to be performed, such as inspection and test characteristics, records and reports.
- Details of Supplier’s QA activities at source.
- Special acceptance conditions.

7.3.8.3 Surveillance of Procurement Sources

EIDA-R-6540. Implementation of the requirements applicable to the suppliers shall be checked as appropriate for the criticality of the procured item, by surveys and/or audits, witnessing of specifically critical processes, witnessing of inspections or tests, and review of inspection and test results.

EIDA-R-6550. The Supplier shall consider the following criteria to define the most appropriate type and extent of surveillance:

- Testing or critical inspections cannot be accomplished by the Supplier (e. g. environments or test equipment not available at Supplier’s facility).
- Verification tests are destructive in nature and the quality cannot be verified solely by inspection or test at Supplier’s facility.
- Supplies are designated for direct shipment from source to a Customer site or the using site.
- Manufacturing and AIV of complex equipment or subsystems (e.g. payloads).
- Past performance or quality history of the lower level Supplier is marginal.
- Functional criticality and technical complexity of the supplies.

- The degree of responsibility placed on the procurement source.

7.3.8.4 Incoming Inspections

EIDA-R-6560. Incoming Inspections shall be performed on procured items to check their compliance with applicable requirements.

EIDA-R-6570. The visual inspection for completeness and freedom from obvious damage or deficiencies which might result from transportation shall always be performed.

EIDA-R-6580. The following activities shall be performed as appropriate, depending on the verifications already carried out at the supplier's premises or by the supplier itself, the application of the item, and the criticality of specific parameters:

- review of the Certificate of Conformance and of deliverable documentation with inspection/test results;
- remaining life for limited life items;
- sample testing or testing on all items for compliance of the most essential parameters (e.g. interface dimensions of a housing);
- inspection/test of all applicable interface and performance parameters (e.g. on a complete mechanism or sensor).
- Verification of the packaging conditions and of the status of environmental sensors.
- Verification of correct identification and, where appropriate, configuration identification for conformance to the ordering data.

7.3.8.5 Procurement Requirements for EEE Parts

See chapter on EEE parts 7.6.5

7.3.9 *QA Requirements for Manufacturing*

7.3.9.1 Manufacturing and Inspection Flow Chart

EIDA-R-6590. Before the begin of the actual manufacturing the PI shall review the manufacturing readiness in front of the following aspects:

- Status of product definition and requirements
- Status of manufacturing, assembly, inspection and test documentation
- Validation status of manufacturing processes, with particular emphasis on critical processes.
- Availability of required production, measuring and inspection equipment, and calibration status, when relevant.
- Cleanliness of facilities, with respect to the required cleanliness levels

EIDA-R-6600. The manufacturing and assembly process shall be analysed and the sequence of the various steps thoroughly planned.

EIDA-R-6610. Surveillance of manufacturing and assembly activities shall be performed by the designated quality assurance personnel, by means of inspections for:

- critical parameters of the process;
- satisfactory workmanship;
- completion of individual manufacturing and assembly steps.

EIDA-R-6620. The planning of inspections shall take into account the complexity of the operations and their potential effect on the properties and integrity of the end product.

7.3.9.2 Key and Mandatory Inspection Points (KIP/MIP)

Among the inspections and test as part of the production sequence, some selected inspections shall be performed with participation of representatives from ESA.

EIDA-R-6630. A MIP shall require invitation at least one week before the event, and participation of ESA or its written agreement to proceed without ESA participation.

EIDA-R-6640. A KIP shall require the same invitation, but the notified activity may be performed as scheduled if there is no reaction from ESA.

EIDA-R-6650. The PI shall identify Key and Mandatory Inspection Points (KIP/MIP) in accordance with the following criteria:

- when critical processes are performed;
- formal qualification and acceptance tests.
- when the manufacturing sequence is irreversible
- when the manufacturing sequence makes the item difficult and costly to disassemble for inspection
- when the manufacturing sequence or renders the location inaccessible for inspection

EIDA-R-6660. The PI shall propose a list of KIPs and MIPs to ESA together with the manufacturing and inspection flow chart at the IBDR and IHDR. The MIPs where is participation is required will be agreed with the PI.

7.3.10 *Integration and Testing*

7.3.10.1 Test Planning

EIDA-R-6670. An AIT planning shall be prepared as part of the Instrument Development Plan, to cover all test requirements for development, qualification and acceptance test phases for the different models. Details shall be given of :

- hardware configuration;
- test objectives;
- test parameters;
- test sequences (incl. initial and final test conditions);
- acceptance/rejection criteria;
- test equipment (incl. test software) and accuracy required;
- test facilities involved;
- hazards;
- cleanliness of integration/test facilities.

7.3.10.2 Test Procedures

Test procedures are required for all tests on deliverable hardware.

EIDA-R-6680. Test procedures shall be derived from the project requirements of the project AIT plan and shall completely and precisely define the methods and steps by which the tests specified by the relevant test requirements shall be carried out.

EIDA-R-6690. The test procedures shall include**:**

- scope of the test, including the identification of the requirement being verified;
- identification of the test object;
- applicable documents, with their revision status;
- test flow;
- test organisation
- test conditions;

- test equipment and set-up;
- step-by-step procedure, including definition of specific steps to be witnessed by QA personnel
- recording of data;
- pass/fail criteria and test data evaluation requirements;
- guidelines / criteria for deviation from test procedure and for retest (procedure deviation sheets).

Note: Pass/Fail criteria shall be set allowing for test equipment accuracy and measurement uncertainty so that measured/indicated values can immediately be related to the required specification.

EIDA-R-6700. All instrument level test procedures shall be submitted for review and approval by ESA for compliance with all related requirements 4 weeks prior to the Test Readiness Review and performance of the test concerned.

7.3.10.3 Test Facilities / Equipment

EIDA-R-6710. Test facilities required to conduct the test programme shall be specified in the AIT (test) plan and their suitability confirmed well in advance of testing.

EIDA-R-6720. All test equipment including commercial test equipment shall be calibrated as required prior to use and shall remain within calibration during use.

EIDA-R-6730. Prior to unpacking and test of the equipment, the test facility shall have been set up in accordance with the applicable test procedure, and the facility cleared of all obstructions. The facility shall be inspected by QA who shall give approval for the commencement of tests.

EIDA-R-6740. During testing all measurements and tests shall be made in conditions in accordance with the cleanliness and contamination control requirements. Actual ambient test conditions shall be recorded periodically during the test period.

EIDA-R-6750. During tests, only persons associated with the test shall be permitted into the facility.

7.3.10.4 Test Witnessing

EIDA-R-6760. Critical development tests and formal qualification and acceptance tests shall be monitored or witnessed by QA personnel to ensure that applicable procedures are followed without errors, and that adequate records of the activities and test results are taken.

Note: Test witnessing shall be considered when manual intervention is performed, at the setting-up, start and end of continuous fully automated test sequences, or when no automatic recording of test parameters/results is available.

EIDA-R-6770. The QA personnel shall document any variations to test procedures, deficiencies and non-conformances during the test, and monitoring the implementation of dispositions and corrective actions.

7.3.10.5 Test Reviews

EIDA-R-6780. A **Test Readiness Review** (TRR) shall be held prior to any formal instrument qualification and acceptance tests, to determine the following:

- that the as-built configuration status of the test specimen conforms to the released design baseline or differences are acceptable and documented;
- status of existing non-conformances/failures, Requests for Waivers/, open work and assessment that open actions do not affect the test;
- availability and approval status of test procedures;
- verification that hazards and hazardous operations have been clearly identified within the test procedure and appropriate actions are implemented;
- readiness of test facility and associated equipment (cleanliness of test facility, calibration status and validity of all test equipment, including any software programme);

- identify recovery actions for the more probable contingencies in test (e.g. loss of pumping, cooling etc.)assignment of responsibilities during the test;
- conclusion whether to release for testing.

EIDA-R-6790. After major portions of qualification and acceptance tests (e.g. at end of EMC tests and at end of vibration tests), a **Post-Test Review** shall be held to determine that:

- all portions and steps of the applicable procedure have been properly executed, and the test specimen and test equipment have been brought into a safe condition;
- all deviations from or modifications to the initial test procedure which had to be made during the test were properly authorised;
- all required data records are complete and at least a first assessment has been made to determine whether the parameters were within required limits, or whether there is a need for additional testing and/or further analysis of the results before a conclusion can be reached;
- non-conformances/failures have been recorded and at least initial dispositions affecting continuation/completion of the test have been made by the appropriate Material;
- conclusion, whether the test article can be released to the next step or the test set-up can be dismantled.

EIDA-R-6800. Test Review Boards shall include the following representatives of the PI: project management, AIT and product assurance.

EIDA-R-6810. ESA and its selected Prime shall be invited to attend instrument level Test-Readiness Reviews and Post Test Reviews, with a notification at least one week before the event.

7.3.10.6 Test Reports

EIDA-R-6820. A test report shall be provided for each test, including as a minimum :

- a summary of test results;
- an evaluation and verification of test results;
- a list of Non-Conformance Reports raised during the test;
- the as-run filled-in test procedure;
- all test data including environmental test facility records (i.e. vibration plots, vacuum values, temperature and humidity figures, during tests);
- clean room environmental control data i.e. temperature, pressure and humidity, during qualification and acceptance tests.

7.3.11 *QA Requirements for Acceptance and Delivery*

EIDA-R-6830. The PI shall establish a formal acceptance process for all items delivered by collaborating institutes / organisations as well as from contracted industries.

EIDA-R-6840. The PI shall establish a formal acceptance process for all items delivered by his collaboration to ESA and its selected Prime.

EIDA-R-6850. The PI is responsible to organise a formal Delivery Review Board for instrument models to be delivered to ESA or its selected Prime.

The sole basis of this review is the End-Item Data Package (EIDP). The content of this EIDP is described in section 8.6.3

Note: The term ADP (Acceptance Data Package) may be used.

EIDA-R-6860. The PI shall prepare and deliver the EIDP at least 10 days before the DRB takes place.

The DRB consisting of the PI representatives, ESA and selected Prime representatives will review the data package and agree on the consent to ship of the H/W.

It shall be remarked that a "consent to ship" is not automatically considered a formal acceptance. The formal acceptance of the instrument might be subject of closure of open actions, retests etc., in which case a delta DRB might be held.

In this respect the DRB is responsible for authorising the shipment of the items under acceptance, and certifying by writing that:

- a. The items conform to the contractual requirements and to an approved design configuration.
- b. The items are free from material and workmanship deficiencies.
- c. All non-conformances are closed-out, or corresponding plans, compatible with the delivery, are accepted.
- d. The relevant EIDP is complete and accurate.

7.3.12 *QA Requirements for Support Equipment*

Ground Support Equipment (GSE) is clarified as:
“Optical, mechanical, fluidic, electrical and software support equipment or sys-tems used for calibration, measurements, testing, simulation, transportation, handling... of space segment or of space segment elements.”

EIDA-R-6870. For all above defined GSE items which will be mechanically or electrically connected to FM units the same acceptance requirements applies as for FM units.

7.4 Safety Assurance

7.4.1 *General*

EIDA-R-6880. The PI shall implement a safety assurance programme comprising:

- the identification and control of all safety related risks with respect to the design, development and operations of the instrument
- the assessment of the risks based on qualitative and quantitative analysis as appropriate
- the application of a hazard reduction precedence and of control measures of the residual risks.

Note: The objective of safety requirements is to establish methods to be followed during the design, development, fabrication, assembly, integration, testing, transportation, ground operations, launch and orbital operations. These methods will ensure that the risk of hazardous consequences to personnel, flight hardware and facilities are minimised.

EIDA-R-6890. The PI shall identify the responsibility in his team and a contact person for safety related aspects. Description and planning of safety related activities shall be included in the Product Assurance Plan.

7.4.2 *Requirements*

The requirements for safety assurance are governed by the requirements imposed on ESA by the launcher authority, complemented by requirements imposed by ESA itself [RD25] and those of the applicable national safety standards and regulations in the country of origin.

Therefore the design of the instrument and its associated GSE and their operation shall conform to:

- the national and international safety standards and regulations (i.e. during handling and transportation)
- the launcher range safety regulations. [TBD]

This document can be provided by ESA on request.
Launcher's safety requirements, however, have been established to cover different and complete launcher payloads, they are naturally very comprehensive. However only portions of them will really affect the design and operation of the instrument and the tasks to be performed by the PI form only a part of the total safety assurance programme for the system.

In particular, the design of the instrument and its associated GSE and their operation shall conform to the following failure tolerance requirements (or to the requirements of the launcher authorities if they are more severe):

EIDA-R-6900. The instrument and GSE design and operation shall ensure that no single failure or operator error shall have critical or catastrophic consequences.

EIDA-R-6910. The instrument and GSE design and operation shall ensure that no combination of two failures, two operator errors or one failure and one operator error shall have catastrophic consequences.

EIDA-R-6920. The instrument and GSE design and operation shall ensure that all hazards which are not controlled by compliance to failure tolerance shall be controlled by compliance to “design to minimum risk”.

EIDA-R-6930. The instrument and GSE design and operation shall ensure that improper command or command sequences or software errors (e.g. originated from SEU) cause damage of hardware and shall not result in operational conditions, which cannot be restored by ground command. This is also applicable for ground testing of flight hardware. Exceptions shall be accepted by ESA and shall be reported in the User Manual.

EIDA-R-6940. The instrument and GSE design and operation shall ensure that technical requirements for areas of design for minimum risk have to be identified and approved by the ESA selected Prime and agreed by the relevant safety certification authorities.

This will be implemented by an iterative process of:

- identifying potential hazards inherent in the design and operations of an instrument and checking the applicability of established requirements and regulations
- eliminating potential hazards or reducing them to acceptable levels by definition and implementation of requirements on the design and operations and verification by analysis, inspections or tests.

EIDA-R-6950. The consequences of identified hazardous events (according to FMEA) shall be categorised as follows:

I. CATASTROPHIC
Loss of human life; life threatening, permanently disabling injury or occupational illness
II. CRITICAL
Severe injuries to persons and major damage to property, including the environment;
III. SIGNIFICANT
slight injuries to persons; slight damage to or deterioration of (or significant) property, including the environment;
IV. INSIGNIFICANT
without consequence for persons, property and the environment. Failure modes or activities which e.g. in case of human error can lead to any such hazard except "insignificant" shall be identified as "Residual Hazards" and are subject to formal approval.

EIDA-R-6960. All kind of hazardous events shall not propagate across the interfaces.

The ESA selected Prime will act on behalf of ESA as "Payload Authority" for the launcher Interface. It will assure that safety data resulting from the design and operation of an instrument will be integrated into the safety considerations for the system and vice versa the Prime will identify and control the detailed safety requirements to be met by the payload.

7.4.3 *Safety Assurance Tasks*

Responsibilities for safety assurance tasks will be shared between ESA (and its selected Prime) and the PI as defined below.

EIDA-R-6970. The PI shall perform a deterministic Hazard Analysis of the instrument and the GSE used at launch site in order to support the safety submission to the launcher and launch site safety authority on spacecraft level. The HA shall identify and evaluate:

- hazards associated with instrument design, its operation and the operation environment;
- the hazardous effects resulting from the physical and functional propagation of initiator events;
- the hazardous events resulting from the failure of system functions, and functional components;
- time critical situations

EIDA-R-6980. The output of the FMEA shall be used as supporting input. A Preliminary Hazard Analysis shall be submitted for the IPDR.

EIDA-R-6990. As far as possible already at the time of the IPDR, the PI shall identify also the safeguards he intends to implement into the design and operational procedures to reduce potential hazards, as well as the verification methods (analyses, inspections, tests) to assure compliance to the requirements.

In response to the data submitted by the Investigator, ESA / the selected Prime will investigate, together with the spacecraft contractor and the Launcher Authority, the system effects and subsequently define more specific implementation and verification requirements for each instrument (e.g. definition of inhibits for a pyrotechnic function which must be implemented on the instrument side and those which will be implemented on the spacecraft side).

EIDA-R-7000. Safety related test and operating procedures which shall be submitted (at the appropriate time) for formal approval by ESA will also be identified.

EIDA-R-7010. The PI shall eliminate potential hazards, or reduce them to acceptable levels, by definition and implementation of requirements on the design and operations, and verification by analyses, inspections or tests.

EIDA-R-7020. The hazard analysis and the definition of verification methods for all safety design requirements and operational procedures shall be completed as the programme activities progress.

EIDA-R-7030. Updated versions of the hazard analysis, documents demonstrating compliance and verification, Residual Hazard Sheets shall be provided according to chapter 8.6.3.

EIDA-R-7040. All safety verification activities to be performed by analyses or tests for design qualification shall be finalised and the results provided for review at the ICDR.

EIDA-R-7050. Completion of verification activities (acceptance testing, inspections, certifications) on deliverable items and acceptability of residual hazards will be subject to formal review during the acceptance review before delivery.

EIDA-R-7060. The PI shall support, as needed, the preparation of data packages and safety review meetings at spacecraft and spacecraft/launcher level and for integration and launch operations.

7.4.4 *Fracture Control*

EIDA-R-7070. The PI shall apply Fracture Control principles where structural elements of the Instrument or GSE cannot comply to the “Fail Safe” principle and can result in a catastrophic or critical hazard.

Note: The structural design of the instrument shall be based on the "fail safe" principle. Fracture control and fracture mechanics analysis according to ECSS-E-30-01A may also be required for selected structural items and for pressure vessels of instruments, in order to reduce the risk of catastrophic hazards.

EIDA-R-7080. Fracture control principles to be applied on fracture critical elements of the instrument or GSE shall be reviewed and agreed in collaboration with the Prime based on the characteristic of the element.

7.5 Dependability Assurance

7.5.1 *General*

This chapter is based on [RD46], which are tailored here to the instrument and their interfaces with other elements of the spacecraft.

Prime objectives of the reliability assurance activities are:

- to establish and list in a systematic way all possible modes of failure, in order to identify weak elements of the design for improvements, and to support the safety analyses by pinpointing potential hazards (FMEA, HSIA and SPF chapters);
- to assist in the optimisation of system reliability and redundancy concepts with comparative reliability assessments for alternative design options and trade off studies (see chapter on Numerical Reliability Assessment);
- to prevent the propagation of failures to the spacecraft.

EIDA-R-7090. The PA Plan shall describe how compliance with the programme dependability requirements will be met and reliability assurance activities will be interrelated and coordinated with parallel engineering and safety activities. The various steps for the initiation, update and finalisation of the reliability analyses shall be identified in the PA plan.

7.5.2 *Dependability Analysis: Failure Modes, Effects Analysis (FMEA)*

A comprehensive Failure Modes, Effects Analysis (FMEA) should be performed on the functional and physical design (functional FMEA and design FMEA) of the entire instrument and any GSE interfacing physically or functionally with the instrument. In all cases the FMEA shall identify how each failure mode is detected.

The detailed FMEA is mandatory for the instrument parts interfacing with the Spacecraft and is highly recommended on the complete instrument to support failure identification during ground and in orbit operation as well as to support the design process.

The purpose of the FMEA shall be to identify all failure modes of the system and rank them in accordance with the severity of the effects of their occurrence.
Furthermore, it shall be to:

- determine the effects of each failure on the performance of the function under analysis;
- identify all single point failures, classify them according to the severity of their effects, and propose actions to eliminate them from the design;
- establish how the detection, diagnosis, correction, and verification of each failure can be unambiguously implemented.

EIDA-R-7100. FMEA shall be carried out in accordance with [RD24] clause 4.1 and 4.6, for all operational modes of the instrument during orbital phases, launch phases and also for ground testing, if not covered by analyses of the other phases.

Note: The FMEA shall be performed on the basis of the lowest level of design definition which is available at the successive steps in the design and development process, e.g. initially starting with assumed failure modes of basic functions, later at assembly level and finally at instrument level as necessary to cover potentially critical effects. Later, for mechanisms from part level upwards; else from functional blocks without redundancy upwards. The logical sequence of the FMEA shall include the following steps:

- to identify the item under consideration and its function;
- to identify the assumed failure modes for that item or function;
- to analyse and describe the effect of the assumed failure mode on the function of the assembly under consideration and the effects on related and higher level assemblies and functions;
- to identify observable symptoms for the assumed failure mode or its effects (e.g. automatic function monitoring or house-keeping data and telemetry; in orbit or during test).
- to establish what provisions are inherent in the design:

- to compensate the effect of the malfunction (e.g. switching to redundant unit, automatically or by telecommand),
- to isolate the fault, or to switch to contingency operational modes;
- to identify the criticality category of the failure effect according to the definition given below and, specifically, whether the item is a Single Point Failure (SPF).
- provide remarks and recommendations if applicable or necessary or desirable modifications for the design or operations (e.g. elimination of SPFs).

EIDA-R-7110. The following Failure Effect Severity Categories shall be used in the FMEA:

- **Level 1:** - Propagation of failure to other subsystems / assemblies / equipment
- **Level 2:** - Complete Loss of functionality
- **Level 3:**- Degradation of functionality
- **Level 4:** Any other effect.the following attributes shall be added to the criticality category as appropriate:The suffix "S" shall be used to indicate safety impacts.The suffix "R" shall be used to indicate redundancy

EIDA-R-7120. The PI shall submit an updated FMEA at each instrument design review.

7.5.3 *Fault Tree Analysis (FTA)*

The FTA is a top down analysis allowing the identification of failure combinations that can lead to an undesired top event. A FTA is needed for: verifying applicable double-failure tolerance requirements, analysing specific top events (following ESA's request).

7.5.4 *Common –cause and Common-mode analysis*

The FMEA and the FTA can fail to identify common-cause and common-mode failures. A specific Common-cause and Common-mode analysis needs is required for the purpose in coordination with the FMEA, as applicable, with the FTA.

7.5.5 *Hardware / Software Interaction Analysis (HSIA)*

EIDA-R-6870 A hardware / Software Interaction Analysis (HSIA) shall be performed in conjunction with the FMEA

The HSIA shall systematically address the hardware / software interface of a design to ensure that hardware failure modes are being taken into account in the software requirements and design. Detailed requirements are provided in [RD24].

EIDA-R-7130. The HSIA shall be performed for flight H/W controlled by on-board S/W

EIDA-R-7140. The HSIA shall be performed for safety critical / elements of the GSE as identified in the FMEA and Hazard Analysis controlled by S/W

EIDA-R-7150. The HSIA shall be attached to the FMEA.

7.5.6 *Single Point Failures*

On the basis of the FMEA, the PI shall identify Single Point Failures (SPF) and take the necessary actions to eliminate or reduce them. All residual SPFs shall be identified in a SPF List in accordance with template in [RD24], to be a chapter of the FMEA, with a rational for retention.

This rationale shall include an engineering assessment of the likelihood of occurrence, a discussion of the measures, if any, that might be taken to eliminate the SPF, and special provisions to reduce the probability of occurrence or the potential failures effects.

EIDA-R-7160. The PI shall take the necessary action to eliminate Single Point Failures (SPF) related to interface critical elements.

EIDA-R-7170. Any remaining SPF affecting the interface shall be approved by ESA through the Request for Waiver procedure.

7.5.6.1 Reliability Prediction

EIDA-R-7180. Reliability prediction techniques shall be used to optimise the reliability of a design against competing constraints such as cost and mass.

7.5.6.2 Worst Case Analysis

EIDA-R-7190. The PI shall perform a Worst Case Analysis (WCA) in accordance with [RD24], in parallel to electronic design and development activities.

EIDA-R-7200. The WCA shall cover assemblies interfacing with other spacecraft elements to demonstrate that interface requirements (e.g. leakage current) are not violated, taking into account parameter variations of components resulting from initial tolerances, environmental effects (e.g. temperature), ageing, radiation doses, wear-out etc. over the operating life.

EIDA-R-7210. For electronic components the parameter variations have to be substantiated with support from test data (e.g. end of long-term life test limits from qualification tests).

EIDA-R-7220. The replacement of sensitive parts or circuit redesign shall be considered if the WCA indicates a potential problem due to violation of derating requirements or marginal end-of life performance due to aging.

EIDA-R-7230. The adequacy of margins in the design of electronic circuits, thermal and electromechanical systems shall be demonstrated by analysis or test.

EIDA-R-7240. The analysis work shall start during the early design phase and reflect the current design status, and updated as necessary at least for the design reviews.

7.5.7 *Parts Stress Analysis*

EIDA-R-7250. The PI shall perform a Parts Stress Analysis (PSA) in accordance with RD24, in parallel to electronic design and development activities.

EIDA-R-7260. The Parts Stress Analysis shall be performed to verify that the applicable derating factors of RD37 are implemented and have been used for the selection of the EEE parts.

7.6 EEE Parts Selection and Control

7.6.1 *General*

Parts quality play an essential role for the overall chance of success of the spacecraft mission, and therefore their selection and control shall be paid high attention.

In the following, [RD26] has been tailored for the definition of the component requirements to be applied for the instrument.

These requirements apply to flight standard hardware and to components coming into direct contact with flight standard hardware such as the interfacing connectors from GSE cables. For Engineering Models, components shall be used which are equivalent in form, fit, function and materials (e.g. if thermal vacuum tests would be done on EM) but particular quality assurance provisions are not needed.

EIDA-R-7270. The PI shall prepare a Component Control Plan as part of the Product Assurance Plan. This plan shall describe how the component programme will be carried out with identification of the tasks which will be carried out by the PI, or by procurement agents, test houses or consultants as applicable.

The terms "Parts" and "Component" are used here as synonymous.

7.6.2 *Component Programme Management*

Since a deficient identification of the needed components, the usually long delivery times, and the evaluation and tests can have serious impact on the overall schedule, the activities of the component procurement programme need to be planned thoroughly and progress must be closely monitored.

EIDA-R-7280. The PI shall define the responsibility for the component engineering and procurement activities within this team and he shall nominate a contact person for coordination with ESA.

EIDA-R-7290. The PI shall provide as part of the project management plan a EEE parts procurement plan, identifying possible long lead items and eventual re-qualification of parts requiring additional time and effort.

EIDA-R-7300. A Parts Procurement Agency has been selected for the EChO project. The PI shall make use of the services provided by this Agency.

7.6.3 *Component Engineering*

7.6.3.1 Prohibited Materials and Components

EIDA-R-7310. Components with the following characteristics shall be prohibited except where specifically agreed on case-by-case by ESA:

- Limited life
- Known instability
- May cause a safety hazard
- May create a reliability risk

Use of components with known instability shall be avoided unless specifically approved. Examples of unstable components are:

- Plastic encapsulated semiconductors
- Components containing the following materials:
- Beryllium oxide (except if the health and safety hazards are identified in the specification)
- Cadmium
- Lithium
- Magnesium
- Mercury
- Radioactive material
- Pure tin (electroplated or fused)
- Hollow core resistors

- Potentiometers
- Non-metallurgically bonded diodes
- Non-solid tantalum capacitors with silver case
- Dice with no glassivation
- Unpassivated power transistors
- Wet slug tantalum capacitors (except for CLR79 construction using double seals and a tantalum case
- Any component whose internal construction uses metallurgic bonding with a melting temperature not compatible with the end-application mounting conditions
  Wire link fuses

It must be noted that the requirements of this paragraph apply to the entire instrument, not only to critical interface circuits.

EIDA-R-7320. The supplier shall ensure that non-hermetically sealed materials of components meet the requirements of [RD28] regarding outgassing, toxicity and/or other criteria required for the intended use.

7.6.3.2 Component Derating

EIDA-R-7330. In order to enhance the reliability during operation, the components shall not be stressed to the maximum rated values established by the manufacturer, but only to the derated values specified in [RD37].

EIDA-R-7340. Drift and degradation of performance parameters (e.g. increase of leakage current of diodes) shall be taken into account in the design of electronic circuitry. The end-of-life limits of qualification tests or manufacturer may be used.

The verification activities for these requirements are specified in chapter 6.5.6 (Worst Case Analysis) and 6.5.7 (Parts Stress Analysis).

7.6.4 *Component Selection and Approval*

7.6.4.1 Preferred Components

EIDA-R-7350. The European Preferred Parts List (EPPL) [RD27], the ESA/SCC Qualified Parts List and the EChO Preferred Parts List (TBD) shall be used as the primary basis for component selection.

7.6.4.2 Non PPL listed components

EIDA-R-7360. The selection of components which are not in the PPL shall be based on the knowledge of technical performance, qualification status or ability to qualify and history of previous usage in similar applications. Preference shall be given to components from sources which would necessitate the least evaluation / qualification effort.

7.6.4.3 Component Approval

EIDA-R-7370. Components used in flight standard hardware of an instrument are subject to ESA review (all parts used in the instrument) and approval for any EEE parts in the Interface circuitry (power, data etc.).

Component types will be approved by ESA if at least one of the following criteria applies:

- they have been qualified according to the requirements of the applicable SCC specification or to equivalent requirements;
- they have successfully passed the component evaluation and approval programme as outlined in paragraph 7.6.4.4;
- they have received circuit type approval as outlined in [RD40] (for hybrid integrated circuits).

EIDA-R-7380. Type approval will be given if equivalence to ESA/SCC qualification requirements can be demonstrated via existing data or by similarity to qualified components. This information shall be provided on or attached to the Part Approval Document (see [AD-SY-01]). The actual qualification status of the selected manufacturer shall be checked prior to procurement.

EIDA-R-7390. Component approval includes approval of the manufacturer, the procurement specification (and amendments) with definition of all technical requirements, applicable screening and lot acceptance tests and the evaluation/qualification programme, if applicable. Copies of procurement specifications which are not readily available at ESA, shall be provided with the Part Approval Document.

Approval by ESA is given by the signature on the Part Approval Document (PAD) (see 7.6.4.5). An approval reference shall be entered on the DCL to maintain traceability of ongoing work. Standard parts will be approved by acceptance of the DCL.

7.6.4.4 Component Evaluation and Qualification

EIDA-R-7400. In case a valid and acceptable qualification cannot be demonstrated, a component evaluation and qualification test programme shall be implemented.

This programme shall cover the following elements:

- Design assessment for the parameters of the component which are essential for the intended application and which justify the use of a non-preferred part.
- Constructional analysis of the selected part (minimum three components) to assess the standards of fabrication and assembly, potential failure modes, materials and processes which may lead to deterioration or malfunction.
- Manufacturer assessment to assure that the organisation, facilities, production control and inspection system are adequate.
- Evaluation and qualification tests corresponding to those defined in the ESA/SCC specifications for similar technologies.

Further details for an evaluation/qualification programme are outlined in [RD26].

Experienced consultants or procurement agents may have to be used by the PI to perform these tasks. If applicable, the evaluation/qualification programme and the test results for a specific component to be qualified for use on EChO shall be provided with the Parts Approval Document (see 6.6.4.5 below).

7.6.4.5 Application for Part Approval

EIDA-R-7410. A Part Approval Document (PAD) shall be prepared and submitted for approval for all parts not considered as standard parts, i.e. not selected from the PPLs, requiring upscreening activities or violate any other EEE part related requirement as specified in this document.

Parts procured via the EChO CPPA do not require a PAD from the instrument provider.

The PAD shall be in accordance with section 8.6.3. A minimum of 20 working days shall be included in the schedules to allow for the ESA review of the PAD.

7.6.4.6 Declared Components List (DCL)

EIDA-R-7420. All components to be used on flight standard hardware, shall be listed in a Declared Component List, which shall be completed stepwise as the selection of components and the approval process progresses.

This list will be used for comments and advice by components experts from ESA for type reduction or substitution and for evaluation of potential for a coordinated procurement.

EIDA-R-7430. The DCL shall identify the instrument / instrument unit and the design status to which it is applicable.

EIDA-R-7440. The parts shall be grouped according to the families identified in the ESA PPL and the list shall be in accordance with [RD26].

EIDA-R-7450. The Investigator shall prepare and submit at the latest at the Instrument Baseline Design Review a first issue of the DCL, to be regarded as the first choice of components which is subject to further efforts on standardisation and coordination.

EIDA-R-7460. The final version shall be available at the time of the Instrument Critical Design Review.

EIDA-R-7470. The As Built Component list shall be part of the ADP at Delivery.

7.6.5 *Procurement Requirements*

7.6.5.1 Procurement Specifications

EIDA-R-7480. Each type of component used by the PI shall be controlled by a procurement specification, or series of specifications, which must be approved by ESA.

EIDA-R-7490. The PI shall make maximum use of approved specifications issued under existing European component specification systems, either CECC or ESA/SCC as appropriate.

7.6.5.2 Component Screening and Burn-In

EIDA-R-7500. All components to be incorporated into flight-standard hardware shall be subjected to screening test.

EIDA-R-7510. The screening test requirements shall be so designed that the accumulated stresses will not jeopardise the component reliability.

EIDA-R-7520. The following ESA/SCC test levels for the screening of components used in the Instrument Interfaces shall be applied:

- Integrated circuits ESCC level B, or MIL-PRF-38535 class V
- Hybrids ESA PSS-01-608 level B, or MIL-PRF-38534 class K (U.S. manufacturers only)
- Diodes, transistors, optos ESCC level B, or MIL-PRF-19500-JANS
- Crystals ESCC level B
- Relays ESCC level B
- Filters ESCC level B
- CCD ESCC level B
- Connectors/Cables ESCC Level B
- Passives, other components ESCC C, orMIL Spec, as a minimum Failure rate R.

Any additional and/or alternative screening proposals may be applied for procurement ONLY upon approval of the relevant PAD as required in ECSS-Q-60A.

Note: The screening levels stated above are identical to the screening levels used for the Spacecraft units and are the levels the EChO CPPA will work upon.

EIDA-R-7530. For Parts, not in the Interface to the Spacecraft system, the following lower levels are applicable (TBC), however the PI is encouraged to procure the highest levels to guarantee maximum mission success of the instrument:

- Integrated circuits ESCC level C, or MIL-PRF-38535 class Q
- Hybrids ESA PSS-01-608 level C, or
- MIL-PRF-38534 class H (U.S. manufacturers only)
- Diodes, transistors, optos ESCC level C, or MIL-PRF-19500-JANTXV
- Crystals ESCC level B

- Relays ESCC level B
- Filters ESCC level B
- CDD ESCC level B
- Connectors/Cables ESCC Level B
- Passives, other components ESCC C, or
- MIL Spec, as a minimum Failure Rate P or B

Any additional and/or alternative screening proposals may be applied for procurement ONLY upon approval of the relevant PAD as required in ECSS-Q-60A.

All screening test shall be performed at the component manufacturer's premises or at an approved source.

7.6.5.3 Lot Acceptance Test (LAT)

EIDA-R-7540. It shall be ensured that all components shall be subjected to Lot Acceptance Testing (LAT) as defined in the ESCC specifications, or QCI (Quality Conformance Inspection) as defined in the United States Military specifications. The levels shall be as defined below:

- Level LAT1 or QCI compatible: the component is neither ESA/SCC nor United States Military qualified at the time of the procurement and level LAT2 is not applicable
- Level LAT2 or QCI compatible: the component is not space qualified but has successfully supported other long life and/or high reliability space programmes and the reliability/evaluation data are still valid for the current design.
- Level LAT3 or QCI compatible: all cases not included in level LAT1 or LAT2. Level LAT3 tests may be replaced by incoming inspection. Level LAT3 tests may be omitted for qualified ranges of components (e.g. 54HC, ...).

7.6.5.4 Hybrid Circuits

EIDA-R-7550. Hermetic hybrid circuits, if used, shall be procured in accordance with [RD40], to be complemented by a detail specification, from sources which are "capability approved" for all relevant technologies, as per [RD39] for thick film, and per [RD38] for thin film.

EIDA-R-7560. In case hybrid circuits are required from a source which is not yet approved, an evaluation and acceptance testing programme shall be performed as defined in [RD38] or [RD39].

EIDA-R-7570. All add-on components shall be selected as defined herein and shall meet the requirements of [RD40].

EIDA-R-7580. For each hybrid circuit a PAD shall be established, including all add-on components, and submitted to ESA for approval.

7.6.5.5 Relifing

The implementation of a relifing procedure in accordance with [RD44] is necessary for lot/date code exceeding the period defined in [RD44] clause 5

7.6.6 *Component Quality Assurance*

7.6.6.1 Manufacturer Surveillance

EIDA-R-7590. Manufacturer surveillance shall be carried out as necessary with audits or participation at critical processing/inspection steps, e.g. with customer (or procurement agent) participation in precap visual inspections or witnessing of key acceptance tests.

7.6.6.2 Incoming Inspections and Destructive Physical Analysis (DPA)

EIDA-R-7600. Receiving inspection of all components shall be carried out by the user or a procurement agent who is independent of the manufacturer, and this shall include:

- Review of the Manufacturer delivered documentation;
- External visual inspection;
- Electrical measurement of critical parameters (if practicable);
- Destructive physical analysis.
- Solderability test as far as necessary
- RVT results against needs, if RVT is performed

EIDA-R-7610. Destructive Physical Analysis (DPA) shall be carried out by the user or his procurement agent or an independent laboratory on three samples from each date code of the component types listed below:

- discrete semiconductors
- integrated circuits
- filters
- variable resistors
- variable capacitors
- ceramic capacitors
- tantalum capacitors
- relays
- crystals
- hybrids
- switches
- high-voltage components
- high-frequency components
- opto-electronic components

EIDA-R-7620. DPA is not required on components with a valid ESCC qualification. Grouping of DPA for certain families of components (e.g. logic families, capacitor range within one of housing) can be considered. For particularly expensive items the number of DPA samples may be reduced upon agreement with ESA.

EIDA-R-7630. For some selected components ESA reserves the right to request additional samples for DPA or other investigations; this will be identified by ESA when approving the relevant PADs.

7.7 Radiation hardness for EEE components

7.7.1 *Definitions*

Refer to RD43.

7.7.2 *TID Hardness assurance*

EIDA-R-7640. EEE components used in the instrument shall be able to withstand minimum of 40 krad (Si) (tbc) without degradation of the performances.

EIDA-R-7650. Each EEE part belonging to families and sub-families listed in Table 25 shall be assessed for sensitivity to TID effects to the level specified in this table.

Hybrids can also be treated as an electronic box. In this case, RHA requirements, as listed in this document, are applicable to every die used in the hybrid.

EEE part family	**Sub family**	**TIDL**
Diodes	Voltage reference, Zener	All
	Switching, rectifier, Schottky	> 300 krad-Si eq.
Diodes microwave		> 300 krad-Si eq.
Integrated Circuits		All
GaAs Integrated Circuits		> 300 krad-Si eq.
Oscillators (hybrids)		All
Charge Coupled devices (CCD)		All
Opto discrete devices, Photodiodes, LED, Phototransistors, Opto couplers		All
Transistors (MOS and bipolar)		All
GaAs Transistors		> 300 krad-Si eq.
Hybrids containing active parts		All

Table 25 EEE part families potentially sensitive to TID.

EIDA-R-7660. TID test data used to assess TIDS shall comply with the following rules to be acceptable:

- tests are performed in conformance to ESCC 22900, MIL-STD 883 method 1019, or MIL-STD-750 method 1019, and
- devices that contain bipolar transistors are tested at a dose rate of 36 to 360 rad/h, and
- tested parts are manufactured with technology identical to the technology of flight parts: same process, same diffusion mask, and same wafer fabrication facility, and
- test bias conditions are worse or equivalent to the application.

EIDA-R-7670. If acceptable component TID test data does not exist, ground testing shall be performed in conformance to ESCC 22900 and requirements EIDA-R_7410 2 to 4

EIDA-R-7680. Acceptable component TID test data shall be available latest at CDR.

EIDA-R-7690. Component type TIDS shall be based on the parametric and functional limits given in component detail specification or manufacturer data sheet, or on the maximum parameter degradation acceptable to ensure equipment operation in compliance with equipment performance specification at the end of overall lifetime (EOL).

TIDS is defined by comparing part parametric/functional requirements with TID test data

EIDA-R-7700. Component type TIDS shall be the total dose level at which the one sided tolerance limit to guarantee a probability of survival Ps of at least 95 % with a confidence level of at least 90 exceeds its limits as defined in requirement EIDA-R-7640.One sided tolerance limit factor values for probability of survival of 95% with 90% confidence level are given in RD43.

EIDA-R-7710. Component received TID level (TIDL) shall be calculated using tools valid for the expected spacecraft environment in conformance with ECSS-E-ST-10-12 [RD08] .

EIDA-R-7720. Any necessary radiation shielding material shall be defined on the basis of detailed shielding analyses. (tbc)

EIDA-R-7730. Shielding analyses shall be performed at instrument level during all project phases. (tbc)

Shielding analyses will be performed at system level for SRR taking into account preliminary system design and models of equipment's/ instrument.

Integrated analyses of equipment and platform shielding that take into account details of the platform and equipments/instrument will be performed at PDR.

Integrated analysis will be iterated at equipments/instrument CDRs to reflect increased available details.

EIDA-R-7740. Minimum required RDM shall be 1.

EIDA-R-7750. For any component that is estimated to have on-orbit performance degradation due to TID, it shall be demonstrated, performing a WCA in accordance with ECSS-Q-ST-30, that the function performs within EOL technical specification limits.

EIDA-R-7760. If requirements EIDA-R-7750 and EIDA-R-7740 are not met, mitigation shall be implemented to eliminate the possibility of damage to the instrument or degradation of its performance outside its specification limits.

EIDA-R-7770. Mitigation shall be verified by analysis or test.

EIDA-R-7780. The PI shall document the TID analysis in the equipment radiation analysis report in conformance to Annex B of ECSS Q-ST-60-15C [RD43].

EIDA-R-7790. TID radiation verification test (RVT) or RADLAT on flight lots shall be performed in accordance with Table 26.

Family	Sub-family	RDM	RVT Requirement
Diode	Zener, voltage reference	-	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 10 years
integrated circuits	Silicon Monolithic CMOS	-	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 4 years
	Silicon Monolithic bipolar, BiCMOS	> 4	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 4 years
		<4	RVT required
Transistors	High power NPN High power PNP	> 4	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 4 years
		<4	RVT required
	FET P channel, FET N channel	-	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 4 years
CCD, CMOS APS		> 4	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 4

			years
opto discrete devices		< 4	RVT

Table 26 TID RVT criteria

EIDA-R-7800. Conformity of RVT or RADLAT results with as designed radiation analysis shall be checked.

As designed radiation analysis includes TIDL based on shielding, TIDS based on existing data and radiation drifts considered in WCA

EIDA-R-7810. Nonconformities of RVT or RADLAT results with as designed radiation analysis shall be reported in a NCR in conformance with RD47 .

7.7.3 *TNID hardness assurance*

EIDA-R-7570 EEE components used in the instrument shall be able to withstand a minimum of 9,7*10^{10} cm-2 (10 MeV proton equivalent fluence) (tbc)

Each EEE part belonging to families and sub-families listed in Table 27.

Guidelines and NIEL rates for calculating monoenergetic equivalent proton fluences are provided in ECSS-E-10-12C clause 7.5 [RD08].

Family	Sub-Family	TNIDL
CCD, CMOS APS, opto discrete devices	all	All
Integrated circuits	Silicon monolithic bipolar or BiCMOS	> 2x10^{11} p/cm2 50 MeV equivalent proton fluence
Diodes	Zener Low leakage Voltage reference	> 2x10^{11} p/cm2 50 MeV equivalent proton fluence
Transistor	Low power NPN Low power PNP High power NPN High power PNP	> 2x10^{11} p/cm2 50 MeV equivalent proton fluence

Table 27 List of EEE part families potentially sensitive to TNID

EIDA-R-7820. TNID data used to assess TNIDS shall satisfy the following criteria to be acceptable:

- Tests are performed with protons or neutrons and tested levels encompass the specified mission environment;
- Tested parts are manufactured with technology identical to the technology of flight parts: same process, same diffusion mask, and same wafer fabrication facility.

EIDA-R-7830. If acceptable component TNID test data does not exist, ground testing shall be performed in conformance to requirement EIDA-R-7820 point 2.

EIDA-R-7840. TNID irradiation test plans shall be submitted to ESA approval.

This is because no standard method exists for TNID testing.

EIDA-R-7850. TNID irradiations should be performed with protons and electrons at several energies encompassing the specified mission radiation environment.

This is because of the limitations of NIEL calculations for some technologies and component families.

EIDA-R-7860. Acceptable TNID test data shall be available latest at CDR.

EIDA-R-7870. Component type TNIDS shall be based on the parametric and functional limits given in detail specification or manufacturer data sheet, or on the maximum parameter degradation acceptable to ensure equipment operation in compliance with equipment performance specification at the end of overall lifetime (EOL).

TNIDS is defined by comparing part parametric/functional requirements with TNID test data

EIDA-R-7880. Component type TNIDS shall be the TNID level at which the one sided tolerance limit to guarantee a probability of survival Ps of at least 95% with a confidence of at least 90% exceeds its limits as defined in requirementEIDA-R-7870.

EIDA-R-7890. Component TNID level (TNIDL) shall be calculated using tools valid for the expected spacecraft environment in conformance to ECSS-E-ST-10-12 RD08.

EIDA-R-7900. Minimum required RDM shall be 1

EIDA-R-7910. For any component that is estimated to have on-orbit performance degradation due to TNID, a WCA of the function shall be performed in accordance with requirements of ECSS-Q-ST-30 [RD24] to demonstrate that the function performs within specification despite radiation induced drifts in its constituent part parameters at EOL.

EIDA-R-7920. Both TNID and TID degradations shall be combined to define the component parameter drifts for WCA.

If Combined TNID and TID tests are used to get the combined TID/TNID sensitivity, such test plans shall be submitted to ESA approval.

Generally, TNID sensitive parts are also sensitive to TID.

EIDA-R-7930. If requirements EIDA-R-7900, EIDA-R-7910 and EIDA-R-7920EIDA-R-7920 cannot be met, mitigation shall be implemented to eliminate the possibility of damage to the instrument or degradation of its performance outside its specification limits.

EIDA-R-7940. Mitigation shall be verified by analysis or test.

EIDA-R-7950. TNID analysis shall be documented in the equipment radiation analysis report in conformance with Annex B-DRD of ECSS-Q-ST-60-15C [RD43.

EIDA-R-7960. TNID radiation verification test (RVT) or RADLAT on flight lot shall be performed in accordance with Table 28.

Family	**Sub-family**	**RDM**	**RVT Requirement**
Diodes	voltage regulator, Zener	-	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 4 years
integrated circuits	Silicon Monolithic bipolar	-	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 4 years
Transistors	Low power NPN, Low power PNP, High power NPN, High power PNP	-	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 4 years
CCD, CMOS APS		-	RVT required

opto discrete devices		-	RVT if flight diffusion lot number different of data diffusion lot number and date code older than 4 years

Table 28 TNID RVT requirements

It is part of hardness assurance to perform RVT or RADLAT on flight lot based on the following criteria: age of available test data, part type and technology, and RDM.

EIDA-R-7970. Conformity of RVT or RADLAT results with as designed radiation analysis shall be checked.

As designed radiation analysis includes TIDL based on shielding, TIDS based on existing data and radiation drift considered in WCA

EIDA-R-7980. Nonconformities of RVT or RADLAT results with as designed radiation analysis shall be reported in a NCR in conformance with ECSS-Q-ST-10-09 [RD47].

7.7.4 *SEE hardness assurance*

EIDA-R-7990. No SEE shall cause damage to the instrument or induce performance anomalies or outages not compliant with the instrument specifications.

EIDA-R-8000. Each EEE part belonging to families and sub-families listed in Table 28 shall be assessed for sensitivity to SEE.

A description of different types of SEE can be found in ECSS-E-ST-10-12 [RD08].

Family	Sub-family
Integrated Circuits	all
Integrated Circuits Microwave	all
Transistors	FET N channel FET P channel
Transistors Microwave	all
CCD, CMOS APS, opto discrete devices	all

Table 29 List of EEE part families potentially sensitive to SEE

EIDA-R-8010. SEE test data shall meet the following criteria to be acceptable:

- Test are performed in conformance to
- MIL-STD-750E method 1080 for power MOSFET,
- ESCC25100 for all other parts.
- Useful information about SEE testing is also provided in EIA/JESD 57.
- Tested parts are manufactured with technology identical to the technology of flight parts: same process and same diffusion mask
- Test conditions are worse or equivalent to the application
- Test conditions include, but are not limited to, bias conditions, clock frequency, test pattern, and temperature.

If acceptable component test data does not exist, heavy ion ground testing shall be performed.

EIDA-R-8020. For the SET criticality analysis of SET in analog ICs, worst case SET templates in Table 30 may be used in the absence of acceptable test data.

Device type	SET nature at device output
OP-amps	$\Delta V_{max} = \pm V_{cc}$ & $\Delta t_{max} = 15\ \mu s$
Comparators	$\Delta V_{max} = \pm V_{cc}$ & $\Delta t_{max} = 10\ \mu s$
Voltage Regul.	$\Delta V_{max} = \pm V_{cc}$ & $\Delta t_{max} = 10\ \mu s$
Voltage Ref.	$\Delta V_{max} = \pm V_{cc}$ & $\Delta t_{max} = 10\ \mu s$
Optocouplers	Susceptible to SEU $\pm V_{cc}$ & $\Delta t_{max} = 100ns$

Table 30 worst case SET templates.

EIDA-R-8030. All SEE testing shall be performed in conformance to requirements of EIDA-R-8010.

EIDA-R-8040. SEE analysis and proton testing shall take place based on LET threshold (LETth) of the candidate devices as specified in Table 31.

In accordance with this table, no further analysis is necessary above a LETth of 60 MeVcm2/mg, because parts are commonly considered immune to SEE in the space environment.

Device LETth (MeVcm^2/mg)	Environment to be assessed
LETth < 15	Heavy ions (GCR, solar event ions) Protons (trapped, solar event protons)
LETth= 15-60	Heavy ions (GCR, solar event ions)
LETth>60	No analysis required

Table 31 Environment to be assessed based on LETth.

EIDA-R-8050. Below a LETth level of 60 MeVcm2/mg, heavy ion induced SEE analysis shall be performed.

EIDA-R-8060. Below a LETth of 15 MeVcm2/mg proton and heavy ion induced SEE sensitivity analysis shall be analyzed.

EIDA-R-8070. Proton SEE sensitivity of SEE hardened parts shall be assessed.

The LETth of 15 MeVcm2/mg for performing proton SEE tests is not an absolute value. For VLSI hardened IC employing high-Z material in the vicinity of sensitive volumes, the LET of secondaries can be higher than 15 MeVcm2/mg.

EIDA-R-8080. The LETth levels as described in EIDA-R-8040 and EIDA-R-8070 shall be recalculated for parts made of other material than Silicon (i.e. GaAs).

EIDA-R-8090. Proton SEE test data shall satisfy the requirement EIDA-R-8010 to be acceptable.

EIDA-R-8100. If acceptable proton SEE data is not available, proton ground testing shall be performed.

EIDA-R-8110. Proton SEE testing shall be performed according to requirement EIDA-R-8010.

EIDA-R-8120. Acceptance of simulation tools to obtain proton SEU cross-section curves on digital devices shall be subject to ESA approval.

For SEUs, proton cross-section curve can be obtained from heavy ion cross-section curve with simulation tools such as SIMPA or PROFIT.

EIDA-R-8130. For any component that is not immune to destructive SEE analysis, it shall be demonstrated that the probability of occurrence in the mission environment is more than 10 times lower than component intrinsic failure rate.

Examples of destructive SEE are: SEL, SEB, SEGR and SEDR.

EIDA-R-8140. One of the following two power MOSFE0T SEB/SEGR assessment methods shall be applied**:**

- SEB/SEGR failure rates based on SEB/SEGR cross-section versus equivalent LET curves;

- V_{DS}max, V_{GS}off max derating based on V_{DS} versus V_{GS} SOA.

Note: Power MOSFET have a deep sensitive volume. Therefore, LET can vary significantly along ion path in sensitive volume.

EIDA-R-8150. Practical implementation of the method used to assess power MOSFET SEB/SEGR sensitivity, as specified inEIDA-R-8140, shall be submitted to ESA approval.

EIDA-R-8160. For non-destructive SEEs the criticality of a component in its specific application shall be defined including impacts at higher level, ie. subsystem and system.

Examples of non-destructive SEE are: SEU, SET, MCU, and SEFI.

EIDA-R-8170. For the criticality analysis of SET in analog ICs, the analysis method, electrical simulations or hardware electrical injection, shall be submitted to ESA approval.

EIDA-R-8180. The mission event rate shall be calculated when a SEE on a given component for a given application is considered critical or potentially critical..

EIDA-R-8190. The mission event rate shall be calculated for the mission background environment and a solar event environment as defined in mission radiation environment specification in conformance to ECSS-E-ST-10-12 [RD08].

EIDA-R-8200. When proton SEU rate is based on simulation from heavy ion data, A SEE RDM of 10 shall be applied on calculated error rate.

When proton SEU rate is based on actual proton test data, no SEE RDM applies on proton SEU rate

EIDA-R-8210. The calculated event rates, shall be such that the application meets the instrument availability, performance, and reliability requirements.

EIDA-R-8220. If requirements EIDA-R-8130 and EIDA-R-8210 are not met, mitigation shall be implemented to eliminate the possibility of damage to equipment or degradation of its performance outside its specification limits.

EIDA-R-8230. Mitigation shall be verified by analysis or test.

EIDA-R-8240. All data and analysis shall be documented in Radiation Analysis report in conformance with Annex B– DRD of ECSS-Q-ST-60-15C

7.7.5 *Equipment radiation reviews*

A dedicated radiation review will be organized at IPDR to assess the delivered documentation related to radiation hardness of EEE components.(tbc)

7.8 Materials and Process Selection and Control

7.8.1 *General*

7.8.2 *Evaluation Programme*

EIDA-R-8250. Materials and processes for which positive and negative experience has been gathered in previous space projects are listed in [RD35]. The use of ESA-known materials and processes is highly recommended; however, their suitability for use on the programme shall be evaluated for each application.

EIDA-R-8260. Materials which may constitute a safety hazard or can cause contamination are prohibited from being used without prior approval by ESA. Examples are of these materials are:

- Beryllium-Oxide
- Cadmium
- Zinc
- Mercury
- Radioactive Materials
- PVC.

EIDA-R-8270. Material and processes which cannot be considered either space proven or standard/established shall be subjected to an evaluation programme, to assess the suitability for the intended application.

Typical elements of an evaluation programme are:
a. **Vacuum:** Outgassing tests shall be carried out as per specification [RD29] or ASTM E 595-90 on Materials whose conditions of use may lead to contamination. The acceptance criteria for Materials used in space applications shall be generally as follows :
- Residual Mass Lost < 1.00%.
- Collected Volatile Condensable Material < 0.10%
Materials close to optical surfaces may require additional testing to be evaluated on a case-by-case basis. The use of pure mercury, cadmium and zinc is prohibited.

Please note that for material experiencing operating temperatures hire then 80 deg. C dedicated outgassing tests are required.

b. **Thermal cycling:** Materials subject to thermal cycling shall be assessed to ensure their capability to withstand the induced thermal stresses.

c. **Radiations:** Materials used on the spacecraft's external surfaces shall be assessed to determine their resistance to the radiation dosage expected during the mission. Specification PSS-01-706 shall be applied in order to demonstrate resistance of Materials to radiation (electromagnetic and particles).

f. **Electrochemical compatibility:** When bimetallic contacts are used, the choice of the pair of metallic materials used shall take into account [RD35] or MSFC-SPEC-2 50 data.Maximum allowed couple is 0.5 V in controlled environments and 0.25 V in un-controlled environments (no temperature or humidity controls).

g. **Corrosion:** Corrosion resistance may have to be demonstrated for Materials subject to corrosion throughout their life cycle (storage, transportation, launch...). Data are available in MFSC HDBK 527 (guideline document).

h. **Stress corrosion:** As far as Materials used for the structure are concerned, they shall be chosen in compliance with table 1 of [RD32] ; any Material not covered by specification ECSS-Q-70-36A shall be tested according to specification [RD33]. The criteria g and h shall also apply to GSE

7.8.3 *Materials and Process Selection and Approval*

EIDA-R-8280. The PI shall be responsible for the selection of materials and processes, and for demonstrating their suitability for the intended application.

EIDA-R-8290. To this end, he shall plan and enforce an effective material control and standardisation programme. Materials and processes shall be selected in accordance with the criteria summarised in 6.7.2; full details are given in [RD28].

EIDA-R-8300. Materials, mechanical parts and processes shall be approved by ESA before they can be used for the production of flight standard hardware as outlined below; detailed instructions are provided in [RD28].

EIDA-R-8310. The PI shall submit to ESA for approval a Declared Material List (DML) (see [RD-PA-07]), a Declared Mechanical Parts List (DMPL) (see [RD28]) and a Declared Process List (DPL) (see [RD28]). Materials and process used by Co-Investigators and/or contractors shall be consolidated in the lists produced by the PI.

EIDA-R-8320. For materials or mechanical parts with limited or no test data available, the PI shall submit a Material or Mechanical Part Request for Approval in accordance with [RD-PA-07], proposing an evaluation programme. ESA will provide advice on and approve the evaluation programme and its results. ESA may request material samples for additional evaluation and comparative testing. These samples shall be provided with a Material Identification Card in accordance with [RD-PA-07].

EIDA-R-8330. Critical processes shall be identified in the DPL and PIs shall submit Process Requests for Approval (see [RD28]) together with the DPL. Critical processes are those which can have an effect on the structural integrity of the instrument, are novel or the quality of which cannot be assessed solely by examining the end product (e.g., bonding, potting, painting and soldering).

EIDA-R-8340. The PI shall identify in these documents all materials involved (also cleaning agents), all processing steps, in-process and final inspections and tests, and the proposed test programme for process evaluation. At the end of the evaluation programme, a report shall be submitted to ESA upon which the approval of the process will be based.

EIDA-R-8350. A first issue of the DML, DMPL and DPL shall be submitted in the conceptual design phase for ESA comments and guidance for replacement of unacceptable materials and processes with suitable ones.

EIDA-R-8360. DML, DMPL and DPL shall be updated to reflect the degree of definition of the design in the following phases of the programme and revisions shall be provided for each of the project design reviews.

EIDA-R-8370. The review/approval activities and all necessary evaluation / qualification programmes for materials and processes shall be scheduled such that they will be finalised at the Instrument Critical Design Review (ICDR) (start of manufacturing of qualification/flight hardware).

7.8.4 *Materials Control*

EIDA-R-8380. Each type of material to be used shall be covered by a procurement specification or standard. The contractor is encouraged to use existing international and national standards at the maximum extent, in order to expedite the approval process of the DML. When developed by the PI, procurement specifications shall be made available upon request to ESA for review; proprietary rights will be respected.

EIDA-R-8390. Receiving inspections, lot/batch testing and in-process inspections/test shall be carried out to the degree necessary to ensure that variable and significant characteristics of the materials are within required limits.

EIDA-R-8400. Lot/batch acceptance test reports shall be kept at the investigator's or contractor's plant for at least 10 years together with other historical manufacturing/production records for the assemblies.

EIDA-R-8410. Non-conformances on materials and processes shall be recorded and treated as specified in chapter 7.3.4. of this document.

EIDA-R-8420. The PI shall be responsible for the performance of all inspections and tests necessary for evaluation, qualification and production surveillance.

EIDA-R-8430. ESA reserves the right to require samples of raw or processed materials for evaluation and testing in its own or other laboratories.

EIDA-R-8440. Mechanical parts (for bolts/nuts at least for size M4 and larger) shall be covered by procurement specifications including all technical requirements and adequate quality assurance provisions.

Materials, semi-finished products, and parts shall be procured from sources which can demonstrate previous deliveries of products with the required characteristics and quality or which have been formally qualified.

EIDA-R-8450. The name of the source/manufacturer shall be entered in the DML together with the name of a back-up source for critical procurement.

Printed Circuit Boards should preferably be procured from ESA qualified sources.

EIDA-R-8460. Material design allowables used in mechanical stress analyses shall correspond to "A-values" as defined in MIL-HDBK-5 or equivalent documents. Strength values for mechanical parts shall not be assumed to be higher than the values specified for the relevant qualification and acceptance tests.

7.8.5 *Process Control*

EIDA-R-8470. Each process used by the PI and listed in the DPL shall be covered by a process specification or standard.

The PI is encouraged to make maximum use of existing ESA specifications or ESA approved specifications/standards produced by international organisations and national agencies, because they reflect a consolidated experience and in order to expedite the approval process of the DPL. The complete list of approved documents and standards is contained in [RD30] and [RD31]. ECSS-Q-70-38 draft is applicable for surface mount and mixed technology mounting techniques, i.e. CGA or BGA.

EIDA-R-8480. When developed by the PI, process specifications / procedures shall include sufficient in-process and final inspections and controls to ensure that characteristics of the product are within the required limits. Process procedures shall be made available or accessible to ESA upon request for review.

The PI shall be aware that new mounting techniques, e.g. CGA or BGA assemblies of EEE parts do require a process qualification activity, which can be very difficult to achieve due to the lack of experience of these processes for space applications.

7.9 Software Product Assurance

7.9.1 *General*

EIDA-R-8490. An effective Software Product Assurance (SPA) programme shall be implemented. It shall ensure that :

- software design requirements are properly specified;
- formal definition documents are issued;
- standards, practices and conventions are applied (e.g. logic structure, coding, commentary);
- design and development activities are subjected to formal reviews;
- all testing carried out to formal test procedures;
- configuration management control procedures are applied.

EIDA-R-8500. The SPA requirements shall be applicable to:

- flight S/W (application and operating S/W);
- GSE S/W.

7.9.2 *Software Product Assurance Activities*

EIDA-R-8510. The following fundamental tasks of SPA activities shall be performed:

- establishment of standards and quality assurance procedures. Examples of ESA software engineering standards are listed in [RD34];
- participation in writing coherent development, analysis, production and test plans for PA related issues;
- participation in reviews, audits and meetings;
- ensuring adherence to standards and procedures;
- liaison with configuration management;
- involvement in problem reporting and resolution;
- control of supplies/contractors;
- validation and acceptance test follow-up including non-conformance control

Note: The SPA can be part of the overall Product Assurance Plan. As such the verification of this requirement can be assessed in combination of that Plan..

7.9.3 *Software Product Reviews and Inspections*

EIDA-R-8520. The Software Development shall be done in accordance with [RD17].

EIDA-R-8530. The traceability shall be ensured during all development and test phases from requirements via intermediate steps, down to code.

Formal acceptance release is mandatory for each step.

7.9.4 *Hardware / Software Interaction Analysis (HSIA)*

This subject is covered by chapter 7.5.5

7.9.5 *Software Configuration Management*

EIDA-R-8540. Software and software related documents shall be placed under configuration control not later than the start of formal verification and acceptance testing.

EIDA-R-8550. Configuration management and change control activities shall be performed in accordance to the configuration management requirements (see chapter 8.7).

7.9.6 *Software Problem Reporting*

EIDA-R-8560. Software non-conformance shall be treated as defined in the Non-Conformance Control chapter, but the terminology used may be different.

7.10 Cleanliness and Contamination Control

EIDA-R-8570. The PI shall define in the PA plan the criteria and tasks for the contamination control, taking into account the guidelines provided in [RD36].

EIDA-R-8580. After establishing the cleanliness requirements for his instrument, the PI shall identify the provisions, activities and verification methods necessary to achieve the cleanliness levels through all stages of fabrication, handling, transportation and testing. Also the precautions and provisions to be taken during the integration, transportation and launch preparations of the spacecraft shall be defined, and the ESA selected Prime shall be notified accordingly so that the necessary arrangements can be made in due time.

EIDA-R-8590. The following potential contamination sources shall be considered:

- choice of materials;
- lack of degreasing of raw materials;
- residues from cleaning agents, fluxes or machine lubricant;
- insufficient curing and bake-out of materials;
- handling of flight hardware with bare hands or dirty tools;
- inadequate clean room clothing or discipline of personnel in clean rooms;
- condensation of moisture or contaminants on cold surfaces during tests or transportation;
- suitability and cleanliness of packing and packaging materials.

EIDA-R-8600. Appropriate provisions for their control shall be defined for facilities and procedures, and their implementation shall be verified.

EIDA-R-8610. 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 (see sections 4.12.2.2) is not of the same high cleanliness standard which can be achieved in a laboratory where sensitive equipment is assembled. Therefore, protection devices shall be incorporated in the design, and also provisions for cleaning sensitive areas at later integration phases shall be identified, if necessary.

EIDA-R-8620. Bake-out in vacuum at elevated temperatures of contamination sensitive items before integration into the instrument shall be considered as an effective method to reduce the molecular contamination accumulated, and the potential for cross-contamination when in orbit.

EIDA-R-8630. For planning and analysis of contamination budgets on system level the following information shall be provided by the PI for each unit:

- Purge interface
- Purge rate
- Allowed EoL budget for MOC and PAC
- MOC and PAC budget at unit delivery to system

8 MANAGEMENT REQUIREMENTS

8.1 Introduction

This chapter provides a preliminary description of the requirements on the Consortium Leads/Principal Investigators/Funding Agencies relevant for project management, organization, programmatic and deliverable aspects. The final management principles of the mission organisation and the assignment of responsibilities will be described in the Science Management Plan. Should the mission be selected, this document will be approved by the Science Programme Committee in preparation for the mission Implementation Phase. Where relevant, the Science Management Plan will take precedence over the requirements reported in this document.

8.2 Organization and Responsibilities

8.2.1 *ESA EChO Project office Responsibilities*

The management of the EChO mission will be under the responsibility of the ESA EChO Project Manager located at ESTEC, Noordwijk, The Netherlands.

The ESA EChO Project Manager will have full responsibility for all aspects of the development, launch and initial operations of the mission.

If, in the interest of the overall programme, significant technical and/or programmatic changes to an experiment are necessary, then ESA will be responsible for the definition of the required change to be implemented by the Principal Investigator (PI).

The ESA EChO Project Manager will be directly supported in the execution of the programme by the engineering, administrative and project control staff of the ESA EChO Project Office located at ESTEC.

The EChO Instrument is managed by the EChO Payload Manager and his team of engineers under the overall responsibility of the ESA EChO Project Manager.
The EChO Payload Manager and his team of engineers will deal with the day to day Instrument activities and follow up on a regular basis the progress to ensure that they meet the EChO programme objectives.

The EChO Payload Manager and his team of engineers will have in particular the following responsibilities:

- Support the PI team in solving technical and programmatic issues.
- Accommodation of the payload into the spacecraft in line with the technical and programmatic requirements defined in the Experiment Interface Document (Part A and Part Bs).
- Assess and disposition engineering change requests (ECRs[1]).
- Oversee acceptance tests of the Instrument deliverable items as part of the delivery procedure to the Industrial consortium
- Supervise and coordinate with the PI the support and inputs required for the spacecraft 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 the PI or the Prime Contractor in relation to the accommodation of the instrument in the spacecraft

The ESA EChO Project Office will fulfil its function until the completion of the spacecraft in-flight commissioning phase.

An ESA EChO Mission Operations Manager will be responsible for the conduct of the mission operations from the end of the commissioning phase until the end of the mission.

1 ECR will become only active when the documentation has been formally issued and not considered as draft anymore.

8.2.2 *ESA EChO Project Scientist Responsibilities*

The ESA Project Scientist is responsible for ensuring that the scientific objectives of the mission are achieved through the verification of the instrument performance and for the science operation planning. As such she/he is the formal interface between ESA and PIs for all scientific matters.

Further description of the responsibilities can be found in RD04.

8.2.3 *Principal Investigator Responsibilities*

8.2.3.1 General Requirements

EIDA-R-8700. The PI shall ensure that the complete Instrument is–developed and implemented within the mission and schedule constraints of the approved EChO Programme.

EIDA-R-8710. The PI shall be responsible for the overall instrument management and for his/her team organisation.

EIDA-R-8720. The PI shall be fully responsible for the instrument programme and delivery of instrument models to ESA.

EIDA-R-8730. 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-R-8740. 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-R-8750. There shall be a single PI for each instrument.

EIDA-R-8760. The PI shall be the ultimate managerial and decision making authority interfacing with the ESA EChO Project Office.

EIDA-R-8770. The PI shall appoint an instrument manager for the running of the day to day activities of the instrument team.

EIDA-R-8780. The PI shall ensure that instrument team include, as a minimum, personnel responsible for the following tasks:

- Project Management
- Project Control
- Schedule Control
- Documentation and Configuration Control
- System Engineering
- Assembly Integration Test and Verification
- Product Assurance

EIDA-R-8790. 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.

EIDA-R-8800. 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-R-8810. The PI team, during the relevant instrument system level activities, shall be integrated with the ESA EChO Project Office team and work under its technical management.

EIDA-R-8820. The PI shall make available the necessary resources to support the technical Working Groups, chaired by ESA.

EIDA-R-8830. The PI shall create and maintain an instrument EID Part B, up to a time agreed with the ESA EChO Project Office.

EIDA-R-8840. The PI shall ensure compliance with all ITAR regulations in a timely manner.

EIDA-R-8850. The PI shall report to the ESA EChO Project Office any surveillance requirements arising from ITAR regulations.

EIDA-R-8860. The PI shall bear any costs associated with such surveillance requirements.

EIDA-R-8870. The PI shall participate to Science Working Team meetings as called by the ESA Project Scientist.

EIDA-R-8880. The PI shall be responsible for the fulfilment of the instrument scientific requirements towards the Science Working Team.

EIDA-R-8890. The PI shall submit a Science Performance Report as a minimum at every project review.

EIDA-R-8900. 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.
- A complete PI team directory and organograms containing the names of all partners: PI, CO-I's, Instrument Development Manager, and all key personnel; their roles and responsibilities..
- The qualifications and experience of the PI team members
- A Product Tree (PT) to identify and break down the instrument into its components, both hardware software and GSE and identify the related responsibilities
- 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, documentation and the science operations activities.

EIDA-R-8910. The PI shall develop, as part of his Management Plan, a Risk Management Plan.

For each identified major risk, the following information are expected to be specified:

- The name of the custodian for control of the risk
- An explanatory description
- Reasons for its criticality
- Importance of their consequences (classification and severity)
- Magnitudes of consequences (e.g. schedule and/or cost impacts)
- Probability of their occurrence
- The preferred solution, with reasons
- Alternative solutions and contingencies
- Current status

EIDA-R-8920. The PI shall comply with the scientific data policy of the Agency as defined in the Science Management Plan RD05. The PI shall provide the inputs for the definition and implementation of the science operations planning, and data handling and archiving concepts;

EIDA-R-8930. The PI shall make available necessary resources for the definition and the implementation of the EChO ESA scientific data archive.

EIDA-R-8940. The PI shall support the definition of the instrument interfaces to the spacecraft in coordination with the ESA EChO Project Office and the Industrial Prime contractor.

EIDA-R-8950. The PI shall participate in the technical working groups and the control boards as requested by the ESA EChO Project Office.

EIDA-R-8960. The PIS shall write and maintain a Science Implementation Plan (SIP) to answer to the Science Implementation Requirement Document (SIR) for their relevant areas of responsibility

8.2.3.3 Instrument system engineering requirements

8.2.4 *System Engineering Plan (SEP)*

EIDA-R-8970. The PI shall produce a system engineering plan (SEP) as defined in annex D of ECSS-E-ST-10C [RD06]

8.2.5 *Requirements Management*

EIDA-R-8980. The PI shall ensure forward and backward traceability of all requirements:

- 1. to their sources;

Note: For example: a higher level requirement, an imposed management constraint, an applicable standard, an accepted lower level constraint.

- 2. to the lower level requirements;
- 3. to changes in the design inducing modifications of the requirements;
- 4. to their verification close-out.

(ECSS-E-ST-10C RD06, 5.2.2a)

EIDA-R-8990. The PI shall establish the requirements compliance, traceability and verification matrix in conformance with DRD-SE-15 (ECSS-E-ST-10C, RD06, 5.2.2b)

EIDA-R-9000. The PI shall ensure that the close-out traceability is documented in the Verification Control Document (VCD) in conformance with DRD-SE-25 (RD06,ECSS-E-ST-10C, 5.2.2c)

EIDA-R-9010. The PI shall establish for its own product and lower level ones a specification tree in conformance with DRD-SE-07 (ECSS-E-ST-10C RD06,, 5.2.3.1c)

EIDA-R-9020. The PI shall ensure that for each requirement contained in a technical requirement specification, one or a combination of verification methods are identified. (ECSS-E-ST-10C RD06,, 5.2.3.4a)

8.2.6 *Functional Analysis*

The functional analysis is used throughout the development cycle to identify and describe the functions of the system. Its purpose is to identify and partition the functions of any system to perform the intended objectives.

EIDA-R-9030. The PI shall perform a Functional analysis as part of the overall design development process (ECSS-E-10-05a)[RD05].

Note: the analysis can be performed using one or more of the following techniques:

- Function tree
- Functional matrix
- Functional Block Diagram

8.2.7 *Hardware and Software Requirements*

EIDA-R-9040. 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-R-9050. 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 EChO Project Office, in accordance with the standards, technical and programmatic requirements defined in the Experiment Interface Document, Part A and Part B.

EIDA-R-9060. 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.

EIDA-R-9070. The PI shall identify and document all the critical instrument technologies and components.

EIDA-R-9080. 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-R-9090. 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-R-9100. 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-R-9110. The PI shall be responsible for the development, procurement, manufacturing, testing and delivery of all instrument software and related documentation to the ESA EChO 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-R-9120. 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-R-9130. The PI shall establish, maintain and deliver the Instrument Data Base (IDB) for AIT and Instrument Operation

EIDA-R-9140. 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.

EIDA-R-9150. The PI shall make available the necessary resources for supporting joint tests and integration activities of the instrument software after relevant model delivery.

8.2.8 *Operations Requirements*

EIDA-R-9160. The PI shall make available the necessary resources to support all in-flight mission phases at the MOC/SOC, including the commissioning phase, supporting for example resolution of anomalies and malfunctions of the instrument (see section 5)

EIDA-R-9170. The PI shall make available the necessary resources to support the preparation and the implementation of the mission and science operations up to the end of the mission including:

- Delivery of an instrument user manual
- Delivery of inputs to the data-base
- Delivery of inputs to the Flight Operations Plan
- Delivery of algorithm/pipeline/ input data/calibration files for level 1/2 processing by SOC
- Participation to all Science Planning related activities (coordination telecons..)
- Delivery of data products to be put into the SOC mission archive

8.2.9 *Data Processing and Dissemination Requirements*

EIDA-R-9180. The PI shall support the implementation of data processing, analysis and reporting according to plans established in collaboration with the SOC.

EIDA-R-9190. The PI shall maintain and deliver to the SOC calibration files needed to run the data processing pipelines at the SOC until end of mission.of the archiving phase

EIDA-R-9200. The PI shall provide support to the SOC for, and participate in the organisation and running of, EChO data processing workshops for the astronomical community (TBC)

EIDA-R-9210. The PI shall provide due acknowledgement to ESA in all published material related to the EChO mission.

8.2.10 *Public Relations Requirements*

EIDA-R-9220. The PI shall make available the necessary resources to adequately support ESA science communications and public relations activities.

EIDA-R-9230. The PI shall provide data and scientific results to ESA in a timely manner and in a form suitable for public relations purposes.

8.3 Communications Requirements

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.

EIDA-R-9240. All formal communication concerning technical and programmatic agreements shall be made between each PI and the ESA EChO Project Manager.

They will be the single points of contact for the ultimate negotiation and resolution of programmatic and technical requirements and issues.

EIDA-R-9250. No other party, including the Prime Contractors and its subcontractors shall have formal authority, without written delegation from the ESA EChO Project Manager.

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).

Working level communication concerning technical and programmatic aspects between each PI and ESA are delegated to the EChO Payload Manager and his team of engineers, in coordination with the Prime Contractor Payload Manager

Each instrument project manager and the EChO Payload Manager will be the single “Point of Contact” for all working level programmatic and technical issues. Point of Contact details are specified in chapter 2.

EIDA-R-9260. 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 EChO Project Office.

EIDA-R-9270. The Prime Contractor team and the PI teams shall ensure that informal communications shall always be coordinated with the ESA Project team.

EIDA-R-9280. The PI shall treat any industrial information provided (through ESA) by the competing prime contractors during phase A/B1 as confidential.

8.4 Project Phasing, Planning and Schedule Requirements

For the implementation phase, the main spacecraft milestones are as follows:

• Preliminary Requirements Review	September-October 2013 (TBC)
• Confirmation of Launch date (2022 vs. 2024)	January 2014 (TBC)
• Initiation Phase B1	May 2014 (TBC)
• System Requirements Review:	tbd
• Initiation of Phase B2/C/D	June 2016 (TBC)
• Preliminary Design Review:	tbd
• Critical Design Review:	tbd
• Qualification Review	tbd
• Flight Model Acceptance Review:	tbd
• Flight Readiness Review	tbd
• Launch	June 2022 (or 2024 subject to L1 schedule) (TBC)

EIDA-R-9290. 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-R-9300. The PI shall include in the Instrument Schedule as a minimum the following programme activities~~:~~

- HW, SW and GSE delivery dates
- Design, development, integration , testing and calibration of each Instrument model, and, where applicable, also of breadboards and/or of development models / subsystems
- Qualification activities
- Long lead items procurement
- all ITAR related approval aspects
- Activities on the critical path
- Main instrument milestones (including , for example TRRs, PTRs)
- Main instrument reviews
- Main spacecraft milestones
- System schedule Margin

EIDA-R-9310. The PI shall identify for each activity / task included in the Instrument schedule their interdependencies, durations, constraints, slack.

EIDA-R-9320. The PI shall notify the ESA EChO Project Office of any change to the instrument Baseline Master Schedule that affect agreed instrument milestones within 5 working days

EIDA-R-9330. The PI shall seek approval with the ESA EChO Project Office about (changes to) the instrument Baseline Master Schedule to ensure that it is in line with the S/C schedule

EIDA-R-9340. The PI shall submit the Instrument Schedule to the ESA EChO Project Office, as a minimum, every three months, identifying all the major changes wrt the previous issue.

EIDA-R-9350. The PI shall identify additional milestones as required and shall agree them with the ESA EChO Project Office.

8.5 Progress Control and Reporting Requirements

EIDA-R-9360. 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-R-9370. 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)
- Synthetic instrument GSE (MGSE, EGSE, OGSE) status and progress
- Status of design changes and open Engineering Change Requests (ECRs) vis a vis the EID-A and B, overall progress status
- Design Development and Verification status, covering status of design definition and verification of interfaces, test and calibration, GSE, operations,
- PA status, including NCR and RFW status,
- Overall programmatic status, including procurement and long lead items activities.
- Overall funding and contractual status
- List of the main measurable milestones for the past three months and for the following six months,
- Science Performance status,
- Problem areas and corrective actions.
- Resource budgets status (including as a minimum: mass, power, thermal, SW, pointing) highlighting changes wrt previous issue and anticipated future changes
- Current status of each major activity
- Major existing technical, programmatic, funding, and contractual issues together with the proposed remedial closure action plan
- Urgent issues under the responsibility or to be addressed together with the ESA EChO Project Office and/or with the Prime Contractor
- Major technical, programmatic, funding, and contractual risks (potential issues) together with proposed remedial closure action plan
- 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
- Open Action list

EIDA-R-9380. The PI shall provide to the ESA EChO Project Office a monthly schedule report as part of the Monthly Progress Report

8.6 Meetings, Teleconferences and Reviews Requirements

EIDA-R-9390. The PI shall organize progress Technical Interface Meeting (TIM) & Progress Meetings (PM) at his/her premises, at least every three months (TBC), among the relevant members of the ESA EChO Project Team, the PI team and the Prime Contractor Team(s) (TBC). These meetings can also be done through videoconferencing when agreed with the ESA EChO Project team.

The 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.
Detailed technical problems occurring on either side of the interface will be flagged during these TIM meetings and corrective actions, including their schedule impact, will be agreed and implemented

EIDA-R-9400. 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 EChO Project Team, the PI team and the Prime Contractor Team

EIDA-R-9410. 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 EChO Project Office or the Prime Contractor.

EIDA-R-9420. The Prime Contractor shall take the minutes of the MTI meetings, of the monthly telecons and of the ad-hoc meetings / telecons

Minutes of the meetings will be finalised and agreed by the end of meetings / telecons.

EIDA-R-9430. The PI shall agree with the ESA EChO 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.

The following is an indicative list of presently foreseen reviews at instrument, ground segment and mission level

a. Instrument Level
   i. Instrument Preliminary Requirements Review, IPRR
   ii. Instrument Consolidation Review, ICR
   iii. Instrument Science performance Verification Review, ISVR
   iv. Instrument Preliminary Design Review, IPDR
   v. Instrument Critical Design Review, ICDR
   vi. Instrument Qualification Review, IQR
   vii. Instrument FM Delivery Review
   viii. Instrument Flight Acceptance Review, IFAR
   ix. Other Reviews as required (e.g. Test Readiness Reviews (TRR), Pre-Environment Review (PER), Post-Test Review (PTR), etc)

b. Ground Segment Level
   i. Ground Segment Requirements Review
   ii. Ground Segment Design Review
   iii. Ground Segment Implementation Review
   iv. Ground Segment Readiness Review

c. Mission Level
   i. Preliminary Requirements Review, PRR
   ii. System Requirements Review, SRR
   iii. Preliminary Design Review, PDR
   iv. Critical Design Review, CDR
   v. Qualification Review, QR
   vi. Flight Acceptance Review, FAR
   vii. Flight Readiness Review, FRR
   viii. Mission Commissioning Results Review, MCRR
   ix. Other Reviews as required

The instrument reviews will take place according to the following planning, with all 11 (TBD) instrument reviews completed by the specified dates:

- Start September 2013 (TBC) Instrument Preliminary Requirements Review (IPRR)
- Start May 2014 (TBC) Instrument Consolidation Review (ICR)
- June 2016 (TBC) Instrument Science Verification Review (ISVR)
- tbd Instrument Preliminary Design Review (IPDR)
- tbd Instrument Critical Design Review (ICDR)
- tbd Instrument Qualification Review (IQR)
- tbd Instrument Flight Acceptance Review (IFAR)

The ESA EChO Project Office will organise, and conduct the Instrument Level reviews.

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

The Instrument Level Reviews 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.

ESA, at its discretion, may identify other reviews and/or milestones.

EIDA-R-9440. The PI shall provide, for each Instrument Level review a specific set the documents, the Review Data Package, as defined in sections 8.6.2 (TBC) and 8.6.3 (TBC) .

EIDA-R-9450. The PI shall provide the relevant review data package 2 weeks before the review kick-off date to be agreed with the ESA EChO Project Office.

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.

8.6.1 *Document Deliverables for Assessment Phase*

DRD ID	Title	Provider	Assessment Phase (0/A)
			IPRR
PM-01	Instrument Development Plan (DP)	PI	X
PM-02	Management Plan	PI	X
PM-03	Preliminary Long Lead Item List (LLIL)	PI	X
PM-04	Preliminary SW Development Plan	PI	X
PM-05	Configuration Management Plan (CMP)	PI	
PM-06	Statement of Compliance (SoC)	PI	X
PM-07	Instrument risk management Plan	PI	X

N/A	Experiment Interface Document Part A (EID-A)	ESA	X
SE-01	Experiment Interface Document Part B (EID-B)	PI	X
SE-03	Instrument Technology Development Plan	PI	X
SE-04	Preliminary Instrument Calibration Plan	PI	X
SE-05	Instrument AIV/AIT Plan	PI	X
SE-07	Instrument Requirements Specification (S/S level)	PI	X
SE-09	Technical budget Report	PI	X
SE-13	Preliminary Software Requirements Document (SRD)	PI	X
SE-15	Compliance, Traceability, and Verification Matrix	PI	X
SE-17	Trade-offs report	PI	X
SE-18	Instrument Performance Analysis Report	PI	X
SE-19	Instrument operation concept	PI	X
SE-122	Instrument Science Implementation Plan (SIP)	PI	draft
Product Assurance Documentation			
PA-00	Preliminary Product Assurance Plan	PI	X
PA-08.02	Contamination Analysis Report	PI	X
Mathematical models			
MA-01	Preliminary SMM	PI	X
MA-03	Preliminary GMM and TMM	PI	X
MA-05	Preliminary Optical model	PI	X

8.6.2 *Document Deliverables for Definition Phase*

DRD ID	Title	Provider	Definition Phase	
			ICR	Updates
Management Documentation				
PM-01	Instrument Development Plan (DP)	PI	X	
PM-02	Management Plan	PI	X	
PM-03	Long Lead Item List (LLIL)	PI	X	
PM-04	SW Development Plan	PI	X	
PM-05	Configuration Management Plan (CMP)	PI	X	
PM-06	Statement of Compliance (SoC)	PI	X	
PM-07	Instrument risk management Plan	PI	x	
System Engineering Documentation				
N/A	Experiment Interface Document Part A (EID-A)	ESA	X	- As generated
SE-01	Inputs to Experiment Interface Document Part B (EID-B)	PI	X	- As generated
SE-02	Instrument Mechanical Interface Control Documents (MICD)	PI	X	
SE-03	System Engineering Plan (SEP)	PI	X	- As generated
SE-04	Instrument Calibration Plan	PI	X	
SE-05	Instrument AIV/AIT Plan	PI	X	
SE-06	EMC Control Plan	PI	X	
SE-07	Instrument Requirements Specification	PI	X	- As generated
SE-08	Instrument Design Definition File (DDF)	PI	X	- As generated
SE-09	Technical budget Report	PI	X	As generated
SE-10	Instrument Subsystem Functional and Performance Requirement Specification	PI	X	
SE-11	Instrument subsystem Interface requirement document	PI	X	
SE-12	Harness Requirement Specification	PI	X (TBC)	
SE-13	Software Requirements Document (SRD)	PI	X	
SE-14	Instrument Design Justification File (DJF)	PI	X	- As generated
SE-15	Compliance, Traceability and verification matrix	PI	X	
SE-16	Requirement justification file	PI	X	
SE-17	Trade-offs report	PI	X	
SE-18	Instrument Performance Analysis Report	PI	X	- As generated
SE-19	Instrument operation concept	PI	X	
SE-110	Instrument scientific performance report	PI	X	
SE-121	Inputs to Science Implementation Requirement Document (SIRD)	PI	X	
SE-122	Instrument Science Implementation Plan (SIP)	PI	X	
Product Assurance Documentation				
PA-00	Preliminary Product Assurance Plan	PI	X	- As generated
PA-08.02	Contamination Analysis Report	PI	X	

DRD ID	Title	Provider	Definition Phase	
			ICR	Updates
Mathematical models				
MA-01	SMM	PI	X	On demand by agency
MA-03	RTMM	PI	X	On demand by agency
MA-04	RGMM	PI	x	On demand by agency
MA-05	Optical model	PI	X	On demand by agency

Table 32 – Deliverable Documents for Definition Phase

For the ISVR, the following documents shall be updated and delivered to industry:

- Instrument scientific performance report
- Instrument Performance Analysis report
- Instrument risk management plan
- TRL status report

8.6.3 *Document Deliverables for Implementation Phase*

DRD ID	Title	Agency Approval	Provider	Implementation Phase					
				ISVR	IPDR	ICDR	IQR	IFAR	Updates
Product Management Documentation									
PM-01	Instrument Development Plan (DP)		PI		X				
PM-02	Management Plan		PI		X				
PM-03	Long Lead Item List (LLIL)		PI		X				
PM-04	Software Development Plan		PI		X				
PM-05	Configuration Management Plan		PI						
	Documentation Management Plan								
	Risk Management Plan								
	Photographic and Video Documentation								
PM-06	Statement of Compliance (SoC)		PI						
PM-07	Left blank intentionally								
PM-08	PI Monthly Progress Report		PI						- 5 days after the end of each month
PM-09	Schedule		PI						- Monthly
PM-11	ISVR Data pack		PI	X					- 30 days prior to the review
PM-12	Inputs to SDR Data-package		PI						- 15 days prior to the review
PM-13	iPDR Data-package		PI		X				- 30 days prior to the review

DRD ID	Title	Agency Approval	Provider	Implementation Phase					
				ISVR	IPDR	ICDR	IQR	IFAR	Updates
PM-14	iCDR Data-package		PI			X			- 30 days prior to the review
PM-15	iQR Data-package		PI				X		- 30 days prior to the review
PM-16	iFAR Data-package		PI					X	- 30 days prior to the review
PM-17	Instrument End-Item Data Package (EIDP)		PI						- 30 days prior to instrument FM delivery.
System Engineering Documentation									
N/A	Experiment Interface Document Part A (EID-A)		ESA						- As generated
N/A	Experiment Interface Document Part B (EID-B)		ESA						- As generated
SE-01	Inputs to Experiment Interface Document Part B (EID-B)		PI	X	X				
SE-02	Instrument Mechanical Interface Control Drawing		PI	X	X	X	X		- As generated
SE-03	System Engineering Plan (SEP)		PI						- As generated
SE-04	Instrument Calibration Plan		PI	X	X	X			
SE-05	Instrument Assembly Integration and Verification Plan		PI	X	X	X			
SE-06	Instrument EMC Control Plan		PI	X	X	X			
SE-07	Instrument Requirements Specification		PI	X	X	X	X	X	
SE-08	Instrument Design Definition File (DDF)		PI	X	X	X		X	
SE-09	Technical Budget Report		PI	X	X	X	X	X	- Monthly as part of PM-08
SE-10	Instrument Verification Matrix		PI	X	X	X	X	X	
SE-11	Instrument Subsystem Functional and Performance Requirement Specification		PI	X	X				
SE-12	Instrument Harness Requirement Specification		PI	X	X				
SE-13	Instrument Software Requirements Document (SRD)		PI		X				
SE-14	Instrument Design Justification File (DJF)		PI	X	X	X	X	X	
SE-15	Compliance, traceability and verification Matrix		PI						
SE-16	Requirement Justification File		PI						

DRD ID	Title	Agency Approval	Provider	Implementation Phase					
				ISVR	IPDR	ICDR	IQR	IFAR	Updates
SE-17	Trade-Off report		PI	X	X				
SE-18	Instrument Performance Analysis Report		PI	X	X	X	X	X	
SE-19	Instrument Operations Concept Document (OCD)		PI		X	X		X	
	Left intentionally blank								
SE-21	Instrument Predicted Science Performance Document		PI	X	X	X		X	
SE-22	Instrument As-Built Configuration List (ABCL)		PI		X	X	X	X	
SE-23	Instrument Configured Item Data List (CIDL)		PI		X	X	X	X	
SE-24	Instrument MICD		PI	X	X	X	X	X	
SE-25	Instrument Verification Control Document		PI	X	X	X	X	X	
SE-26	Instrument User Manual		PI					X	- 1st Draft 1 month prior to EM delivery. - 2nd Draft 6 months prior to FM delivery - Final version at AR. - Updates as revised
SE-27	STM EIDP		PI						- 30 days prior to STM Delivery
SE-28	EM EIDP		PI						- 30 days prior to EM Delivery
SE-29	Trend Analysis Report / Trend data		PI				X	X	
SE-30	Instrument Critical Item List and Single Point Failure List		PI		X	Final	X	X	
SE-35	Printed Wire Board Coupons		PI				X	X	
SE-31	Fracture Control Plan		PI		X	X			
SE-32	Test and Verification Reports		PI						- 30 days after end of test
SE-33	Instrument & GSE Packaging, Storing, Transport and Handling Procedures		PI						- Draft at CDR - Update 6 months prior to STM delivery. - Update X months prior to EM delivery - Final 3 months prior to FM delivery.
SE-34	GSE Description and User Manual		PI						
SE-101	PP requirement document	X	PI		X	X	X	X	As generated

DRD ID	Title	Agency Approval	Provider	Implementation Phase ISVR	IPDR	ICDR	IQR	IFAR	Updates
SE-102	PP plan	x	PI		X	X	X	X	As generated
SE-103	PP Implementation plan	x	PI		X	final	X	X	As generated
SE-104	PP inputs to pre-launch report							X	At Flight readiness review
SE-110	Instrument scientific performance report		PI	X	X	X	X	X	
SE-35	Test Specifications		PI		X	X			- Draft at CDR - Final 3 months before FM TRR
SE-122	Instrument Science Implementation Plan		PI	X	X	X	x	x	
SE-37	Inputs to Spacecraft Levels Integration and Test Plan and Procedures		PI						
Product Assurance Documentation									
PA-00	Preliminary Product Assurance Plan		PI	X					
PA-01.01	Product Assurance Plan	x	PI		X				- As generated
PA-01.02	Qualification Status List		PI		X	X	X	X	- As part of monthly reports
PA-01.03	Critical Items List		PI	X	X	X	X	X	- As part of monthly reports
PA-01.04	Alerts and Warnings Status List		PI	X	X	X	X	X	- As part of monthly reports
No DRD nr. Yet	Non-conformance Report (NCR)		PI	X (only major)	X (only major)	X (only major)	X (only major)	X (only major)	- In accordance to NCR agreed procedure
No DRD nr. Yet	NCRs status list		PI		X	X	X	X	- 15 days prior to any review and milestone (e.g. MRRs, TRRs, PTRs) - As part of monthly reports
PA-02.01	Quality Assurance Plan	x	PI		X				- As generated
PA-02.02	Qualification Plan	x	PI		X	X			- As generated
PA-02.03	Log Book		PI					X	
PA-02.04	Acceptance and Delivery Plan	x	PI			X			- As generated
PA-02.05	EIDP		PI					X	- 30 days prior to the review
PA-02.06	Certificate of Conformance		PI					X	
PA-02.07	Flight Spares Control Plan	x	PI			X		X	- As generated
PA-02.08	Qualification Status Report		PI				X		- 30 days prior to the review
PA-02.09	Inspection Plan (or Inspection Procedure)		PI						- 15 days prior to Inspections (e.g.

DRD ID	Title	Agency Approval	Provider	Implementation Phase					
				ISVR	IPDR	ICDR	IQR	IFAR	Updates
									KIP and MIP)
PA-02.10	Test Procedure (or Test Specification)				X	X	X		
PA-03.02	Reliability Apportionment and Prediction Analysis Report		PI		X	X			- A 176onsolidate Instrument Reliability Apportionament and Prediction Analysis Report shall be delivered at the completion of lower level PDRs - As generated
PA-03.03	FMEA Report		PI		X (functional FMEA)	X (product FMEA)		X (product FMEA)	- Consolidated Instrument functional FMEA shall be delivered at the completion of lower level PDRs - As generated
PA-03.04	Hardware-Software Interaction Analysis Report		PI		X	X		X	- A consolidate Instrument Common Cause / Common Mode Failure Analysis shall be delivered at the completion of lower level PDRs - As generated
PA-03.05	Common Cause / Common Mode Failure Analysis Report		PI		X	X			- As generated
PA-03.08	Fault Detection, Isolation and Recovery (FDIR) Analysis Report		PI		X	X		X	- A consolidate Instrument FDIR Analysis shall be delivered at the completion of lower level PDRs? - As generated
No DRD nr. Yet	Fault Tree Analysis (FTA)		PI		X	X			- A consolidate Instrument FTA shall be delivered at the completion of lower level PDRs - As generated
PA-03.06	Worst Case Analysis Report		PI			X			- As generated
PA-05.03	Part Approval Documents	X (PCB)	PI			X	X	X	- 15 days before PCBs
PA-05.04	EEE components procurement specifications		PI						- 15 days before PCBs
PA-07.01	Declared Materials List	X (MMPP control board)	PI		X	X	X	X (as-built)	- 15 days before MMPP Control Boards
PA-07.02	Declared Mechanical Parts List	X (MMPP control board)	PI		X	X	X	X (as-built)	- 15 days before MMPP Control

DRD ID	Title	Agency Approval	Provider	Implementation Phase					
				ISVR	IPDR	ICDR	IQR	IFAR	Updates
									Boards
PA-07.03	Declared Processes List	X (MMPP control board)	PI		X	X	X	X (as-built)	- 15 days before MMPP Control Boards
PA-08.01	Cleanliness and Contamination Control Plan		PI	X	X	X			- As generated
PA-08.02	Contamination Analysis Report		PI		X	X			- As generated
PA-09.01	Software Product Assurance Plan	X	PI		X				- As generated
PA-09.02	Software Product Assurance Milestone Report		PI		X	X	X	X	
Other									
	All Mathematical models		PI	X	X	X	X	X	On demand by Agency
	Example science data as input for ESOC instrument simulator.								On demand by Agency

Table 33 - Deliverable Documents for Implementation Phase

8.7 Configuration Management Requirements

The objectives of Configuration Management are to establish:

- a **configuration identification** baseline system which defines through approved specifications, interface documents and associated data the requirements for the instrument,
- a **configuration control** system which controls all the changes to the identified configuration of the instrument,
- 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).

EIDA-R-9460. 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-R-9470. The PI shall ensure that configuration changes to his / her documents are introduced, only after consultation with the ESA EChO Project Office, if such change impact on technical interface or programmatic agreement between them.

EIDA-R-9480. The PI shall allow the ESA EChO 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-R-9490. 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-R-9500. The PI shall ensure compatibility between their own configuration management scheme and the one implemented by all other participants to their instrument programme.

EIDA-R-9510. The PI shall be responsible for the management of the Configuration Control Board (CCB) at his level.

EIDA-R-9520. The PI shall establish, for each model delivered to the ESA EChO Project Office, an instrument configuration baselines with respect to requirements, design and verification documents.

EIDA-R-9530. The PI shall include as a minimum in the instrument configuration baseline the following documents:

- Instrument requirement specifications
- GSE description and user manual
- Interface Control Documents, including the EID-A and the EID-B
- Instrument Subsystem Functional and performance requirement specifications
- Applicable References, called up in chapter 9.1 of the EID-A
- Design Specification
- Drawings
- Manufacturing Procedures
- Control and Inspection Procedures
- Operating and Handling Procedures
- Test specifications
- Test Procedures
- Design Development & Verification Plan
- Assembly, Integration and Test Plan
- Compliance, Traceability and Verification Matrix
- TBC

EIDA-R-9540. The PI shall prepare a Compliance, Traceability and Verification Matrix wrt the above mentioned Requirements Baseline documents.

The Compliance, Traceability and Verification Matrix is used for the following reasons:

- To state compliance to the identified set of requirements (e.g. scientific, functional, performance, instrument interface, subsystems requirements, etc)
- To ensure forward and backward traceability of all requirements
- to define the required verification method

The Compliance, Traceability and Verification Matrix need not trace the References requirements, called up in chapter 10 of the EID-A. Compliance statement to the Reference Documents will be sufficient.

EIDA-R-9550. The PI shall present the instrument configuration baseline at each Instrument Level review, identifying any change introduced since the previous review.

Instrument configuration baseline~~s~~ may also be reviewed, if requested by the ESA EChO Project Office, other intermediate stages of the instrument life cycle.

EIDA-R-9560. 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.

EIDA-R-9570. The PI shall inform the ESA EChO 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-R-9580. The PI shall identify and document, for each non-flight model delivered to the ESA EChO Project Office, the differences, if any, with respect to the (as designed) FM instrument configuration baseline.

EIDA-R-9590. The PI shall propose changes to the EID-B, once the EID-B is signed by means of an Engineering Change Request (ECR).

The ECR may be initiated at any time by either the PI or ESA in writing.

EIDA-R-9600. The PI (or any raising party) shall complete the ECR with all relevant entries.

The ECR will be addressed to the PI, ESA Project Manager, with copy to the relevant Payload or instrument managers

EIDA-R-9610. The PI shall ensure that adequate resources and funding are available for execution of a proposed change prior to submittal to the ESA EChO Project Office

EIDA-R-9620. The PI shall submit for approval to the ESA EChO Project Office and justify deviations to the requirements defined in EID-A by means of a Request for Waiver (RFW).

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.

EIDA-R-9630. The PI shall identify in the RFW the baseline and specification affected, provide an estimate of the impact on schedule, and logistics.

EIDA-R-9640. The PI shall identify uniquely and unambiguously each ECR or RFW identified by an individual number by a suitable numbering system of his / her choice.

EIDA-R-9650. The PI shall keep the ECRs and RFDs/RFWs under configuration control.

EIDA-R-9660. The PI (or any other initiating party) shall ensure that following its receipt, the ECR / 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 (ECR / RFW disposition within 4 weeks).

The Change Control Process constitutes of the following:

ECR from PI to ESA:

1) Upon receipt of the ECR 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.
2) The Prime Contractor will assess the consequences by a Change Control Board (CCB) and (typically within 1 week TBC) 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.

ECR from Prime/ESA to PI:

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.
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.

RFD/RFW

1) Upon receipt of the RFD/RFW ESA will carry out an investigation as to the consequences of the 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.

8.8 Deliverable Items Requirements

EIDA-R-9670. The PI shall deliver to the ESA EChO Project Office and maintain under configuration control as a minimum the documents listed in Table 32 and Table 33

The objective and content of each document are specified in [TBW].
The CAD Model check list properties are specified in Annex A1.

EIDA-R-9680. The PI shall include all document kept under configuration in a Document Delivery List.

EIDA-R-9690. The PI shall deliver, in line with the baselined instrument model philosophy, the following models, by the following deadlines:

- Structural Thermal Model, STM: Date: tbd
- Engineering Model, EM: Date: tbd
- (Proto) Flight Model, (P)FM: Date: tbd (at least 24 month before launch)
- Flight Spares, FS: not applicable, the FS will be delivered to ESA only if needed

EIDA-R-9700. The PI shall deliver the instrument SW relevant to the delivered instrument models, including the executable code(s)

EIDA-R-9710. The PI shall provide together with each delivered Instrument Model, an End-Item Data Package (EIDP), as defined in documents listed in Table 32 and Table 33

The PI will propose and agree possible tailoring of the content of the EIDP with the ESA EChO Project Office for the STM and EM instrument models.

EIDA-R-9720. 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.

The points of delivery of all items will be determined later in the programme.

EIDA-R-9730. The PI shall be responsible for the shipment back of the instrument models in case of repair.

EIDA-R-9740. 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-R-9750. 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 Contractor~~s~~ or on the launch site.

EIDA-R-9760. The PI shall be responsible for the preparation of all ITAR papers necessary for shipment prior to the required shipment date

EIDA-R-9770. 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-R-9780. The PI shall make available the necessary resources to support the verification of updated instrument software at system level.

EIDA-R-9790. The PI shall deliver, together with each instrument model, suitable Mechanical Ground Support Equipment (MGSE) necessary to transport, handle and integrate the instrument

EIDA-R-9800. 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

Interfaces between instrument EGSE connected to S/C EGSE will be agreed between the PI, ESA and the Prime Contractor.

EIDA-R-9810. 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-R-9820. The PI shall ensure that the delivered Instrument EGSE consists at least of the following items:

- 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).
- A dedicated Interface Test Equipment to verify the health status of the Instrument stand-alone, prior integration to the spacecraft.
- All cabling and ancillary items necessary to properly use and operate the abovementioned equipments.

The instrument ground support equipment will remain at the spacecraft integration site until launch.

EIDA-R-9830. The PI shall replace or update the HW and/or SW of the EGSE at each instrument model delivery to maintain its compatibility.

EIDA-R-9840. The PI shall be responsible for the maintenance of his/her Ground Support Equipment

EIDA-R-9850. The PI shall deliver, if necessary, any special Ground Support Equipment in support of instrument calibration and verification

9 APPLICABLE AND REFERENCE DOCUMENTS

9.1 Applicable Documents

Applicable Documents [ADs] are applicable in their entirety or to the extent called up in individual sections of this document and are listed below as dated or undated references. These may be cited at appropriate places in the text of the EID-A.

Ref. No.	Document
AD01.	EChO Environmental Specification, JS-1-12
AD02.	EChO Documentation Configuration and Management Procedure TBW
AD03.	EChO Science Requirements Document, SRE-PA/2011.037
AD04.	EChO Mission Requirement Document, SRE-PA/2011.038
AD05.	Format of the prescription of the optics for EChO, SRE-F/2012.026/

9.2 System Design Reference Documents

Reference documents [RDs] contain supplementary information about the mission and related issues. They do not contain directly applicable requirements. However, clauses of reference documents may have been copied directly, or modified, into Applicable Documents, through which these clauses are then applicable.

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 EChO EID-A.

Ref. No.	Document
RD01.	EChO Payload Definition Document, EChO PDD, SRE-PA/2011.039
RD02.	EChO Assessment Study Report (Yellow Book), tbi
RD03.	Consolidated Report on Mission Analysis (CReMA), tbi
RD04.	EChO science management plan, tbw
RD05.	ECSS-E-10-05a Space system functional analysis
RD06.	ECSS-E-ST-10C, System engineering general requirements
RD07.	ECSS-E-ST-10-04C Space Environment
RD08.	ECSS-E-10-12C, Space engineering- Methods for the calculation of radiation received and its effects, and a policy for design margin
RD09.	ECSS-E-ST-20C, Electrical and electronic, general principles
RD10.	ECSS-E-ST-20-06C, Spacecraft charging
RD11.	ECSS-E-ST-20-07C, Electromagnetic compatibility
RD12.	ECSS-E-ST-31C, Thermal control, general requirements
RD13.	ECSS-E-ST-32C Rev.1, Structural general requirements
RD14.	ECSS-E-ST-32-01C Rev.1, Fracture Control
RD15.	ECSS-E-ST-32-08C, Materials
RD16.	ECSS-E-ST-33-01C, Mechanisms
RD17.	ECSS-E-40C, Software
RD18.	ECSS-E-ST-50-12C, SpaceWire – Links, nodes, routers and networks
RD19.	ECSS-E-ST-50-14C, Spacecraft discrete interfaces
RD20.	ECSS-E-ST-70-41A, Telemetry and Telecommand Packet Utilization
RD21.	EChO Baseline Telescope for Phase 0, SRE-F/2012.069/

9.3 Product Assurance reference documents

RD22. ECSS-Q-20-ST-20C Quality Assurance

RD23. NCTS (Non Conformance Control System) http://prisma.esa.int

RD24. ECSS-Q-ST-30-02 Template for FMEA

RD25. ECSS-Q-ST-40 C Safety

RD26. ECSS-Q-ST-60 C Rev.1 EEE Components

RD27. European Preferred Parts List and its Management https://escies.org

RD28. ECSS-Q-ST-70 C Materials, Mechanical Parts and Processes

RD29. ECSS-Q-ST-70-02 Thermal Vacuum outgassing test for the screening of space materials

RD30. ECSS-Q-ST-70-08 Manual soldering of high-reliability electrical connections

RD31. ECSS-Q-ST-70-28 Repair and modification of printed circuit board assemblies for space use

RD32. ECSS-Q-ST-70-36 C Material selection for controlling stress-corrosion cracking

RD33. ECSS-Q-ST-70-37 Determination of the susceptibility of metals to stress-corrosion cracking

RD34. ECSS-Q-ST-80C Software Product Assurance

RD35. ECSS-Q-ST-70-7 Data for the Selection of Space Materials and Processes

RD36. ECSS-Q-ST-70-01C Contamination and cleanliness control

RD37. ECSS-Q-ST-30-11 Derating - EEE Components

RD38. ESA PSS-01-605 Capability Approval Programme for Hermetic Thin Film Hybrid Micro-Circuits

RD39. ESA PSS-01-606 Capability Approval Programme for Hermetic Thick Film Hybrid Micro-Circuit

RD40. ECSS-Q-ST-60-05C Generic Procurement requirements for hybrid microcircuits

RD41. ECSS-Q-ST-10C Product Assurance management

RD42. ECSS-Q-ST-10-04C Critical Item Control

RD43. EChOECSS-Q-ST-60-15C, Radiation hardness assurance EEE components.

RD44. RD-PA-29 ECSS-Q-ST-60-14 relifing procedure- EEE components

RD45. ESA alert system http://alerts.esa.int

RD46. ECSS-Q-ST-30C Dependability

RD47. ECSS-Q-ST-10-09 Non Conformance Control System

10 ACRONYMS

ABCL	*As Built Configuration List*
AC	Alternating Current
AFT	Abbreviated Functional Test
AIT	Assembly, Integration and Test
AIV	Assembly, Integration and Verification
AKE	Attitude Knowledge Error
AOCS	Attitude and Orbit Control System
APE	Absolute Pointing Error
APS	Active Pixel Sensor
ASIC	Application Specific Integrated Circuit
AVM	Avionics Validation Model
BOL	Beginning of Life
CCB	Configuration Control Board
CCD	Charge Coupled device
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
DCL	Declared Part list
DDV	Design Development Validation
DMS	Data Management System
DPU	Digital Processing Unit
DTMM	Detailed Thermal Model
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
ELDRS	Enhanced Low Dose rate Sensitivity
EMC	Electromagnetic Cleanliness/Compatibility
EMI	Electromagnetic Interference
EOL	End of Life
EPLM	EChO Payload Module
EPS	Electrical Power Subsystem
EQM	Electrical Qualification Model
ESD	Electro-Static Discharge
ESVM	EChO Service Module
EUV	Extreme Ultra-Violet
FDIR	Failure Detection Isolation and Recovery
FEE	Front End Electronics
FEM	Finite Element Model
FFT	Full Functional Test
FM	Flight Model
FMEA	Failure Modes, Effects 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
HGA	High Gain Antenna
HSIA	Hardware Software Interaction Analysis
HV-HPC	High Voltage High power Pulse Commanl
H/W	Hardware
ICDR	Instrument Critical Design Review
ILS	Instrument Line of Sight
I/O	Input/Output
IPDR	Instrument Preliminary Design Review
IR	Infra Red
KIP/MIP	Key/Major inspection point
LEOP	Launch and Early Orbit Phase
LET	Linear Energy Transfer
LCL	Latching Current Limiters
LISN	Line Impedance Stabilization Network
LOS	Line Of Sight
MCU	Multiple cell upset
MGA	Medium Gain Antenna
MGSE	Mechanical Ground Support Equipment
MICD	Mechanical Interface Control Document
MLI	Multi Layer Insulation
MOC	Mission Operations Centre
MOS	Metal Oxide Semiconductor
MTL	Mission Time Line
NCR	Non-Conformance Report
NIEL	Non-Ionizing Energy Loss
OBC	On Board Computer
PA	Product Assurance
PDE	Pointing Drift Error
PCDU	Power Conditioning and Distribution Unit
PI	Principal Investigator
PS	Project Scientist
QA	Quality Assurance
QM	Qualification Model
RADLAT	Radiation Loat Acceptance Testing
RDM	Radiation Design Margin
RF	Radio Frequency
RFW	Request for Waivers
RHA	Radiation Hardness Assurance
RMS	Radiated Magnetic Susceptibility
RPE	Relative Pointing Error
RTU	Remote Terminal Unit
RVT	Radiation Verification Testing
S/C	Spacecraft
SEB	Single Event Burnout
SEDR	Single Event Dielectric Rupture
SEE	Single Event Effect

SEL	Single Event Latch-up
SEU	Single Event Upset
SEFI	Single Event Functional Interrupt
SEGR	Single Event Gate Rupture
SET	Single Event Transient
SMM	Structural Mathematical Model
SOC	Science Operations Centre
SpW	Space Wire
SRDB	System Requirement database
SRP	System Reference Point
SSMM	Solid State Mass Memory
STM	Structural Thermal Model
SVT	System Verification Test
SWT	Science Working Team
TBC	To Be Confirmed
TBD	To Be Determined
TC/ TM	Telecommand / Telemetry
TID	Total Ionizing Dose
TIDL	Total Ionizing Dose Level
TIDS	Total Ionizing Dose Sensitivity
TNIDL	Total Non Ionizing Dose Level
TNIDS	Total Non Ionizing Dose Sensitivity
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
WCA	Worst case analysis

11 INSTRUMENT CAD MODEL CHECK LIST

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).	