**Project:** GMES Sentinel 4 / UVN instrument

**Doc. Title:** FEE Requirement Specification

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<tr>
<th>Name</th>
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<tr>
<td>Checked by:</td>
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<td>2</td>
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1 INTRODUCTION

The Global Monitoring for Environment and Security (GMES) is a European initiative to provide independent and operational information about the Earth's health required to support environmental policies and information services. Supported by in-situ measurements, the GMES space component is the core information source for six main interacting themes: land, ocean, emergency response themes, atmosphere, security and climate change.

Based on the GMES defined mission requirements, ESA is developing five space borne missions called Sentinels.

Sentinel-4 will provide data for atmospheric composition monitoring and related information services with the focus on air quality and climate. S4 and S5 are using the same measurement principal but are providing data with a different time resolution and coverage. Sentinel-5 is defined for a low Earth orbit with global coverage for which the observation time is locally fixed. In contrast, Sentinel-4 observations are performed from a geostationary position. They are spatially limited to Europe, but allow to make continuous monitoring and to resolve the diurnal cycle of the atmospheric processes.

The observations of the two Sentinel-4/UVN instruments are planned to cover the time scale of 2018 - 2033.
2 SCOPE OF THE DOCUMENT

This document specifies the requirements of the Front End Electronics (FEE) for the Sentinel 4 UVN UV/VIS and NIR detectors.
3 DOCUMENTS

3.1 Applicable Documents

The following documents are applicable to this specification. In the case of conflicts between this document and the applicable documents the conflict shall be brought to the attention of the Prime for resolution. Note: The latest issue of the applicable document shall pertain unless otherwise identified.

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<th>Documentation Number</th>
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<td>AD 1</td>
<td>Contractual Baseline Document List for FEE/FSE</td>
<td>GS4.ASG.UVN.LI.00033</td>
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3.2 Reference Documents

<table>
<thead>
<tr>
<th>RD</th>
<th>Title</th>
<th>Documentation Number</th>
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<tbody>
<tr>
<td>RD 04</td>
<td>UVIS FEE I/F Control Drawing</td>
<td>GS4.ASG.UVN.DI.1116100.A</td>
</tr>
<tr>
<td>RD 05</td>
<td>NIR FEE I/F Control Drawing</td>
<td>GS4.ASG.UVN.DI.1116200.A</td>
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3.3 List of Abbreviations

The following abbreviations are defined and used within this document:

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<th>Description</th>
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<td>A</td>
<td>Analysis</td>
</tr>
<tr>
<td>ADP</td>
<td>Acceptance Data Package</td>
</tr>
<tr>
<td>ADS</td>
<td>Astrium Documentation System</td>
</tr>
<tr>
<td>ASIC</td>
<td>Application-Specific Integrated Circuit</td>
</tr>
<tr>
<td>ASM</td>
<td>Analogue Status Monitor</td>
</tr>
<tr>
<td>ATC</td>
<td>Automatic Temperature Control</td>
</tr>
<tr>
<td>AUX</td>
<td>Auxiliary</td>
</tr>
<tr>
<td>BDM</td>
<td>Bi-Level Digital Monitoring</td>
</tr>
<tr>
<td>BERT</td>
<td>Bit Error Rate Test</td>
</tr>
<tr>
<td>BLD</td>
<td>Bi-Level Digital</td>
</tr>
<tr>
<td>BOL</td>
<td>Begin OF Life</td>
</tr>
<tr>
<td>BOM</td>
<td>Bill Of Materials</td>
</tr>
<tr>
<td>BSM</td>
<td>Bi-Level Status Monitor</td>
</tr>
<tr>
<td>CCS</td>
<td>Constant Current Source</td>
</tr>
<tr>
<td>CDR</td>
<td>Critical Design Review</td>
</tr>
<tr>
<td>CIDL</td>
<td>Configuration Item Data List</td>
</tr>
<tr>
<td>CMD</td>
<td>Command</td>
</tr>
<tr>
<td>CVM</td>
<td>(Power) Converter Module</td>
</tr>
<tr>
<td>DAC</td>
<td>Digital to Analog Converter</td>
</tr>
<tr>
<td>DAP</td>
<td>Detector Assembly Package</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DCB</td>
<td>Detector Conditioning Board</td>
</tr>
<tr>
<td>DM</td>
<td>Development Model</td>
</tr>
<tr>
<td>EDAC</td>
<td>Error Detection And Correction</td>
</tr>
<tr>
<td>EM</td>
<td>Engineering Model</td>
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<tr>
<td>EOL</td>
<td>End Of Life</td>
</tr>
<tr>
<td>FEE</td>
<td>Front End Electronics</td>
</tr>
<tr>
<td>FM</td>
<td>Flight Model</td>
</tr>
<tr>
<td>FMECA</td>
<td>Failure Modes &amp; Effects Analysis</td>
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<tr>
<td>FPA</td>
<td>Focal Plane Assembly</td>
</tr>
<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
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</table>
### Acronym | Description
---|---
FPS | Focal Plane Subsystem (FPA + FEEs + FSE)
FS | Flight Spare
FSE | Frontend Support Electronics
H/W | HardWare
HK | House Keeping
I/F | Interface
ICU | Instrument Control Unit
IO | Input/Output
ISO | International Organization for Standardization
ITAR | International Traffic in Arms Regulations
LCL | Latching Current Limiter
LED | Light Emitting Diode
LPC | Low Power Command
LVDS | Low Voltage Differential Signal(ing)
MUX | Multiplexer
NC | Non-Conformance
P/F | Platform
PCB | Printed Circuit Board
PDR | Preliminary Design Review
PFM | Proto Flight Model
QM | Qualification Model
R | Review of Design
RSA | Relay Status Acquisition
Rx | Receiver
S/C | Spacecraft
S/W | SoftWare
SBDL | Standard Balanced Digital Link
SHP | Standard High Power (Command)
SLS | Spectral Light Source
T | Test
TC | Telecommand
TM | Telemetry
TSM | Temperature Status Monitoring
Tx | Transmitter
SEE | Single Event Effect
TRP | Temperature Reference Point
UART | Universal Asynchron Receive/Transmit
USL | UART based Serial Link
UT | Unit Tester
UUT | Unit Under Test
UVIS | UV-VIS
UVN | UV-VIS-NIR
w.r.t. | with respect to
WLS | White Light Source

### 3.4 Terms

The following terms and definitions are specific to this document:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Binning</td>
<td>The process of combining charge from adjacent lines in a CCD during...</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Binning Factor</td>
<td>The number of lines of which the charge is combined</td>
</tr>
<tr>
<td>Co-adding</td>
<td>Adding the pixel values of n-image frames</td>
</tr>
<tr>
<td>Co-adding factor</td>
<td>The factor n above</td>
</tr>
<tr>
<td>Co-Addition Period</td>
<td>Sum of Frame Periods for co-addition of one set of Measurement Data.</td>
</tr>
<tr>
<td>Co-addition time, Co-addition period</td>
<td>The time required to collect n-image frames (n times the exposure time)</td>
</tr>
<tr>
<td>Dwell Time</td>
<td>The Dwell time is the (absolute real) time during which in the Earth observation mode of the S4 instrument a Level1b sample is recorded. Note: Dwell time is necessarily a multiple of the Frame Period(s).</td>
</tr>
<tr>
<td>Excess Pixel</td>
<td>(Dark) Prescan Pixel. First N pixel from a CCD output port</td>
</tr>
<tr>
<td>Exposure Time</td>
<td>The time during which a pixel accumulates charge</td>
</tr>
<tr>
<td>Frame</td>
<td>A (detector) frame is the entire zone of pixels of the NIR detector or of each of the UV/VIS 1 and UV/VIS 2 detector areas. A detector frame consists of an image zone and a memory zone.</td>
</tr>
<tr>
<td>Frame Data</td>
<td>Pixel values of a read out of one detector memory zone</td>
</tr>
<tr>
<td>Frame Period</td>
<td>Periodicity of the timing pattern with which the image zone is transferred into the memory zone and a new frame is integrated. The Frame Period is an integer factor of the Frame Period Increment.</td>
</tr>
<tr>
<td>Frame Period Increment</td>
<td>Fundamental increment for the frame period duration.</td>
</tr>
<tr>
<td>Frame Period Sync</td>
<td>Synchronization signal indicating the Frame Period</td>
</tr>
<tr>
<td>Frame Start Time</td>
<td>Time latched with the Frame Period Sync signal, which initiates the start of a frame period.</td>
</tr>
<tr>
<td>Image Transfer Time</td>
<td>Total time required for the transfer from the image zone to the memory zone, including the transfer of smear lines.</td>
</tr>
<tr>
<td>Integration Time</td>
<td>Effective time during which signal of a raw sample is accumulated in the image zone. Integration Time is given by the time between two subsequent Image Transfers (Frame Transfers).</td>
</tr>
<tr>
<td>Line Readout Time</td>
<td>Time required for the readout of one detector line including possible excess pixels of the register.</td>
</tr>
<tr>
<td>Line Transfer Frequency</td>
<td>Inverse of the Line Transfer Time.</td>
</tr>
<tr>
<td>Line Transfer Time</td>
<td>Time of the transfer of a single detector line to the next line or into the shift register.</td>
</tr>
<tr>
<td>Measurement Data</td>
<td>Co-added pixel values of several Frames</td>
</tr>
<tr>
<td>Measurement Start Time</td>
<td>Time latched with the Frame Period Sync signal which initiates the start of a measurement, i.e. which corresponds to the start of the first Frame Period of a series of Frame Periods belonging to one measurement. The Measurement Start Time corresponds to the first Frame Start Time.</td>
</tr>
<tr>
<td>Memory Scrubbing</td>
<td>The process of detecting and correcting bit errors in memory</td>
</tr>
<tr>
<td>Oversampling</td>
<td>Number of recordings per Dwell Time. The oversampling of the raw data (raw frames) is therefore equal to Dwell Time divided by Frame Period.</td>
</tr>
<tr>
<td>Pixel Clock</td>
<td>Frequency that corresponds to the read-out of one pixel of the shift register. This is thereby the also the sampling frequency of the entire video chain from the CCD to the ADC.</td>
</tr>
<tr>
<td>Recording Time</td>
<td>In instrument measurement modes other than the Earth Radiance and the Sun Irradiance measurement modes the term &quot;Dwell Time&quot; does not make sense. Therefore the term Recording Time is introduced for these other measurement modes, which include in particular all on-ground and in-flight calibration measurements. Let N2 be the number of raw frames that are co-added to give one measurement sample. Then the Recording Time is equal to N2*Frame Period.</td>
</tr>
<tr>
<td>Small Pixel Column</td>
<td>A copy of a column of the CCD which is binned but not co-added</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
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</tr>
<tr>
<td>Smear</td>
<td>The effect of photons collected in a pixel during the frame transfer</td>
</tr>
<tr>
<td>Smear Line or Dark Line</td>
<td>Lines which are only exposed to photons during a frame transfer</td>
</tr>
<tr>
<td>Spectral Range</td>
<td>Range of optical wavelengths</td>
</tr>
<tr>
<td>Subdwell Time</td>
<td>&quot;Dwell Time&quot; of the L0 data. By on-board co-addition of N1 raw frames</td>
</tr>
<tr>
<td></td>
<td>L0-data are generated, which accordingly have a Subdwell Time equal</td>
</tr>
<tr>
<td></td>
<td>to N1*Frame Period.</td>
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4 SENTINEL 4 UVN TECHNICAL DESCRIPTION

The compact and mass optimized instrument is based on robust optical, mechanical, thermal and electrical designs. It features a large aperture (80mm) entrance telescope combined with two spectrographs, covering the UV-VIS and NIR bands. High stability of radiometric and geometric performance is supported by the structural design, which provides overall high thermal-mechanical stability and stiffness. The instrument thermal control is primarily realized through a simple and reliable solution based on passive cooling with radiators. Using controlled heaters it provides a stable thermal environment for the sensitive optical modules and the required lower temperatures for the detectors. The electrical architecture is characterized by a relatively small number of interfaces, low onboard processing complexity, an autonomous and flexible operation concept and a high level of redundancy for good instrument reliability. The detector solution is based on the use of CCD technology and all proposed instrument components and materials have been selected in view of instrument end of life performance optimization by reduction of degradation and contamination during handling and storage on ground and operation in the orbital environment.

In the UVN Earth Observation mode, the sun radiance reflected by the Earth atmosphere enters the instrument through the aperture cover onto a two-axis scanning mirror surrounded by the Nadir Baffle. One scan axis provides for E/W coverage with a maximum repeat cycle of 60 minutes, the second axis for the seasonal latitude shifts of the coverage areas including the yaw-flip. The N/S coverage is achieved by an extended slit long enough to cover the required N/S scene. The light reflected by the scan mirror passes the refractive telescope followed by a polarization scrambler that ensures depolarization of any polarized incident light. The subsequent dichroic beam splitter assembly divides the signals into the UV-VIS and NIR spectral inputs to the dedicated slits. For spectral dispersion, both spectrometers use refractive collimating optics, a prismatic grating (GRISM) for the UV-VIS and a reflective grating for the NIR spectral band. The radiation is detected by CCD arrays which generate a data cube composed of one spectral and two spatial axes. The co-registration compensator as part of the NIR spectrographs compensates potential spatial mismatches of the UV-VIS and NIR detector pixels. The Front End Electronics (FEE) and Front-end Support Electronics (FSE) serve to control the detectors and incorporate the functions for analogue read out and AD conversion. The data are finally transferred to the ICU for on-board co-addition, data processing and formatting. The Instrument Control Unit (ICU) then provides a serial data stream via SpaceWire towards the platform.
5  SENTINEL 4 UVN FRONT-END ELECTRONICS DESCRIPTION

The Focal Plane Subsystem (FPS) is part of the UVN instrument and encompasses the detectors, the Front-End Electronics (FEE) and the FEE Support Electronics (FSE), see block diagram Figure 5.5.

The FPS is built around two detectors. The first one is dedicated to the UV/VIS band (Figure 5.1) and the second one to the NIR band (Figure 5.3).

---

**Figure 5-1: Architecture of the UVN UV/VIS detector**

- **S4 UVN UVVIS Flight CCD**
- **600 spatial pixels + 3 x 8 excess (pre-scan) pixels (on each end)**
- **660 columns in memory zone**
- **Gain UVVIS1a**
- **Alternate readout to left or right, with different gates**
- **UV-VIS1 Memory Zone**
  - 271 horizontal lines x 600 vertical columns
  - 5 masked isolation lines
  - 5 masked dark columns + 3 masked isolation columns
- **Image Zone**
  - 1290 lines (spectral) x 600 vertical columns (spatial)
  - (280 UVVIS I & 1030 UVVIS II)
  - **5 masked dark columns + 3 masked isolation columns**
  - **5 masked isolation lines**
- **UV-VIS2 Memory Zone**
  - 1039 horizontal lines x 600 vertical columns
- **Gain UVVIS2**
- **Gain UVVIS2**
- **Gain UVVIS2**
- **Gain UVVIS2**
- **Gain UVVIS2**
- **Gain UVVIS2**
- **Gain UVVIS1b**
- **Gain UVVIS1a**
- **Alternate readout to left or right, with different gates**
- **Yellow = masked area in image zone**
- **Masked area in Memory Zone**
- **Pixel Size:** 15 μm (spectral) x 27.5 μm (spatial)
  - Equal for Zone I and Zone II
- **CCD Readout Register detailed view**
  - Excess Pixels (pre-scan) and Output Amplifier with bendel/ corner design
  - on Chip pseudo differential readout amplifier with One dummy output

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Figure 5-2: Masked lines/rows and optical alignment/margin lines/rows of the UVN UV/VIS detector
Figure 5-3: Architecture of the UVN NIR detector
The Front End Support Electronics (FSE) provides the support functions of the Focal Plane Subsystem (FPS).

The Front-End Electronics (FEE) includes all the electronics circuitry which has to be located close to the detector. The FEE is particularly in charge of the detectors electrical conditioning and the signal video processing up to and including the digitization. The scientific data are sent by the FEEs directly to the ICU.

There is one separate and non-redundant FEE per detector: FEE-UV/VIS and FEE-NIR.

In addition the FEE-UV/VIS is divided into two functional groups: one for each spectral band UV/VIS1 and one for UV/VIS2.

The Front-End Electronics (FEE) provides the following functions:

- The video chains which are in charge of the CCD video signals processing up to and including digitization
- The clock drivers and DC bias regulation functions which electrically condition and operate the CCDs
- The sequencer which provides the detectors and the video chains with clocks and synchronizes the control signals exchanged between the detection functions.
- Redundant data interfaces which transmit the video data into a multiplexed serial redundant link towards the ICU

The FSE provides each FEE with the necessary secondary power supplies and main clocks for detector and FEE synchronisation and operation. The configuration and control of both FEEs takes place via FSE (which is under control of the ICU)
The UV/VIS detector characteristics are recalled in the following table (size of the memory zone).

<table>
<thead>
<tr>
<th>UV/VIS CCD</th>
<th>UV/VIS1</th>
<th>UV/VIS2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lines</td>
<td>271</td>
<td>1039</td>
</tr>
<tr>
<td>Number of columns</td>
<td>632</td>
<td>632</td>
</tr>
<tr>
<td>Number of output ports</td>
<td>1 Gain A, 1 Gain B (only one output signal shall be processed)</td>
<td>4</td>
</tr>
</tbody>
</table>

The NIR detector characteristics are recalled in the following table (size of the memory zone).

- **Note**: to fulfill the timing requirements of the CCD sometimes additional wait times are introduced.
- **Note**: in these calculations spectral and spatial pixels means, all pixels in the memory zone, including all masked pixels/lines + the storage lines for the smearlines.
- **Note**: all these timings refer to the flight layout of the S4 UVN CCDs. These timings are NOT possible with the BB CCDs!

<table>
<thead>
<tr>
<th>NIR CCD</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lines</td>
<td>740</td>
</tr>
<tr>
<td>Number of columns</td>
<td>632</td>
</tr>
<tr>
<td>Number of output ports</td>
<td>1</td>
</tr>
</tbody>
</table>

Two independent Front-End Electronics (FEE) are in charge of the detectors electrical conditioning and the signal video processing up to and including the digitization. Each FEE is set as close as possible to the detector.

An additional redundant unit referred as FEE Support Electronics (FSE) encompasses all the functions that are not necessarily set close to the detectors: DC/DC converters for FSE and FEEs, main clock generator, and electrical interfaces with units out of Focal Plane Subsystem (FPS).

Both FEEs interfaces with the FSE and the detectors as well as with the Instrument Control Unit (ICU) for video data exchange. The ICU and FSE are redundant.

The flexible cold harness between FEE and the Detector Conditioning Board (DCB) as well as the DCB itself is under responsibility of the FEE supplier. The DCB, including flex harness with connector is called Detector Assembly Package (DAP). The detector is a customer furnished item (CFI).

Only a set of EM detectors will be proposed to the FEE supplier for development support. The final detectors for EM up to FM will be assembled by the customer after delivery.

If not stated otherwise in this document the “FEE” includes the “DAP”

The electrical architecture of the Focal Plane Subsystem (FPS) and its interfaces are presented in Figure 5-5.
Figure 5-5: Electrical overview of the Focal Plane Subsystem (FPS)

The figure below shows the principle functional diagram of the Front End starting at the detector (on the left), connected via flex harness to the FEE on the right side. The FEE shown in the figure represents the maximal configuration, necessary for UV/VIS with up to six analogue video chains where the similar FEE for NIR needs a reduced configuration with only one channel.
The FEE includes the CCD clock conditioning and drivers, a bias and supply conditioning as well as the local sequencer for clock generation and FEE internal sequencing. Additional blocks are the TM/TC interface communicating with the FSE, the local power conditioning and the handling of the telemetry lines which are routed to the FSE for digitisation.

Finally the digital data combiner and serializer is included and provided in redundancy for efficient transmission of the video data forward directly to the ICU.

Figure 5-6: Functional Front End diagram over Detector and FEE
6 DETECTOR ASSEMBLY PACKAGE (DAP) REQUIREMENTS

The Detector Assembly Package (DAP) consists of the detector chip including package, mounted on a Detector Conditioning Board (DCB, as defined in section 6.1) and the necessary number of flex harness (one or two) to connect the DAP to the FEE (as defined in section 6.2).

![Diagram of the Detector Assembly Package (DAP)](image)

**Figure 6-1:** Items of the Detector Assembly Package to be mounted into the FPA

The DAP will be populated with a detector and mounted into the Focal Plane Assembly (FPA) by the customer.

**FEERS-2226:**

Created

After assembling of the detector and finally after assembly of the DAP into the FPA it shall be possible to adjust the fine timing of clocks individually for the dedicated detector to fulfill the performance requirements. For this purpose the FEE shall provide the necessary functionality.

**FEERS-2222:**

Created

The Detector Assembly Package (DAP) shall be delivered by the FEE subcontractor for mounting into the Focal Plane Assembly (FPA) under customer responsibility.

*Note:* Only a set of packaged EM detectors (CCDs) will be delivered as a customer furnished item. Further detectors will be mounted by the customer and mounted as well as adjusted with subcontractor support.
6.1 Detector Conditioning Board

FEERS-2247: R
Created
Thermistor connection tracks from the detector shall be routed through the flex harness backwards to the FEE

FEERS-2260: R
Created
The DCB dimensions shall be less then 70mm (diameter) and less then 6mm height (TBC).

6.2 Flexible Cold Harness

FEERS-2242: A
Created
The thermal conductivity of the flexible harness(es) shall not exceed the following values per DAP:
- Between UV-VIS cryostat-internal PCB (DCB) and UV-VIS FEE: 0.002 W/K (TBC)
- Between NIR cryostat-internal PCB (DCB) and NIR FEE: 0.001 W/K (TBC)

FEERS-2244: R
Created
The length of the flex harness shall be 200mm (TBC)

Note: Measured from the FPA mounting flange until the front side of the FEE connector

Note: The specified length is the worst case value. The final dimensions specified in FEERS-2244 will be detailed latest at the PDR.

FEERS-2248: R
Created
A connector shall be fixed at the end of the harness (FEE side). The type of connector shall be agreed with the customer

FEERS-2249: I,R
Created
Connectors shall be sized, oriented, keyed or otherwise protected from an improper connection that would result in damage to the equipment connected to either end of the harness

FEERS-2250: I,R
Created
Connector savers shall be utilized on all flight connectors prior to connector/flight harness mate after delivery

6.3 Special conditions for the DAP

FEERS-2238: T,A
Created
The DAP shall be designed to survive during none operation (zero dissipation) any temperature between 190 K and the bake-out temperature of at least 80°C without any performance degradation.

**FEERS-2239:**

Created

Justification: FPARS-1198

The total DAP power dissipation (inside the FPA), plus the power dissipated in the flexible harness to the FPA shall be less than 540mW (TBC) for the UV/VIS and less than 220mW (TBC) for the NIR - including a 20% contingency.

*Note: This includes the total detector power dissipation, the power dissipated from possible parts mounted on the DAP and the thermal conductivity of the flex harness as specified in FEERS-2242*

**FEERS-2246:**

Created

The final heat flow budgets shall be included in the budget report and shall be updated accordingly.
7 FUNCTIONAL REQUIREMENTS

7.1 General Functional Requirements

FEERS-2307: Created
If not otherwise specified, requirements shall be considered end-of-life and worst-case.

FEERS-2730: Created
Cross coupling between the two (redundant) FSE sides and the two non-redundant FEEs shall be supported.

FEERS-2909: Created From: S4IRS-13949
Each detector shall interface with a dedicated FEE, the FEE-UV/VIS and the FEE-NIR.

FEERS-2911: Created From: S4IRS-13951
The detector pixel signals shall be acquired by the FEE frame by frame (read out of the detector memory zone).

FEERS-2731: Created
The FEEs shall provide a differential serial interface for TM/TC communication with the redundant FSE.

FEERS-2862: Created From: S4IRS-13950
The FEE shall provide a programmable sequencer to operate the CCD in the required operating conditions and within the specified readout-modes.

FEERS-2863: Created From: S4IRS-13950
The FEE shall generate the detector’s biases and filtering the secondary voltage delivered by FSE.

FEERS-2864: Created From: S4IRS-13950
The FEE shall receive the analogue video input signals from the CCD, condition the signals including Correlated Double Sampling (CDS) and convert the video data in 16 Bit digitized values.

FEERS-2865: Created From: S4IRS-13950, S4IRS-13952
The FEE shall serialise the digitized values and transmit the information in a serial stream to the ICU.
FEERS-2866: T
Created
The FEE shall provide house keeping functions to support the FSE for health status reporting.

FEERS-2867: T
Created
The FEE shall be able to receive configuration and settling commands from FSE to operate the CCD in the required readout modes and timings.

FEERS-2910: T
Created From: S4IRS-13959, S4IRS-13978
The periodicity of the frame period synchronization signals shall result from the implemented Frame Period Increment, common for UV/VIS 1, UV/VIS 2 and NIR, and the number of increments, which shall be commandable individually for UV/VIS 1, UV/VIS 2 and NIR.

7.2 Redundancy

FEERS-574: T
Created
Each FEE shall provide two serial output links (in redundancy) for transmission of the video data to the nominal and redundant ICU.

FEERS-575: T
Created
Each FEE shall operate with the nominal and redundant side of the Front End Support Electronics (FSE) Unit.

Note: The FSE provides the interfaces in cold redundancy. The FEE shall be able to handle the doubled lines in any nominal operating case (only one FSE side active).

FEERS-2914: R
Created
Any cross coupling between main and redundant shall be realised in separate devices/packages.

7.3 Operational Modes

FEERS-579: T
Created
It shall be possible to operate each FEE (UV/VIS and NIR) independently (one FEE switched off) and with full performance.

FEERS-580: T
Created
Each FEE shall support the FSE in acquisition of the health status. This includes temperature measurement of the CCD and the FEE itself.

FEERS-581: T,R
Created
Four high accuracy temperature sensor signals from CCD shall be routed through the FEE to FSE and the FEE shall provide thermistors for temperature measurement via FSE.

7.3.1 Operating Modes

FEERS-2870:  

Created

The FEE shall operate in the following modes:

Off Mode

- The FEE is switched off (no supply from FSE). The FEE is not able to receive configuration settings.

Standby Mode

- All CCD clocks are running with default timings or with the last configured settings. Image data to ICU are marked as not valid (hence it will not be processed further and withdrawn in ICU). The FEE is able to receive new configuration settings from FSE.

Image Mode

- FEE delivers valid image data to the ICU, all CCD clocks are running with default or configured settings. The FEE is able to receive new configuration settings from FSE.

Diagnostic Mode

- All CCD clocks are running, diagnostic test pattern is sent to ICU, image data from CCD outputs are not sent to ICU. The FEE is able to receive new configuration settings from FSE.

7.4 Generation of CCD clocks

FEERS-584:  

Created

The UV/VIS FEE shall perform the image acquisition with split frame for the UV/VIS 1 and UV/VIS 2 spectral band.

Note: The frame transfer shall be in spectral direction for the UV/VIS CCD.

FEERS-1600:  

Created

The NIR FEE shall perform the image acquisition for the NIR spectral band.

Note: The frame transfer shall be in spectral direction for the NIR CCD.

FEERS-586:  

Created

The FEE shall receive from the FSE:

- The Master Clock (MC)
- FEE synchronisation Clock(s) to synchronise both FEEs operation.

Note: The FSE provides identical connectors for UV/VIS and NIR.

Note: The synchronisation clock is synchronised to the MC.

FEERS-588:  

Created
The Frame Period Sync signals shall be generated by the FEE individually with period durations as programmed by the FSE (as a result of an ICU command to FSE).

**FEERS-2610:**

The Frame Period Sync shall be routed back to the FSE for further distribution to ICU and a test connector located on the FSE.

*Note:* The ICU uses these signals for OBT latching and time stamping information.

### 7.4.1 Exposure time flexibility

**FEERS-2725:**

The maximum integration time for all CCDs shall be programmable for up to 10 minutes in steps of the Frame Period Increment.

**FEERS-2726:**

To guarantee synchronisation it shall be possible to use only combinations, where

\[
\text{UVVIS1/UVVIS2 = integer if UVVIS1} \geq \text{ UVVIS2 (or UVVIS2/UVVIS1 = integer if } \text{ UVVIS1 < UVVIS2)}
\]

AND

\[
\text{UVVIS1/NIR = integer if UVVIS1} \geq \text{ NIR (or NIR/UVVIS1 = integer if UVVIS1 < NIR)}
\]

AND

\[
\text{UVVIS2/NIR = integer if UVVIS2} \geq \text{ NIR (or NIR/UVVIS2 = integer if UVVIS2 < NIR)}
\]

This would allow (list is not complete):

- 125 ms : 125 ms : 375 ms (1:1:3)
- 125 ms : 375 ms : 375 ms (1:3:3)
- 375 ms : 375 ms : 375 ms (3:3:3)
- 125 ms : 125 ms : 500 ms (1:1:4)
- 250 ms : 125 ms : 500 ms (2:1:4) - nominal mode for atmospheric measurements
- 125 ms : 250 ms : 500 ms (1:2:4)
- 125 ms : 125 ms : 625 ms (1:1:5)
- 625 ms : 125 ms : 625 ms (5:1:5)
- 750 ms : 125 ms : 375 ms (6:1:3)
- 250 ms : 250 ms : 750 ms (2:2:6)
- 250 ms : 125 ms : 750 ms (2:1:6)
- 125 ms : 125 ms : 875 ms (1:1:7)
- 500 ms : 500 ms : 1000 ms (4:4:8)
500 ms : 250 ms : 1000 ms (4:2:8)
500 ms : 125 ms : 1000 ms (4:1:8)

Note: The above combinations are possible with 125 ms steps (Frame Period Increment).

FEERS-2612: Created
The FEE shall provide full performance after any change of integration time.

FEERS-592: Created
The UV/VIS FEE shall generate the following clocks:
- 2 x 4 Image zone clocks
- 2 x 4 Memory zone clocks
- 1 Transfer clocks for UV/VIS 1
- 1 Transfer clocks for UV/VIS 2
- 6 Register clocks for UV/VIS 1
- 5 Register clocks for UV/VIS 2

The characteristics of the CCD clocks to be generated are specified in section 9.3.3.

FEERS-593: Created
The NIR FEE shall generate the following clocks:
- 4 Image zone clocks
- 4 Memory zone clocks
- 1 Transfer clocks
- 5 Register clocks

The characteristics of the CCD clocks to be generated are specified in section 9.3.3.

FEERS-2729: Created
Justification: S4IRS-6743, Table S4IRS-6745
It shall be possible to perform on-chip binning of flexibly commandable spectral bands with a spectral size up to entire detector frames (e.g. entire UV-VIS1)

FEERS-595: Created
Each FEE shall support a programmable readout-register binning over 4 (TBC) programmable areas of the whole memory zone (specific imaging mode like star detection).

FEERS-596: Created
Binning should not change the over-all time scheme given in Figure 7-1 and should be realised by disabled readout sequence line by line.
FEERS-2637:  
Created From: S4IRS-11231

An Extended Frame Transfer Mode (see also "Definitions" chapter) shall be implemented, in which the effective integration time of each frame (UVVIS1, UVVIS2 and NIR) can be commanded via the serial I/F individually and independent of the other frames to any multiple of the Nominal Frame Period.

Note 1: In terms of real integration time these are not exact multiples, but only multiples modulo the Frame Transfer Time. However, since the Frame Transfer Time is always short with respect to the Nominal Frame Period these are almost quite exact multiples.

7.4.2 Nominal Frame sequencing

FEERS-598:  
Created

The frame sequencing shall be implemented as shown in Figure 7-1:
Figure 7-1: Clock readout sequencing for both detectors
The Timing diagram in Figure 7-1 shows the detailed timing of the three spectral bands. In the left of this drawing the operations which are done during a complete readout of the detector are shown. Green is for the UVVIS 2, blue is for the UVVIS 1 and red for the NIR. The UVVIS 2 is the first one, as this timing is the spectral band with the most spectral lines and therefore the driver for the overall timing.

**Frame Time** is the complete time which is needed to readout the complete data of one memory zone.

**Shift Image to Memory Zone** (Image Transfer Time) is the time which is needed to shift the whole image from the image zone to the memory zone.

**Shift one Row into Readout Register** (Line Transfer Time) is the time which is needed to shift always the last line above the readout register into the readout register.

**Readout one Row** (Line Readout Time) is the time to readout one line out of the readout register.

There is one main difference between Zone 2 and the two other spectral bands. Zone 2 has four outputs, with 8 excess pixels each. The two other spectral bands use only one output at a time (Zone 1 has two outputs, which are used for gain switching and are used alternately). Both bands have four times eight dummy pixels, which are located at the same place equivalent to the excess pixels in the Zone 2 readout register. While the readout of these two readout registers have to be stopped (see Row 9 and 14 in Figure 7-1) during the shift of one Row in the Zone 2 for 2.5 µs, the eight dummy pixels in the two other spectral bands ensure, that all levels in the video processing chain are settled.

The UVVIS 1 needs 0.7ms and the NIR needs 1.8ms to shift their image-zones into the memory, while the UVVIS 2 needs 2.56 ms to do this. To keep all three spectral bands synchronized, the UVVIS 1 and the NIR detector have to wait 1.9ms and 0.8 ms, before the readout sequence can be started.

**FEERS-2575:**

The possible ratios between the integration (frame time) of the three spectral bands are shown in Figure 7-2. The step-size for increasing or lowering the integration shall be 125 ms. The minimum Frame Time, which can not be shortened further is the second timing shown in Figure 7-2 and based on 125 ms steps.
Figure 7-2: Possible variations of the integration time for all three spectral bands
FEERS-2593:
Created

In addition to these fixed ratios of the three spectral bands as shown in Figure 7-2, the minimum Frame Time for UV/VIS 2 (green), which is the master for all timings, shall be extendable in steps of 125 (TBC) milliseconds up to the maximum integration time as specified in requirement FEERS-2725. Such an extension affects all other spectral bands. Furthermore the frame rate ratios possible with this increased frame time shall be the same as shown above.

FEERS-2594:
Created

The FEE shall assure, that during an increased frame time (more than the minimum integration period specified in FEERS-2593), the readout registers are running and the converted dummy or fill pixels are marked as invalid pixels in the FEE output data stream or shall not transmitted to the ICU.

Note: the readout-sequence shall not be interrupted to guarantee a continuous operating environment and to avoid load changes in the power supply. So "dummy pixels" means all converted pixels which are not relevant and a result of this uninterrupted readout.

FEERS-601:
Created

The UV/VIS FEE shall provide all necessary drivers and driver capabilities for two independent frame transfers of the UV/VIS 1 and UV/VIS 2 CCD area.

Note: See section 9.3.3 for the detailed definition of the clocks to be provided by the FEE.

FEERS-603:
Created

The NIR FEE shall provide all necessary drivers and driver capabilities for the frame transfer of the NIR CCD area.

Note: See section 9.3.3 for the detailed definition of the clocks to be provided by the FEE.

FEERS-605:
Created

The UV/VIS FEE shall initiate and control each frame transfer within the UV/VIS 1 detector area.

FEERS-606:
Created

The UV/VIS FEE shall initiate and control each frame transfer within the UV/VIS 2 detector area.

FEERS-607:
Created

The NIR FEE shall initiate and control each frame transfer within the NIR detector area.
The readout scheme shall be started synchronously for all image areas and on request from FSE (after command from ICU) and triggered by the sync Pulse, provided by the FSE.

**Note:** After first synchronised start both FEEs are free running but synchronised by the common Master Clock (MC).

**FEERS-2708:**
Created From: S4IRS-6535

All Smear Lines (in the UV-VIS1, UV-VIS2 and NIR) shall be on-chip binned in the R/O register

**FEERS-2912:**
Created

On request and for trouble-shooting smear lines shall be processed without on-chip binning.

### 7.4.3 Pixel readout sequencing

**FEERS-609:**
Created

The following readout of one CCD frame shall be supported for the different spectral ranges:

- UV/VIS 1: 282 lines (two output ports selected by shift direction)
- UV/VIS 2: 1020 lines (four output ports)
- NIR: 708 lines (one output port)

**FEERS-610:**
Created

Justification: S4IRS-6821, Table S4IRS-6831

Pixel readout frequency for all spectral bands shall be: 1.40Msps @ 630kHz line transfer rate

**FEERS-611:**
Created

The FEE shall be compliant to a Master Clock (MC) frequency with a multiple (32) of the pixel clock frequency, provided and distributed by the FSE.

**FEERS-613:**
Created

The UV/VIS FEE shall provide all necessary drivers and driver capabilities for two independent video line readouts of the UV/VIS 1 and UV/VIS 2 CCD area.

**Note:** See section 9.3.3 for the detailed definition of the clocks to be provided by the FEE.

**FEERS-615:**
Created

The NIR FEE shall provide all necessary drivers and driver capabilities for the video line readout of the NIR CCD area.

**Note:** See section 9.3.3 for the detailed definition of the clocks to be provided by the FEE.
During readout shift (and data processing) no frame transfer in any detector shall occur to avoid disturbances of the sensitive video signal.

**Note:** Readout (shift) has to be stopped during line or frame transfer in any other section.

### 7.5 Video chains

**FEERS-620:**

Created

The FEE shall include one video chain per CCD output port.

**Note:** The UV/VIS 1 CCD frame provides two outputs with different gains which will be addressed by two different CCD readout directions.

**FEERS-2913:**

Created

The FEE shall take care which readout direction is used and therefore which CCD signal has to be processed. The readout direction shall be in-flight programmable for four (TBC) spectral regions of the CCD.

**FEERS-2309:**

Created

The FEE shall allow changing the read-out direction of the UV/VIS1 CCD by changing the read-out clock sequence. Such a change of the read-out direction shall not impact the performance for the following lines.

**FEERS-2310:**

Created

It shall be possible to change the read-out direction after each line transfer to offer a gain switch from one line to the adjacent.

**FEERS-622:**

Created

The video chains shall be based on a Correlated Double Sampling (CDS).

**FEERS-623:**

Created

Justification: S4IRS-6821, S4IRS-6865, Table S4IRS-6831

Each sample shall be digitised with 16 bits.

**FEERS-624:**

Created

The video chain gain referenced to the FEE input signal shall be:

- UV/VIS 1 32.8 LSB/mV (TBC)
- UV/VIS 2 32.8 LSB/mV (TBC)
- NIR 32.8 LSB/mV (TBC)
The maximum input signal swing (AC) for each chain is 2.5V<sub>pp</sub> (TBC) instantaneously.

**Note**: The real video signal (as result of the CDS) is expected with 2.0V<sub>pp</sub> (TBC). This includes a possible dark current offset signal from the CCD.

FEERS-626: T
Created
An input signal outside the ADC conversion range shall not affect adjacent sampling results (clipping without saturation recovering).

FEERS-627: T
Created
The CDS times (hold & convert) shall be individually settable for each chain via FSE TC interface.

FEERS-628: T
Created
The time for CDS hold shall be programmable in 25 steps of 11ns (half period of the MC) around the nominal value.

FEERS-629: T
Created
The time for CDS convert shall be programmable in 25 steps of 11ns (half period of the MC) around the nominal value.

### 7.6 Serial Video Link

FEERS-1118: T
Created From: S4IRS-13952
The UV/VIS FEE digitized video data shall be sent to ICU-N or ICU-R through redundant serial links. The used link shall be selectable by command from FSE (to reduce power consumption of the FEE).

FEERS-2917: T
Created From: S4IRS-13952
The NIR FEE digitized video data shall be sent to ICU-N or ICU-R through redundant serial links. The used link shall be selectable by command from FSE (to reduce power consumption of the FEE).

FEERS-2750: T
Created
The default setting after switch on shall be the output link to ICU-N

FEERS-632: R
Created
The FEE shall provide dedicated and identical connector layout sets for each of the nominal and the redundant interfaces to the Instrument Control Unit (ICU).

FEERS-633: R
Created From: S4IRS-13953
Each FEE (UV/VIS and NIR) shall provide two (2) redundant data interfaces to the ICU on-board processing. Each data interface is assigned to one of the two UVN detectors (UVIS and NIR).

![Diagram of data interface between FPS FEEs and ICU](image)

**Figure 7-3: Cross coupling for data interface between (FPS) FEEs and ICU**

The FEE shall provide redundant data combiner/multiplexers and redundant serializer as shown in the following principle block diagram:
In this proposed concept the data combiner offers four inputs for the four channels of the UV/VIS2 and one separate input for the two outputs of the UV/VIS1 (one active at a time and derived from two different gain chains). Additionally a link for checksum insertion and test pattern transmission is foreseen.

The NIR combiner provides only two channels, used for video information and the checksum.

A complete set of data is called a “video page”.

The digitized video data is packetized into “video pages”. Each UV/VIS video page consists of the following content in the given consecutive order:

- Header Data Word
- UV/VIS1
- UV/VIS2 Output 1
- UV/VIS2 Output 2
- UV/VIS2 Output 3
- UV/VIS2 Output 4
CheckSum (as defined in FEERS-649 ff).

**FEERS-2618:**

Created

The digitized video data is packetized into “video pages”. Each NIR video page consists of the following content in the given consecutive order:

- Header Data Word
- NIR Output
- CheckSum (as defined in FEERS-649 ff).

**FEERS-640:**

Created

Invalid data (idle pattern) shall be flagged by an inactive "Valid" bit or not transmitted to ICU.

**FEERS-641:**

Created

The UV/VIS and NIR FEE shall send the video data with a transmit clock synchron to the MC.

**FEERS-643:**

Created

The first video page in a new frame shall be marked with active synchronisation flags in the video data header word which are called "Frame Sync" bit (active high). These bits are delivered together with the video data (see Figure 7-5).

**FEERS-2620:**

Created

The first video page in a new line shall be marked with active synchronisation flags in the video data header word which are called "Line Sync" bit (active high). These bits are delivered together with the video data (see Figure 7-5).

**FEERS-644:**

Created From: S4IRS-13955

Only valid video data shall be flagged by an active (high) "Valid" bit (see Figure 7-5) or transmitted to ICU.

*Note:* Valid data are all values from one exposed frame within memory zone including excess pixels.

**FEERS-2753:**

Created

The capability shall be provided to enable/disable the setting of the validity bit by command via TM/TC interface from ICU via FSE.

*Note:* This is needed to enable and disable on-board video processing within ICU without interruption of the CCD readout sequence.

**FEERS-2622:**

Created From: S4IRS-13979, S4IRS-13981
An enable/disable of the “Valid” flag setting via TM/TC interface shall be synchronised to the next frame start to avoid processing of incomplete or interrupted video frame packages.

FEERS-645:

The FEE shall use the following data bit assignment within the header data word (TBC). Least Significant Bit (LSB) is defined as $2^0$.

```
MSB

7 6 5 4 3 2 1 0
```

**Figure 7-5: Bit assignment used on the Header Data Word**

FEERS-2918:

The "Channel Identification" bits shall be used in the UV/VIS link as follows (TBC):

- 0b00: don't care
- 0b01: UV/VIS output signal
- 0b10: don't care
- 0b11: don't care

*Note: Bit 3 shall be understood as LSB (Bit 4 is MSB for Channel Identification)*

FEERS-2920:

The "Channel Identification" bits shall be used in the NIR link as follows (TBC):

- 0b00: don't care
• 0b01: don’t care
• 0b10: NIR output signal
• 0b11: don’t care

**Bit 3 shall be understood as LSB (Bit 4 is MSB for Channel Identification)**

**FEERS-649:**

In case where no other FEE/ICU link integrity failure detection is implemented a checksum shall be inserted as specified in FEERS-2617 and FEERS-2618. Such a checksum shall be calculated as given in FEERS-650.

**FEERS-650:**

The checksum shall contain the CRC16 checksum over one video page and excluding the CRC field itself. The algorithm for the CRC16 shall be as defined CRC-CCITT (CRC-16) i.e. using the polynominal 1+x^5+x^12+x^16.

**Note**: Least Significant Bit (LSB) is defined as 2^0

**FEERS-651:**

On request (command from FSE initiated by ICU) the FEE shall change to the diagnostics mode. In this mode the FEE shall generate and send digital data representing full operating CCDs and FEE for test purpose. The test pattern to be implemented shall be defined together with and agreed by the customer.

**7.7 Generation of CCD DC biases**

**FEERS-653:**

The FEE shall generate up to 4 DC biases for each CCD.

**Note**: The voltage of each DC bias shall be such as specified in section 9.3.2.

**7.8 Housekeeping**

**FEERS-656:**

The FEE shall provide the housekeeping sensors for temperature measurements, analogue voltages and digital information for health status acquisition of the FEE by the FSE or ICU.

**7.9 Power architecture**

**FEERS-658:**

Each FEE shall receive individual secondary power lines from each side of the FSE:

• one set supplying the FEE-UV/VIS
• one set supplying the FEE-NIR

**Note**: The voltages provided by FSE are galvanical isolated from any secondary or primary ground to fulfil the grounding requirements as specified in section 10.2.1.
FEERS-659:

The FEE shall not be damaged or permanently degraded in a situation where nominal and redundant FSE secondary power lines are activated simultaneously.

FEERS-660:

At FEE level, a logical "OR" shall be implemented between the secondary voltages coming from the nominal and redundant FSE.

**Figure 7-6: Principle secondary power distribution from redundant FSE to none redundant UV/VIS FEE (NIR FEE supply identical to UV/VIS but not shown)**

*Note: Each FEE DC/DC converter within the FSE can be switched ON/OFF independently by commands.*

*Note: All the DC/DC converters are synchronised by a clock derived from the master clock (MC).*

FEERS-665:

The total power consumption for the UV/VIS FEE is limited to 6.5W including all externally connected loads.

These values shall be fulfilled accounting for the maturity margins as specified in 4.7.10 [AD-34C]

FEERS-666:

The total power consumption for the NIR FEE is limited to 2.5W including all externally connected loads.

These values shall be fulfilled accounting for the maturity margins as specified in 4.7.10 [AD-34C]
7.10 TM/TC interface between FSE and FEE

The command and control interface is the link between the FSE and FEE realized as 16-bit bi-directional serial digital (BSD) interface accordingly to [AD-34C] (BSD). Via this link the complete function of the FEE is controlled as well as the monitoring of the health of this system and its status. This includes the configuration of the system which implies the configuration of the Detectors/FEE and necessary parameter settings. Additional discrete interfaces - as far as necessary (see FEERS-671) - shall be acceptable but realized accordingly to [AD-34C].

FEERS-669: R
Created
The FEEs shall provide dedicated and identical connector layout sets for each of the UV/VIS and the NIR FEE interfaces to the FSE.

FEERS-670: T
Created
The FEE shall act as a "PERIPHERAL" on the BSD interface

FEERS-671: T,A
Created
The FEE shall provide discrete HK information for direct measurement by FSE. This shall include (TBC):

- Temperatures as defined in Table 7-1
- Voltages from the FEE (2 voltages per FEE)
- Digital status from the FEE (64 bits per FEE)

<table>
<thead>
<tr>
<th>Table 7-1: Thermistors to be provided from FEE for FSE measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>UV/VIS FEE TRP</td>
</tr>
<tr>
<td>NIR FEE TRP</td>
</tr>
<tr>
<td>UV/VIS FEE hot point</td>
</tr>
<tr>
<td>NIR FEE hot point</td>
</tr>
</tbody>
</table>

FEERS-720: T
Created
The FEE shall route 3 (TBC) high accuracy four-wire temperature sensor signals from each CCD to the nominal as well as to the redundant half of the FSE.

FEERS-2885: T
Created
The access from FSE to the detector temperature sensors shall be possible also in any operating mode also in case of a switched off FEE.
Note: this implies a simple routing of the detector temperature sensor signals from the detector to the FSE

FEERS-721: T

Created

Each FEE shall be accessible and controllable by the main as well as by the redundant FSE (cross coupling capability)
8 PERFORMANCES REQUIREMENTS

The following requirements are applicable in the environment conditions specified in section 10.5 and for the lifetime specified in section 13.5.1 and with interface conditions as per section 9.

8.1 Gain and dynamic range

FEERS-1013:
Created
Justification: S4IRS-6550, S4IRS-6552, S4IRS-6555, S4IRS-6579, S4IRS-6583, S4IRS-6587, Table S4IRS-6581, Table S4IRS-6585, Table S4IRS-6589, Table S4IRS-6551, Table S4IRS-6554, Table S4IRS-6557

The initial video chain gain knowledge shall be better ±0.3% at BOL

FEERS-1015:
Created
Justification: S4IRS-6821, Table S4IRS-6831

The video chain gain deviation over lifetime shall be better ± 1.0% (EOL)

FEERS-2586:
Created
Justification: S4IRS-5466, S4IRS-5471, S4IRS-5476, S4IRS-6550, S4IRS-6552, S4IRS-6555, S4IRS-6579, S4IRS-6587, Table S4IRS-5468, Table S4IRS-5473, Table S4IRS-5478, Table S4IRS-6581, Table S4IRS-6585, Table S4IRS-6589, Table S4IRS-6551, Table S4IRS-6554, Table S4IRS-6557

Absolute video chain gain deviation shall be better then ±0.25% (TBC).

Note: This requirement specifies the stability between two (sun) calibrations, i.e. over 24h.

Note: This requirement applies to every video chain individually.

Note: This requirement is meant at 1σ confidence level.

FEERS-2215:
Created
Justification: S4IRS-6657, S4IRS-6695, S4IRS-6728, Table S4IRS-6730, Table S4IRS-6659, Table S4IRS-6697

The relative video chain gain deviation shall be better ± 0.015%.

Note: "Relative video chain gain" is the ratio between two video chain gains; Unit = dimensionless.

Note: This requirement specifies the stability between two (sun) calibrations, i.e. over 24h.

Note: This requirement applies to the relative video chain gain stability between any pair of video chains of the UV-VIS detector.

Note: This requirement is meant at 1σ confidence level.

8.2 Offset

FEERS-1018:
Created

The output DC offset shall be between 250 and 600 digits (from 16 Bit ADC)

Note: this offset shall be provided from FEE to avoid any ADC underruns as a result of CCD offset variation and noise

FEERS-1019:
Created
Offset deviation: ± 0.2% (from initial offset)

8.3 Bandwidth

FEERS-1022: Created
Justification: S4IRS-6821, Table S4IRS-6831

The FEE over-all bandwidth for all spectral channels shall be at least 8.4MHz @-3dB (6 * pixel rate).

8.4 Signal Sampling

FEERS-1607: Created
Justification: S4IRS-6821, Table S4IRS-6831

The CCD signal sampling jitter is specified with ±2ns (max) for reference and video (CDS).

8.5 Noise

FEERS-1038: Created
Justification: S4IRS-6821, Table S4IRS-6831

The FEE (from CCD socket connection to digital output) shall provide an Effective Number Of Bits (ENOB) of ≥13.5 Bits

Note: This number includes ADC noise (analogue), jitter noise and quantisation noise and expresses the sum as an effective quantisation noise.

8.6 Linearity

FEERS-1086: Created From: S4IRS-859

- ADC Differential Non-Linearity (DNL): <1 LSB
- No missing codes
- ADC Integral Non-Linearity (INL): ±10 LSB

Note: From input of the FEE to digitised output

FEERS-2889: Created From: S4IRS-859

The FEE over-all non linearity shall be less then ±0.1% over full scale.

8.7 Uniformity

FEERS-1088: Created

When the input video level is constant, the sample value non-uniformity shall be lower than the noise figure.
8.8 Crosstalk

FEERS-2570: Created

Channel to channel crosstalk shall be less than 84dB

*Note*: Detector output to any other detector output (UV/VIS) and between UV/VIS outputs to NIR output

*Note*: Measured at the digital output of the FEE and with fully operating CDS
9 INTERFACE REQUIREMENTS

9.1 Mechanical Interfaces

FEERS-2633:  
Created
For all mechanical interfaces the coordinate frame as defined in [AD-29C] (Satellite and Subsystem Reference Coordinate System) shall be used.

9.1.1 Mass

FEERS-1092:  
Created
The mass of the UV/VIS FEE (excluding DAP) in flight configuration, including mounting brackets and connectors, but excluding mounting bolts, shall be less than 1.5 kg incl. a contingency of 20%. This shall be verified by mass measurement on the fully assembled unit.

FEERS-1093:  
Created
The mass of the NIR FEE (excluding DAP) in flight configuration, including mounting brackets and connectors, but excluding mounting bolts, shall be less than 1.2 kg incl. a contingency of 20%. This shall be verified by mass measurement on the fully assembled unit.

FEERS-1094:  
Created
The mass of the FEE shall be measured to within an accuracy of ±0.05kg.

FEERS-1095:  
Created
The centre of gravity (COG) of the FEE (excluding DAP) shall be measured to within an accuracy of ±5mm, referenced to the FEE coordinate axes as documented in the ICD.

FEERS-2908:  
Created From: S4IRS-1999
The equipment supplier shall provide the Moments of Inertia (MoI) of the unit with the measurement accuracy being equal to or better than 5% (TBC).

9.1.2 Envelope

FEERS-1097:  
Created
The overall dimensions of the FEE without DAP but including mounting feet, connectors and thermal hardware shall not exceed the dimensions; W x D x H: 200mm x 120mm x 100mm (TBC) as shown in drawing GS4.ASG.UVN.DI.1116100.A (TBC) [RD3] for the UV-VIS FEE and drawing GS4.ASG.UVN.DI.1116200.A (TBC) [RD4] for the NIR FEE. This shall be verified by dimension measurement.

FEERS-2732:  
Created
Mass, COG and Moment of Inertia shall be measured according requirements Mechanical and Thermal Design Requirements Specification [AD-35C]

9.2 Thermal Interfaces

9.2.1 Power dissipation

FEERS-1100: Created
The UV/VIS FEE power dissipation without DAP shall be less than 6W.

Note: without mean heater power dissipated by the heater as specified in FEERS-1109

FEERS-1101: Created
The NIR FEE power dissipation without DAP shall be less than 2.5W.

Note: without mean heater power dissipated by the heater as specified in FEERS-1109

9.2.2 Conductive Thermal Interface

FEERS-1103: Created
The conductive heat flux across the interface to the instrument baseplate shall be less than ±0.5 W (TBC) for an instrument baseplate temperature of 20°C ± 5 K and a nominal FEE operational temperature of 20°C, measured at the TRP.

FEERS-1104: Created
The conductive heat transfer across the interface to the FEE-radiator shall be better than 800 W/(m²K) and the total FEE -Y box side shall act as heat-conducting area.

Note: An interface filler and sufficient bolts can be applied to achieve the required contact conductance.

Note: The complete power dissipations shall be rejected via the according radiator (UV/VIS-FEE: A_radiator = 260 cm², epsilon = 0.9, NIR-FEE: A_radiator = 100 cm², epsilon = 0.9, all values are TBC) towards deep space (T_space = 3 K).

9.2.3 Radiative Thermal Interface

Thermal hardware as heaters and thermistors will be provided by the instrument prime.

FEERS-1107: Created
The FEE box surface shall be coated with a black high emissive coating (black paint or black anodized) with a hemispherical emissivity > 0.85.

9.2.4 FEE External Thermal Hardware

FEERS-772: Created
The mounting areas and areas where thermal hardware has to be attached shall be left blank.
FEERS-2880:  
Created  
On request the FEE contractor shall attach to the external sides of the FEE-box housing a nominal and a redundant operational heater circuit and three thermistors (type TSM) for survival heater control.

FEERS-2567:  
Created  
The Analogue Temperature Sensor Monitor interface (TSM) for FSE-2880 shall be as detailed in [AD-34C] (TBD).

FEERS-1111:  
Created  
On request the FEE contractor shall attach to the external sides of the FEE-box housing a nominal and a redundant substitution (survival) heater circuit and three thermistors (type TSM) for survival heater control.

FEERS-2568:  
Created  
The Analogue Temperature Sensor Monitor interface (TSM) for FEERS-1111 shall be as detailed in [AD-34C] (TBC).

FEERS-2142:  
Created From:  S4IRS-2309  
Bi-layers heaters are forbidden, such that the Prime & Redundant heaters must be different. (TBC)

FEERS-2739:  
Created  
Two thermistors according (TSM) shall be attached close to the FEE TRP for acquisition of the TRP temperature by each side of the ICU.

FEERS-2882:  
Created  
The Analogue Temperature Sensor Monitor interface (TSM) for FEERS-2739 shall be as detailed in [AD-34C] (TBC).

9.3 Electrical Interface Requirements

9.3.1 ICU Interfaces

FEERS-2922:  
Created  
The electrical interface of the serial link between FEE and ICU shall be realised either as ChannelLink or SpaceWire. See SSOW for clarification.

FEERS-2923:  
Created
The clock of the serializer shall be synchronised to the readout clock (integer multiples of the CCD readout clock, derived from the master clock).

FEERS-2297:  
Created  
The connector layout as well as the harness for this link shall follow the rules given in ECSS -E-ST-50-12C SpaceWire - Links, nodes, routers and networks [ND-35]

FEERS-2877:  
Created  
An eye-pattern diagram shall be provided for each deliverable unit. Further necessary measurements will be defined after final definition of implementation and first results of the Bread Board activity.

9.3.2 FSE Interfaces

9.3.2.1 Main Clocks

FEERS-1126:  
Created  
The FEEs will receive the master clock and a synchronisation signal from the FSE. The detailed definition of the interface is under responsibility of the FEE/FSE supplier. The interface must be approved by the customer.

9.3.2.2 Sync Clocks

FEERS-2635:  
Created  
Each FEE shall deliver the Frame- and Line-Sync signal backward to the FSE. The sync I/F shall be of type SBDL as defined in [AD-34C].

9.3.2.3 Secondary Power Lines:

FEERS-1130:  
Created  
Each FEE shall receive from the FSE the following pre-conditioned secondary voltage power lines:

- \( V_{ccd} \) for the CCD biases generation.
- \( V_{ckd} \) for the CCD clocks generation.
- \( \pm V_{ana} \) for the analogue video chains.
- \( V_{dig} \) for the digital functions.

FEERS-1131:  
Created  
For each FEE, the characteristics of the secondary power lines are given in the following table (TBC):

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Accuracy</th>
<th>Max overvoltage</th>
<th>Min current</th>
<th>Max current</th>
</tr>
</thead>
<tbody>
<tr>
<td>1400</td>
<td>1132</td>
<td>1400</td>
<td>1132</td>
<td></td>
</tr>
</tbody>
</table>

Table 9-1: Characteristics secondary power lines

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<table>
<thead>
<tr>
<th>Voltage</th>
<th>Accuracy</th>
<th>Max overvoltage</th>
<th>Min current</th>
<th>Max current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vccd</td>
<td>38V</td>
<td>± 3%</td>
<td>45V</td>
<td>2mA</td>
</tr>
<tr>
<td>Vckd</td>
<td>15V</td>
<td>± 3%</td>
<td>20V</td>
<td>100mA</td>
</tr>
<tr>
<td>± Vana</td>
<td>±7V</td>
<td>± 3%</td>
<td>±10V</td>
<td>±120mA</td>
</tr>
<tr>
<td>Vdig</td>
<td>+5V</td>
<td>± 3%</td>
<td>±7V</td>
<td>100mA</td>
</tr>
</tbody>
</table>

**Note:** The following power-on sequence is specified for each FSE power outlet: TBD

**Note:** with max output current the ripple and noise on the secondary lines for each FEE are specified to be lower than:

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Ripple and Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vccd</td>
<td>20 mV p-p (TBC)</td>
</tr>
<tr>
<td>Vckd</td>
<td>100 mV p-p (TBC)</td>
</tr>
<tr>
<td>± Vana</td>
<td>20 mV p-p (TBC)</td>
</tr>
<tr>
<td>Vdig</td>
<td>200 mV p-p (TBC)</td>
</tr>
</tbody>
</table>

FEERS-1183:

Each FEE shall withstand without any damage or stress any voltage between 0V and the Max overvoltage on any secondary power line.

9.3.2.4 TM/TC Interfaces:

FEERS-1185:

Discrete and serial TC and TM interfaces circuitry shall be designed according to [AD-34C].

9.3.3 CCD (DAP) Interfaces

A short flexible cold harness between FEE and CCD is foreseen which is under responsibility of the FEE supplier. This harness has to be defined in close cooperation with the customer and with respect to the CCD requirements. This harness has to take into account the mechanical, the thermal and electrical constraints as given in section 6.2.

A summary of the CCD interfaces is shown in the following Figure 9-1 and Figure 9-2.
Figure 9-1: overview of the UV/VIS CCD interfaces (TBC)

Blue Boxes contain
Electronics which might be located
either in FPA or FEE
These details will be elaborated in B2
Main drivers are:
To reduce Heatload in FPA
To achieve required performance

Figure 9-2: overview of the NIR CCD interfaces (TBC)

Blue Boxes contain
Electronics which might be located
either in FPA or FEE
These details will be elaborated in B2
Main drivers are:
To reduce Heatload in FPA
To achieve required performance
The FEE shall provide a differential input for each video signal.

Note: The CCD provides an active video line and one dummy output signal, representing the CCD reset signal pseudo-differential output of each CCD video signal.

9.3.3.1 CCD Clocks

The UV/VIS CCD clocks characteristics shall be as preliminary defined in the following table:

<table>
<thead>
<tr>
<th>Number of clocks</th>
<th>Low level</th>
<th>High level</th>
<th>Max overvoltage</th>
<th>Load per clock</th>
<th>Overshoot</th>
<th>Rise/fall time</th>
<th>Max noise/ripple (20 MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image zone clock</td>
<td>4</td>
<td>0V ± 0.1V</td>
<td>12V ± 1V</td>
<td>15V</td>
<td>&lt;4nF</td>
<td>&lt; 200 mV</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100 µV p-p</td>
</tr>
<tr>
<td>Memory zone clock</td>
<td>5</td>
<td>0V ± 0.1V</td>
<td>12V ± 1V</td>
<td>15V</td>
<td>&lt;4nF</td>
<td>&lt; 200 mV</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100 µV p-p</td>
</tr>
<tr>
<td>Register clock</td>
<td>3 Zone 1</td>
<td>0V ± 0.1V</td>
<td>12V ± 1V</td>
<td>15V</td>
<td>&lt;1.5nF</td>
<td>&lt; 500 mV</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>4 Zone 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100 µV p-p</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0V ± 0.1V</td>
<td>12V ± 1V</td>
<td>15V</td>
<td>&lt;50pF</td>
<td>&lt; 200 mV</td>
<td>TBD</td>
</tr>
</tbody>
</table>

The NIR CCD clocks characteristics shall be as defined in the following table:

<table>
<thead>
<tr>
<th>Number of clocks</th>
<th>Low level</th>
<th>High level</th>
<th>Max overvoltage</th>
<th>Load per clock</th>
<th>Overshoot</th>
<th>Rise/fall time</th>
<th>Max noise/ripple (20 MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image zone clock</td>
<td>4</td>
<td>0V ± 0.1V</td>
<td>12V ± 1V</td>
<td>15V</td>
<td>&lt;2.5nF</td>
<td>&lt; 200 mV</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100 µV p-p</td>
</tr>
<tr>
<td>Memory zone clock</td>
<td>5</td>
<td>0V ± 0.1V</td>
<td>12V ± 1V</td>
<td>15V</td>
<td>&lt;2.5nF</td>
<td>&lt; 200 mV</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100 µV p-p</td>
</tr>
<tr>
<td>Register clock</td>
<td>3</td>
<td>0V ± 0.1V</td>
<td>12V ± 1V</td>
<td>15V</td>
<td>&lt;1nF</td>
<td>&lt; 500 mV</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100 µV p-p</td>
</tr>
<tr>
<td>Reset clock</td>
<td>1</td>
<td>0V ± 0.1V</td>
<td>12V ± 1V</td>
<td>15V</td>
<td>&lt;50pF</td>
<td>&lt; 200 mV</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100 µV p-p</td>
</tr>
</tbody>
</table>
FEERS-1301: Created

The timing behaviours of the clocks shall be adjustable by command.

9.3.3.2 CCD DC biases

FEERS-1303: Created

The levels of each bias are ranging from -1V to 35V.

FEERS-1304: Created

The accuracy of each bias shall be ±0.1V.

FEERS-1305: Created

The stability of each bias shall be ±25mV.

FEERS-1306: Created

The noise and ripple on the CCD biases shall be less than 100 µV peak to peak in a 20 MHz bandwidth (TBC).

FEERS-1307: Created

Each bias voltage shall be adjustable by command in the range as defined in FEERS-1303, with a nominal resolution according to FEERS-1304 and with stability according to FEERS-1305 while complying with the noise limits as specified in FEERS-1306.

9.3.3.3 CCD Video output

FEERS-1309: Created

The FEE video input shall be able to operate with a DC offset level of 26V (TBC) ± 5V.

FEERS-1310: Created

The FEE shall provide an external load for every CCD output port of 10 kohms (TBC).

Note: CCD output impedance: < 1 kohm (TBC).

9.3.4 Connectors

FEERS-2143: Created

The connectors shall comply with ECSS-E-ST-20C as tailored for MTG [AD-18].
9.3.4.1 FEE Specific Requirements

**FEERS-1314:** R
Created
The FEE shall provide connectors interfacing to the CCD. The type of connectors has to be agreed with customer.

**FEERS-2271:** R
Created
The FEE shall provide a separate connector for each serial video interface to the ICU.

**FEERS-2272:** I,R
Created
The layout of the serial video data connector shall follow the rules as defined for SpaceWire accordingly to ECSS-E-ST-50-12C (§5.2 Connectors and §5.5 PCB and backplane tracking) [ND-35]
10 DESIGN REQUIREMENTS

10.1 General Design Requirements

FEERS-2741: T,A,I,R,S

Created

The FEE general design shall comply with the unit relevant set of requirements specified in the General Design & Interface Specification [AD-33C].

10.2 Electrical Design Requirements

FEERS-724: T,A,R

Created From: S4IRS-4947

The FEE electrical design shall comply with unit relevant set of requirements specified in the Electrical Design Requirements Specification [AD-34C].

FEERS-725: T,A,R

Created

The FEE shall not be degraded or damaged permanently as a result from an accidental power loss.

10.2.1 Bonding, Grounding, Shielding

The FEE receives secondary power lines from the FSE, galvanically isolated from any secondary ground or structure (power which is transformer isolated from the primary power bus is called secondary power).

The following indicative grounding scheme is provided for the FEE in combination with the associated external equipment:
The FEE contractor shall provide the grounding and return line principle of the FEE including FSEs interfaces for power, telemetry, command and clocks. The grounding principle shall require approval from the instrument prime contractor.

The electrical bonding, grounding and shielding shall be according to [AD-34C].

An M4 diameter threaded bonding stud shall be fitted at an accessible position on one lateral side of the equipment and identified on the MICD.

The FEE supplier shall deliver a grounding strap for mounting of the FEE to the mounting structure.

The bonding strap shall be designed accordingly to the definition in [AD-34C].
FEERS-734:  
Created  
FEE secondary power return shall be referenced to the structure locally.

FEERS-735:  
Created  
Power and signal lines and returns shall be separated, housing of electronic boxes shall be isolated from electrical signals, and filters shall be used to reduce conducted emission and susceptibility.

FEERS-2629:  
Created  
Signal circuit receivers shall be isolated from secondary power and chassis. The isolation resistance shall be > 150 kOhm. Exception: Isolated transmitter circuit with isolation resistance of >1MOhm or RS422 and LVDS interface.

FEERS-2630:  
Created  
Only differential signal transmitters and receivers shall be used as interfaces of the FEE except interfaces with the floating CCD.

FEERS-2632:  
Created  
All FEE connectors shall propose sufficient pins for harness shield connection but the pins should be not connected to secondary ground (shield open to fulfil grounding requirements).

10.2.2 Restricted Frequencies

FEERS-2165:  
Created From: S4IRS-6382  
The instrument shall comply with the requirements of section 4.4 of [AD-37C] (EMC Design Requirements Specification).

FEERS-2166:  
Created From: S4IRS-6383  
The frequency plan of the FEE shall be defined by the FEE supplier as input to the instrument ICD identifying all equipment frequencies with accuracy (under consideration of operating temperature ranges and ageing) and bandwidth/ranges.

10.2.3 Radiation Tolerant Design

FEERS-2710:  
Created From: S4IRS-6387  
The FEE design shall be according to the unit relevant requirements listed in [AD-36C] paragraph 4.3.5 (Satellite Environmental Design and Test Requirements Specification). The equivalent aluminium shielding provided by the satellite application to the UVN shall be taken from [AD-36C] (MTG-SAT-EDTRS-REQ-105).
The supplier shall demonstrate by analysis (see [ND-8], ECSS-E-ST-10-12C) that the design of the equipment is capable of withstanding these environmental conditions (see also [ND-5], ECSS-E-ST-10-04C), including the radiation design margin (RDM).

When assessing radiation hardness, the supplier shall take into account the requirements in the ESA standard ESA-TEC-QE/2009/22, issue 1 of 20 May 2009 (Radiation Hardness Assurance). Of particular note are requirements pertaining to RDM and ELDRS (36 rad/hr).

It shall be possible to recover from non-destructive single event effects.

The design shall be such that, upon occurrence of a non-destructive single event effect, any protection circuitry does not trigger the satellite into a (safe) mode implying a mission outage.

The applicability of the following EMC requirements must be clarified in detail together with the customer related to the limited testability of the FEE together with the open DAP which is not shielded in a test on FEE unit level.

The FEE design shall be compliant with the MTG EMC requirement specification [AD-37C], under consideration of the corresponding Applicability Matrix.

The S4-UVN elements shall be protected against the effects of electrostatic discharges according ECSS-E-ST-20-06C, [ND-11] and external surfaces of the instrument shall be conductive to a level compatible with the in-orbit particle environment, and connected to the satellite structure to avoid the effects of differential charging with the exceptions given in paragraph 6-3-2 of ECSS-E-ST-20-06C.

An upper limit particularly for the magnetic momentum is defined in Section 5.4.6 in [AD-37C] (Satellite EMC Requirements Specification).

An upper limit particularly for the RE and RS magnetic field is defined in Section 5.4.6 in [AD-37C] (Satellite EMC Requirements Specification).
10.4 Mechanical Design Requirements

10.4.1 General

FEERS-2743: T,A,I,R,S
Created
The FEE mechanical design shall comply with unit relevant set of requirements specified in the Mechanical and Thermal Design Requirements Specification [AD-35C].

FEERS-738: T
Created
The unit shall withstand all environmental loads on-ground, during launch and in-orbit without any yielding.

FEERS-740: A
Created
A strength analysis shall be performed and demonstrate a positive margin of safety.

FEERS-741: R
Created
The geometry of the FEE shall be expressed in a local coordinate system with axes parallel to axes of the Spacecraft and instrument coordinate system.

The box co-ordinates and the centre of mass co-ordinates shall be related to the centre of the reference hole (one of the FEE fixation holes). The origin of the FEE reference frame shall coincide with the centreline of one of the FEE-to-Instrument mounting fixation bolts.

FEERS-742: R
Created
The FEE shall include the mounting support provisions.

FEERS-743: R
Created
The whole pattern for the mounting provision at the instrument baseplate interface shall be documented and maintained in the ICD

FEERS-744: T,A
Created
The lowest eigenfrequency of the hard mounted FEE shall be above 200 Hz.

FEERS-745: A
Created
The FEE housing and interfaces shall be designed for a design limit load of 95g (TBC) applied at the centre of mass to all axis of the FEE.

FEERS-746: A
Created
The design limit load shall be applied in “worst-case” orientations such as to induce the maximum stresses at the interfaces.

**FEERS-750:**  
Created  
To reduce contamination build-up during bake-out and during launch, the FEE shall have suitable venting provision that is equal or higher than 2 mm² hole area per litre of enclosed volume.

**FEERS-751:**  
Created  
The FEE shall be designed to withstand the mechanical environment loads as specified in section 10.6.3.

**FEERS-752:**  
Created  
The bolts and washers and interface filler shall be delivered by the FEE supplier.

**FEERS-756:**  
Created From: S4IRS-2044  
The location of each attachment hole centre w.r.t. the Reference Hole, shall be within a 0.2mm diameter circle centred on the theoretical position.

**FEERS-757:**  
Created  
Sharp edges shall be avoided.

**FEERS-2564:**  
Created  
The co-planarity of the side wall interfacing the radiator shall be within 0.1mm. The roughness of this side wall shall be Ra <= 1.6 micrometers.

**FEERS-1890:**  
Created  
Numbers, size, position, thermal isolation and type of fixation points of the FEE on the instrument baseplate shall be agreed with the customer. Additional I/F Points have to be agreed in an early stage before PDR.

**FEERS-1891:**  
Created  
The I/F points shall be in one plane according to drawing GS4.ASG.UVN.DI.1116100 [RD4] for the UVSFEE and according to drawing GS4.ASG.UVN.DI.1116200 [RD5] for the NISFEE.

**FEERS-1892:**  
Created  
Bolt Sizing  
All bolts shall be sized to prevent sliding under mechanical environments. All bolts in alignment critical interfaces shall be sized to prevent sliding under mechanical & thermal environments.
FEERS-1893: A,R
Created
Friction Coefficients
Conservative friction coefficients regarding minimum and maximum preload versus clamping and bolt allowables shall be considered for preliminary sizing of the bolts, unless an actual friction coefficient has been determined.

FEERS-2563: A,R
Created
The position and orientation of the connectors shall be agreed by the customer to guarantee access to the connectors.

10.5 Thermal Design Requirements

FEERS-2744: T,A,I,R,S
Created
The FEE thermal design shall comply with unit relevant set of requirements specified in the Mechanical and Thermal Design Requirements Specification [AD-35C].

FEERS-762: A,R
Created
The FEE and the DAP thermal design shall meet the requirements listed in ECSS-E-ST-31C.

FEERS-2883: T
Created
On ground, the FEE shall operate without any duration limitation. In particular, a natural convection cooling shall be sufficient to operate in air at ambient condition.

FEERS-763: T,A,R
Created
The FEE shall be designed for a full performance operating temperature of \( T_0 = +10°C \) to \(+30°C\) over the lifetime and with a maximum temperature variation of \( \pm 3K \) within 24h.

*Note:* The temperatures refer to the Temperature Reference Point (TRP) of the FEE.

*Note:* In case a reduced temperature range should be necessary to fulfil the required performance the subcontractor shall request for the required operating and performance temperature range of the unit. This change must be approved.

*Note:* The active thermal regulation of the FEE takes place via the ICU (heater control)

FEERS-2232: T,A
Created
The DAP shall be designed to operate the detectors (UV-VIS and NIR) with full performance at a temperature down to 200K in nominal operating condition.

*Note:* The detector temperatures will be controlled by a closed-loop heater control under the responsibility of the instrument prime contractor. Herewith the actual temperatures will be measured by thermistors and compared with the set-points. The heater power will be adjusted according to the

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difference between measured actual temperatures and set-points. In this way daily environmental variations impacting the FPA-radiators will be compensated.  

Note: The necessary number of thermistors for detector temperature control are part of the detector (integrated thermistors).

FEERS-765: T,A,R

Created

The FEE shall be designed for a maximum start-up temperature of TSU-high = +55°C and a minimum start-up temperature of TSU-low = -15°C.

Note: The temperatures refer to the TRP of the FEE.

FEERS-767: T,R

Created

The FEE electronics shall be designed to withstand, in non-operating condition, temperatures between the minimum non-operating temperature TNO-min = -25°C and the maximum non-operating temperature TNO-max = +60°C without any degradation.

Note: The temperatures refer to the TRP of the FEE.

FEERS-2193: T

Created

During acceptance testing the specified temperature ranges for start-up and non-operating are to be extended by 5K

FEERS-2323: T

Created

During qualification testing the specified temperature ranges for start-up and non-operating are to be extended by 10K

FEERS-774: I

Created

The FEE thermal hardware shall be supported from the FEE housing and shall not be supported from additional frames or structure interfacing with the Spacecraft.

FEERS-2230: T,R

Created

The complete UV-VIS as well as NIR FEE (including the DAP) shall be fully functional and working flight representatively but with limited detector performance at ambient laboratory conditions.

10.5.1 Temperature Sensors

FEERS-776: T,R

Created

Each FEE shall provide a redundant thermistor in an area representative of the Temperature Reference Point and a further redundant thermistor inside the FEE-electronics representing the "hot spot".

Note: The temperature sensors will be acquired by the FSE.
FEERS-2884:  
Created  
The location of the FEE "hot spot" thermistors shall be deduced from contractor thermal analysis.

10.5.2 Temperature Reference Points

FEERS-779:  
Created  
The location and number of Temperature Reference Points (TRPs) shall be defined by the FEE contractor and approved by the instrument contractor.  
Note: This shall offer a measurement of the temperature directly by the ICU (monitoring and switch on).

FEERS-781:  
Created  
The TRPs shall be defined in the ICD.

10.6 Verification Requirements

10.6.1 General Verification Requirements

FEERS-2270:  
Created  
The FEE verification shall be performed according ECSS-E-10-02C, Verification [ND-2] considering the ECSS E-Series. Tailoring given in MTG.ESA.SA.RS.0074, [AD-18].

FEERS-2176:  
Created From: S4IRS-3116  
The unit verification plan shall specify the method, level(s) and techniques to be applied for verifying compliance with the specified requirements.

FEERS-2177:  
Created From: S4IRS-3118  
The Verification Control Documents shall document for all requirements, compliance status, verification method and any associated non-compliances that are applicable.

FEERS-2178:  
Created From: S4IRS-3119  
Full traceability to all supporting documentation shall also be provided including inspection, analysis and/or test reports and associated waivers and deviations, where applicable.

FEERS-2179:  
Created From: S4IRS-3120  
All redundant functions shall be verified independently.

FEERS-2180:  
Created From: S4IRS-3121  
All cross strapping functions shall be fully verified by test.
FEERS-2181:  
Created From: S4IRS-3122  
All operational interfaces shall be verified by test.

FEERS-2183:  
Created From: S4IRS-3124  
For requirements that can only be directly verified in orbit, indirect verification methods shall be utilised based on ground test with complementary analysis for in-orbit conditions, or analysis alone in some cases to be agreed by the customer.

FEERS-2184:  
Created From: S4IRS-3125  
The integrity of all performance critical interfaces shall be verified, at least once, by performance test.

FEERS-2185:  
Created From: S4IRS-3126  
The integrity of all interfaces shall be verified by functional test which are mated or re-mated during AIV for integration or replacement of units or for tests.

FEERS-2746:  
Created  
The FEE shall comply with the unit relevant test requirements specified in the Satellite Environment and Test Specification [AD-36C].

Note: For OIM units the mechanical loads, thermal and radiation levels are further broken down from the OIM overall requirements and are explicitly listed in the following chapters therefore.

FEERS-783:  
Created  
The FEE shall undergo a qualification and acceptance test programme according to ECSS-E-10-03A [ND-03], as specified for the relevant qualification category of the unit.

FEERS-945:  
Created  
Subsequent to each test program, the Contractor shall generate a test report in which the test results shall be stated including non-conformances.

FEERS-946:  
Created  
The FEE shall be subjected to a pre-shipment functional test.

Note: The testing shall be carried out according a test plan and test procedures as agreed during the Test Readiness Review (TRR).

10.6.2 Electrical Verification

FEERS-2748:  
Created  
Power consumption shall be verified according the durations stated in AD-34C
FEERS-950:
Created

The typical FEE power consumption shall be verified by averaging the power consumption over 200 minutes, while the UVIS- and NIR-Detector (or its equivalent EGSE) is operational and continuously outputting CCD frames, with nominal speed (TBC).

FEERS-951:
Created

The peak FEE power consumption shall be verified under worst case operational conditions by averaging the power consumption over 10 milliseconds window.

Note: Peak power is defined as the maximum power the FEE consumes, exclusive of turn on and mode change transients.

10.6.2.1 EMC verification

FEERS-2749:
Created

EMC levels shall be verified according to AD-37C

FEERS-954:
Created From: S4IRS-6377

The FEE design shall be compliant with the MTG EMC requirement specification [AD-37C], under consideration of the corresponding Applicability Matrix.

FEERS-955:
Created From: S4IRS-6378

The S4-UVN elements shall be protected against the effects of electrostatic discharges according ECSS-E-ST-20-06C, [ND-11] and external surfaces of the instrument shall be conductive to a level compatible with the in-orbit particle environment, and connected to the satellite structure to avoid the effects of differential charging with the exceptions given in paragraph 6-3-2 of ECSS-E-ST-20-06C.

FEERS-2713:
Created From: S4IRS-6379

An upper limit particularly for the magnetic momentum is defined in Section 5.4.6 in [AD-37C] (Satellite EMC Requirements Specification).

FEERS-2712:
Created From: S4IRS-6380

An upper limit particularly for the RE and RS magnetic field is defined in Section 5.4.6 in [AD-37C] (Satellite EMC Requirements Specification).

10.6.2.1.1 Susceptibility to ESD

FEERS-957:
Created

The FEE EM or QM (if any) shall be tested for susceptibility to ESD.
FEERS-959: R
Created
The FEE FM shall not be tested for susceptibility to ESD.

10.6.3 Mechanical verification

FEERS-969: A,I,R
Created
The reduced fracture control program of ECSS-E-ST-32-01C fracture control is applicable.

10.6.3.1 Low Level Sinusoidal Vibration Tests

FEERS-971: T
Created
For the tests the FEE shall be hard-mounted to a fixture through its normal mounting points.

FEERS-972: I
Created
The FEE shall be OFF during the vibration tests.

FEERS-973: T
Created
The FEE shall be tested in each of three mutually perpendicular axes.

FEERS-974: T
Created
Low level sinusoidal vibration tests shall be performed to determine resonance frequencies of the FEE.

FEERS-975: T
Created
Resonance searches shall be carried out before and after the qualification vibration test run sequences for each axis. The resonance search test level and sweep rate shall be as specified in the following table.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>level</th>
<th>Sweep</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 2000 Hz</td>
<td>0.5 g (TBC)</td>
<td>2 oct/minute (up)</td>
</tr>
</tbody>
</table>

10.6.3.2 Sinusoidal vibration tests

FEERS-987: T
Created
Sine vibration tests shall be performed in X, Y and Z axes.

FEERS-2561: T
Created
The FEE shall be designed to withstand without degradation the sinusoidal environment to be applied at the unit to instrument mounting interface as defined in Table 10-2.

**Table 10-2: Sinusoidal Vibration Environment**

<table>
<thead>
<tr>
<th>Axis</th>
<th>Frequency [Hz]</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out of Plane</td>
<td>5-50</td>
<td>25g</td>
</tr>
<tr>
<td>Out of Plane</td>
<td>50-100</td>
<td>20g</td>
</tr>
<tr>
<td>In Plane</td>
<td>5-60</td>
<td>30g</td>
</tr>
<tr>
<td>In Plane</td>
<td>60-100</td>
<td>70g</td>
</tr>
<tr>
<td>Sweep Rate</td>
<td>2 Oct/min</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 sweep up</td>
<td></td>
</tr>
</tbody>
</table>

*Note: The table is still TBC and will be evaluated in detail during phase B2.*

**FEERS-2469:**

*Created*

Notching of the input spectrum shall agreed with the customer.

10.6.3.3 Random vibration tests

**FEERS-989:**

*Created*

Random vibration tests shall be performed in X, Y and Z axes.

**FEERS-2562:**

*Created*

The FEE shall be designed to withstand without degradation the random environment as defined in Table 10-3.

**Table 10-3: Random Vibration Environment**

<table>
<thead>
<tr>
<th>Axis</th>
<th>Frequency [Hz]</th>
<th>Qualification</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Plane</td>
<td>20-70</td>
<td>13.0 dB/Oct</td>
<td>13.0 dB/Oct</td>
</tr>
<tr>
<td>In Plane</td>
<td>70-150</td>
<td>4.0 g²/Hz</td>
<td>1.8 g²/Hz</td>
</tr>
<tr>
<td>In Plane</td>
<td>150-2000</td>
<td>-6.6 dB/Oct</td>
<td>-6.6 dB/Oct</td>
</tr>
<tr>
<td>In Plane GRMS</td>
<td>29.3</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>In Plane Duration</td>
<td>150 sec</td>
<td>60 sec</td>
<td></td>
</tr>
<tr>
<td>Out of Plane</td>
<td>200-400</td>
<td>2.0 g²/Hz</td>
<td>0.9 g²/Hz</td>
</tr>
<tr>
<td>Out of Plane GRMS</td>
<td>30.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Out of Plane Duration</td>
<td>150 sec</td>
<td>60 sec</td>
<td></td>
</tr>
</tbody>
</table>

*Note: The table is still TBC and will be evaluated in detail during phase B2.*

**FEERS-2470:**

*Created*

Notching of the input spectrum shall agreed with the customer.
10.6.3.4 Shock Tests

FEERS-2472: T

Created

The FEE shall withstand without degradation the shock environment as defined in the following table. Shock tests shall be performed on the Qualification Model in x-, y- and z-axis, 2 shocks per axis.

Table 10-4: Shock Vibration Environment

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>Shock Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>20g</td>
</tr>
<tr>
<td>1000</td>
<td>1500g</td>
</tr>
<tr>
<td>10000</td>
<td>1500g</td>
</tr>
</tbody>
</table>

Note: The table is still TBC and will be evaluated in detail during phase B2.
11 GROUND SUPPORT EQUIPMENT REQUIREMENTS

FEERS-2196:  
Created From: S4IRS-3391  
The Ground Support Equipment (GSE) to be used once the S4/UVN has been integrated to the host satellite shall be designed to be fully compatible with the satellite configuration constraints during the on-ground AIT phase.  

*Note:* The host satellite configuration constraints will be defined by the MTG Contractor.

FEERS-2198:  
Created From: S4IRS-3392  
The Ground Support Equipment (GSE) shall include all hardware and software necessary to support the unit AIV activities, at unit and instrument levels, throughout all phases of the program up to and including the launch campaign if necessary.

FEERS-2199:  
Created From: S4IRS-3393  
GSE hardware and software developed for testing at unit and instrument level shall be designed to allow maximum reuse at the higher levels of the satellite activities.

FEERS-2200:  
Created From: S4IRS-3394  
All GSE shall comply with the safety standards applicable at the facilities in which they will be required to operate (including launch campaign if necessary).

FEERS-2201:  
Created From: S4IRS-3395  
All GSE intended for connection to either the S4/UVN once embarked on the host satellite or to the host satellite EGSE, shall be fully verified to be compatible with the satellite/equipments mechanical, electrical, data handling and RF interfaces before connection.

FEERS-2202:  
Created From: S4IRS-3396  
No credible fault or failure mode of the unit GSE shall put at risk and/or overstress interfaces to the S4/UVN flight hardware or to the host satellite or to the host satellite GSE.

FEERS-2203:  
Created From: S4IRS-3397  
Transportation containers shall be designed such that the environments experienced by the (flight) equipments under transport are less severe than those assumed for launch/in orbit or experienced under normal clean room conditions.

FEERS-2204:  
Created From: S4IRS-3398  
The GSE shall be designed to meet the full programme duration including long term storage periods with minimal needs for refurbishment.
Storage and archiving of all data generated during all formal test campaigns shall be undertaken at all levels of the space segment architecture and its constituting elements.

The EGSE shall provide interfaces required to connect to the S4-UVN EGSE.

**Note:** The complete list of such interfaces and applications will be consolidated during the Phase B2.

### 11.1 FEE Simulator

The FEE Simulator shall be used to emulate a functional FEE and shall provide via flight representative interfaces a predictable and known data stream for test and verification of the UVN on-board processing located in the ICU.

*This stand-alone EGSE shall provided to the ICU supplier for AIT.*

The FEE simulator shall provide the following physical interfaces (as a minimum):

- One serial high-speed data interface as specified in section 7.6 usable as NIR- or UV/VIS-FEE replacement
- Outputs, providing sync signals representative to the syncs to be delivered to FSE and as specified in FEERS-2635 (frame/line sync)
- Interface to a COTS PC for control of the FESi and to upload predefined test pattern (USB)

The FEE simulator interface to instrument equipment (ICU) shall be realized as implemented into the real FEE and equipped with flight components or representative replacement parts (prototypes).

Transmission of predefined test pattern previously loaded by PC via configuration port (USB)

The test pattern shall be transmitted in full speed of the real FEE as specified in section 7.6

The storage capability for the test pattern shall be enough to transmit data over a time of 30 seconds without repeating of the loaded test pattern and with the minimum integration period as specified in FEERS-2593.
FEERS-2286: Created T
A repetition of the loaded test pattern shall be possible without interruption of the output data stream

FEERS-2284: Created T
Auxiliary data, packed within the signalling bits, shall be sent by the FESi as well and as defined in section 7.6 (this includes also the check sum and programmable AUX data)

FEERS-2285: Created T
Wrong signalling (signalling bits and/or checksum) shall be possible for test purpose

FEERS-2287: Created I,R
The FESi shall be delivered and mounted in a 19"-Rack for integration into a higher level EGSE

FEERS-2273: Created I
The FEE supplier shall deliver one stand alone FEE simulator for test of the interfaces and functions of the FEE following equipment, especially the digital data processing part of the ICU
12 HANDLING, TRANSPORTATION AND STORAGE

12.1 Handling and Transportation

FEERS-2171: Created From: S4IRS-2980

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 shall not be exceeded:

Hoisting (nominal handling loads):
- Vertical: ± 2.0 g (TBC)
- Horizontal: ± 1.5 g (TBC)

Note: The sub-units shall be designed accordingly.

FEERS-2173: Created From: S4IRS-2984

The unit transport container shall be designed to sustain the following environmental conditions during the transportation and storage periods.

Mechanical Environment:
- Vertical ± 3.0 g (TBC)
- Lateral ± 2.0 g (TBC)

12.2 Storage Requirements

FEERS-2210: Created From: S4IRS-3402

All parts, materials and processes selected for the FEE shall demonstrate compatibility with the specified storage durations with no refurbishment.

FEERS-2211: Created From: S4IRS-3403

Adhesives, coatings and non metallic materials selection shall be fully compatible with the required storage period.

FEERS-2212: Created From: S4IRS-3404

The FEE design shall allow for periodic inspection, maintenance and local testing to be performed (e.g. exercising of mechanisms to allow lubricant redistribution) without the need to remove equipments, if required.

FEERS-2213: Created From: S4IRS-3405

The FEE design shall facilitate easy access for those equipments that must be removed replaced or maintained as part of the long term storage phase or requires special procedures/inspections.
FEERS-2214:

The need for FEE intervention during the storage period shall be minimised by design with the need to perform periodic inspection and maintenance limited to once (TBC) per year.
13 SPECIFIC PRODUCT ASSURANCE REQUIREMENTS

FEERS-1328: T,A,I,R,S
Created

General PA requirements accordingly to PA-Requirements for Subcontractors (AD-6a)

13.1 Environmental and Test Requirements

FEERS-2715: R
Created From: S4IRS-6385

The S4/UVN shall be designed to meet the requirements specified in [AD-36C] (Satellite Environmental Design and Test Requirements Specification).

13.2 Radiation environment

FEERS-1330: A
Created

The ECSS-E-10-04A shall be applicable for the space radiation environment.

FEERS-1896: A
Created

An expected space radiation environment as given in MTG-ESA-SA-RS-0055, chapter 4 shall be considered.

13.2.1 Total Dose

FEERS-1898:
Created

The total radiation dose that reaches the centre of an aluminium sphere at EOL is given as a function of the thickness of the aluminium shielding. The equivalent aluminium shielding as given in the tables below can be assumed for UV/VIS and NIR FEE.

Table 13-1: Result for TID (Solid sphere / SLANT - for sub), applicable for UV/VIS FEE

<table>
<thead>
<tr>
<th>Box face</th>
<th>Dose [krad(Si)]</th>
<th>Solid Angle [sr]</th>
<th>AL eq. Thickness [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>+X</td>
<td>8.82E-01</td>
<td>0.87</td>
<td>6.7</td>
</tr>
<tr>
<td>+Y</td>
<td>8.04E+03</td>
<td>2.52</td>
<td>0.22</td>
</tr>
<tr>
<td>+Z</td>
<td>2.55E+02</td>
<td>2.89</td>
<td>1.53</td>
</tr>
<tr>
<td>-X</td>
<td>4.31E+03</td>
<td>0.87</td>
<td>0.2</td>
</tr>
<tr>
<td>-Y</td>
<td>2.31E+02</td>
<td>2.52</td>
<td>1.55</td>
</tr>
<tr>
<td>-Z</td>
<td>1.49E+04</td>
<td>2.89</td>
<td>0.16</td>
</tr>
<tr>
<td>Total:</td>
<td>2.78E+04</td>
<td>12.57</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Table 13-2: Result for TID (Solid sphere / SLANT - for sub), applicable for NIR FEE

<table>
<thead>
<tr>
<th>Box face</th>
<th>Dose [krad(Si)]</th>
<th>Solid Angle [sr]</th>
<th>AL eq. Thickness [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>+X</td>
<td>6.55E+01</td>
<td>1.96</td>
<td>2.38</td>
</tr>
<tr>
<td>+Y</td>
<td>1.35E+03</td>
<td>0.64</td>
<td>0.35</td>
</tr>
<tr>
<td>+Z</td>
<td>1.25E+04</td>
<td>3.68</td>
<td>0.19</td>
</tr>
<tr>
<td>-X</td>
<td>8.69E+03</td>
<td>1.96</td>
<td>0.19</td>
</tr>
<tr>
<td>-Y</td>
<td>3.19E+02</td>
<td>0.64</td>
<td>0.78</td>
</tr>
</tbody>
</table>
### Displacement Damage and Non-ionising Dose

High energetic protons can induce permanent damage by displacement in the silicon bulk. Estimation of displacement effects are based on mono energetic equivalent proton fluence. Such fluence can be estimated considering the non ionising dose depth curve presented in MTG-ESA-SA-RS-0055, chapter 4.

The external protective shielding hypothesis that the unit supplier can assume shall be as detailed in the tables below for UV/VIS and NIR FEE.

#### Table 13-3: Results for NIEL (Solid sphere / SLANT - for sub), applicable for UV/VIS FEE

<table>
<thead>
<tr>
<th>Box face</th>
<th>10 MeV eq. p Fluence [1e9/cm²]</th>
<th>Solid Angle [sr]</th>
<th>AL eq. Thickness [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>+X</td>
<td>6.03E-01</td>
<td>0.87</td>
<td>10.58</td>
</tr>
<tr>
<td>+Y</td>
<td>7.42E+01</td>
<td>2.52</td>
<td>0.28</td>
</tr>
<tr>
<td>+Z</td>
<td>7.09E+00</td>
<td>2.89</td>
<td>3.06</td>
</tr>
<tr>
<td>-X</td>
<td>3.70E+01</td>
<td>0.87</td>
<td>0.22</td>
</tr>
<tr>
<td>-Y</td>
<td>7.75E+00</td>
<td>2.52</td>
<td>2.6</td>
</tr>
<tr>
<td>-Z</td>
<td>1.35E+02</td>
<td>2.89</td>
<td>0.16</td>
</tr>
<tr>
<td>Total:</td>
<td>2.62E+02</td>
<td>12.57</td>
<td>0.51</td>
</tr>
</tbody>
</table>

#### Table 13-4: Results for NIEL (Solid sphere / SLANT - for sub), applicable for NIR FEE

<table>
<thead>
<tr>
<th>Box face</th>
<th>10 MeV eq. p Fluence [1e9/cm²]</th>
<th>Solid Angle [sr]</th>
<th>AL eq. Thickness [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>+X</td>
<td>6.00E+00</td>
<td>1.96</td>
<td>2.7</td>
</tr>
<tr>
<td>+Y</td>
<td>1.34E+01</td>
<td>0.64</td>
<td>0.48</td>
</tr>
<tr>
<td>+Z</td>
<td>1.18E+02</td>
<td>3.68</td>
<td>0.22</td>
</tr>
<tr>
<td>-X</td>
<td>7.96E+01</td>
<td>1.96</td>
<td>0.2</td>
</tr>
<tr>
<td>-Y</td>
<td>7.01E+00</td>
<td>0.64</td>
<td>0.91</td>
</tr>
<tr>
<td>-Z</td>
<td>2.13E+01</td>
<td>3.68</td>
<td>1.28</td>
</tr>
<tr>
<td>Total:</td>
<td>2.46E+02</td>
<td>12.57</td>
<td>0.55</td>
</tr>
</tbody>
</table>
13.3 Thermal Verification Requirements

FEERS-2188: A
Created From: S4IRS-3382
The uncertainties and the systematic errors (i.e. modelling error, typically 3ºC) shall be added to the analytically calculated temperatures.

FEERS-2189: T,A
Created From: S4IRS-3383
The qualification temperature limits are equal to the acceptance limits extended at both extremes by a qualification margin of 5ºC.

FEERS-2190: T,A
Created From: S4IRS-3384
The acceptance temperature limits are equal to the design limits extended at both extreme by an acceptance margin of 5ºC.

FEERS-2191: T
Created From: S4IRS-3385
The Thermal Balance test shall be representative of the (worst) cases environment, mission flight conditions and operating modes.

13.3.1 Thermal Vacuum verification

FEERS-961: T
Created
The FEE EQM shall be subjected to a Qualification Thermal Vacuum (TV) cycling test in line with [AD-36C].

FEERS-962: T
Created
The FEE FM shall be subjected to the Acceptance Thermal Vacuum (TV) cycling test in line with [AD-36C].

FEERS-963: T
Created
The FEE FM shall be subjected to a thermal balance test according to the requirements specified in ECSS-E-ST-31C. Results from the test shall be applied by the FEE Contractor for the correlation and updating of the FEE thermal mathematical model.

13.4 Contamination Control Requirements

13.4.1 Surface Cleanliness

FEERS-2091: T,A
Created From: S4IRS-14019
Molecular contamination of the surfaces shall be \( \leq 0.5 \times 10^{-7} \) g/cm\(^2\) (TBC) at delivery.

FEERS-2092: T,A
Created From: S4IRS-14019
Particulate contamination of the surfaces shall be $\leq 30$ ppm (TBC) at delivery.

13.4.2 Material Selection Criteria

For all materials the following outgassing requirements shall apply:

<table>
<thead>
<tr>
<th>RML [%]</th>
<th>CVCM [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 0.1$</td>
<td>$\leq 0.01$</td>
</tr>
</tbody>
</table>

Note: This applies also for porous materials and is as such not limited to polymers.

13.4.3 Bakeout

13.4.3.1 Part Level Bakeouts

Bakeouts for all parts which include polymeric or porous materials shall be conducted in vacuum ($p \leq 10^{-5}$ mbar).

The bakeouts shall be performed at the highest for the hardware possible temperature without risk of damage.

For organic or porous materials with mass $> 10$ gr (TBC) the bakeout temperature, monitoring and stop criteria shall be discussed and agreed with the customer.

13.4.3.2 Assembly Level Bakeouts

Once the unit is integrated a TQCM monitored bakeout in vacuum ($p \leq 10^{-5}$ mbar) shall be conducted.

For the bakeout the following temperature settings shall apply:

- Unit at highest possible temperature without risk of damage;
- TQCM at 245K (TBC).

The unit bakeout stop shall be based on the following criteria:
After a minimum period of 48 hours from the moment that \( p \leq 10^{-5}\) mbar, the percentage change of TQCM frequency rate over 5 hours shall be lower than 5%. This condition shall be continuously maintained for at least 3 hours.

### 13.4.4 Unit Sources of Contamination

**FEERS-2130:**

Created

The Contractor shall identify all sources of contamination that can be emitted from the unit and shall document these in the material lists and bake-out test reports.

*Note:* Examples for this are the total assembly outgassing rate and wear debris during operation. Materials that can outgass shall be listed in the DML.

### 13.4.5 Unit Cleaning During Integration and Test

**FEERS-2133:**

Created From: S4IRS-14359

It shall be possible to clean the unit in case of molecular or particulate contamination.

*Note:* For the molecular contamination the 'typical' clean room/TV test contaminates shall be assumed (hydrocarbons, silicones, ester).

**FEERS-2135:**

Created

Cleaning of the unit shall restore its performance to a level which is compliant to the performance requirements specified within this document.

### 13.5 Dependability

#### 13.5.1 Lifetime

**FEERS-1609:**

Created From: S4IRS-598

The FEE including DAP shall be compliant with the following on-ground lifetime post delivery to the customer:

- an AIT period on instrument level of 2.5 years
- followed by an AIT period on MTG-S level of 3 years after delivery of the UVN instrument to satellite AIT
- followed by an on-ground storage period of 10 years

**FEERS-2138:**

Created

The FEE including DAP shall be compliant with the following in-orbit lifetime:

- in-orbit lifetime of at least 8.5 years

**FEERS-2268:**

Created

Life limited items with respect to the long term storage shall be avoided
13.5.2 Reliability

FEERS-1613: A
Created From: S4IRS-605
Justification: Table S4IRS-12413
The failure rate of the UV/VIS FEE (without DAP) shall be lower than 780 fits

FEERS-1615: A
Created From: S4IRS-605
Justification: Table S4IRS-12413
The failure rate of the NIR FEE (without DAP) shall be lower than 480 fits

FEERS-1616: R
Created
The FEE failure rate shall be calculated at a TRP temperature of 21° C (tbc).

FEERS-2905: A
Created From: S4IRS-6472
A failure in one unit or path shall not lead to the failure or exceed the electrical, mechanical or thermal specified maximum rating of another unit or equipment (failure propagation).

FEERS-2906: A
Created From: S4IRS-6473
No failure which causes loss of one functional path shall result in the failure or overstress of a redundant or alternative path.

13.5.3 Availability

Outages can be scheduled or unscheduled as defined in [AD-26]. All outages are considered for availability calculation. Any repeat cycle, which is affected by outage, whether scheduled or unscheduled, is considered as fully lost for the purposes of analysing the total outage duration.

FEERS-1339: A
Created
The FEE shall be fully operational during the mission duration.

FEERS-1340: A,R
Created
If a memory scrubbing function is implemented to fulfil the availability requirements due to radiation environmental conditions, the following design rules shall be fulfilled:

• No functional unavailability of the FEE shall be caused by the scrubbing function
• The period of the scrubbing function shall be defined according to the availability requirements due to radiation event (TBC).

FEERS-1619: A,R
Created
Non-destructive SEU effects shall be described including probability of occurrence, effect, recovery means and time to recover.

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Note: Unscheduled outage is defined in [AD-3]. The assumption for ground recovery after H/W failure is 48 hours. Availability is calculated for on an annual basis for the duration of the satellite nominal operational life, i.e. 8.5 years.

Note: Recovery times following anomalies shall include this time interval to account for interaction to the ground segment. The availability shall include the outage and recovery times.

13.5.4 Maintainability

FEERS-1334: R

Created

The FEE shall be maintenance free.

Note: In case of a necessary maintenance during on-ground operation and/or storage the supplier has to define the necessary operation.

The following requirements apply only to on-ground maintenance.

FEERS-1624: R

Created From: S4IRS-615

Items requiring integration or adjustment at the launch site (for safety, logistic or life reasons) shall be avoided.

If and only following agreement with the customer, FEERS-1624 cannot be reasonably achieved, any items requiring integration or adjustment at the launch site (for safety, logistic or life reasons) shall be accessible without removing any equipment or the instrument.

FEERS-1626: R

Created From: S4IRS-621

Environmental constraints and needed maintenance activities during on-ground storage period shall be identified by the FEE supplier.

Note: This period starts after FEE delivery plus 5,5 years.

13.5.5 Fault-Tolerance Failure Propagation

FEERS-1630: A

Created

Failure propagation shall be avoided by design. That means that a failure leading to lose the data from one spectral band (UV/VIS1, UV/VIS2, NIR) shall not lead to lose the data from any other spectral bands.

FEERS-1631: A

Created

Failure cases shall be identified and their disposition agreed with the customer.

FEERS-1632: R

Created From: S4IRS-623

The failure consequence severity categories shall be as defined in PA Requirements for Subcontractors [AD-6a].

FEERS-1633: A

Created From: S4IRS-624
No single FEE failure (including hardware failure, software failure or human error) shall lead to critical or catastrophic consequences.

**FEERS-1634:**
Created From: S4IRS-625

No combination of two independent FEE failures or operator errors shall have catastrophic consequences.

**FEERS-1635:**
Created From: S4IRS-626

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

**FEERS-1636:**
Created From: S4IRS-627

The failure tolerance needs not to be applied to:
- primary structures,
- load-carrying structures,
- structural fasteners,
- load-carrying elements of mechanisms,

For these items, fracture control shall apply based on [ND-16].

**FEERS-1637:**
Created From: S4IRS-633

A failure in one FEE function/equipment shall not cause a failure or a degradation of another function/equipment.

**FEERS-1638:**
Created From: S4IRS-634

Hardware failures or software errors shall not cause additional failures with hazardous effects or propagate to cause the hazardous operation of interfacing hardware (i.e.: there shall be no failure propagation from the FEE into S4/UVN or into the MTG-S satellite).

**FEERS-1639:**
Created From: S4IRS-635

The FEE shall provide failure tolerance and redundancy status information of safety critical functions.

13.6 **Labelling and Marking**

**FEERS-1342:**
Created From: S4IRS-6407

The unit shall comply with [AD-33C] Identification and product marking requirements.