SPIRE

SUBJECT: DRCU - Architecture and Reliabiliy Analysis Report (FMECA)

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DOCUMENT No: SPIRE-SAP-DOC-001077

ISSUE: 2.0 **Date:** 27th November 2001

APPROVED BY: **Date:**

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REFERENCE: SAp-SPIRE-FLo-0039-01

HERSCHEL/SPIRE

DRCU - Architecture and Reliability Analysis Report

Reference: SAp-SPIRE-FLo-0039-01
Issue: 2
Date: 27/11/2001

	Function	Name	Date	Visa
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DOCUMENT STATUS and CHANGE RECORD

Date	Issue	Affected pages
13/11/2001	1	Creation
27/11/2001	2	Modification of document structure

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1 Purpose

This document presents the results of the architecture and reliability analysis of the SPIRE Detector Readout & Control Unit (DRCU). This analysis aims at identifying the DRCU critical items on the reliability point of view and proposing some ways of optimisation of the subsystem architecture.

This analysis is based on both a qualitative and a quantitative approach:

- The qualitative approach consists in a Failure Modes and Effects Analysis of the DRCU, based on a functional description of the subsystem,
- The quantitative approach includes an intrinsic reliability calculation of the DRCU electronic boards and an evaluation of the subsystem mission reliability. This evaluation is completed by simulations on various configurations of analogue modules (LIA).

2 Applicable documents and reference documents

2.1 Applicable documents

	Title	Author	Reference	Date
AD1	Instrument Requirements Document	B. Swinyard	SPIRE-RAL-N-0034 Issue 1.0	23 Nov. 00
AD2	SPIRE Instrument – Detector Readout & Control Unit – Subsystem Specification	C. Cara	Sap-SPIRE-CCa-25-00 Issue 0.8	12 June 01
AD3	Instrument interface document – Part B - Instrument “SPIRE”	ESA	SCI-PT-IIDB/SPIRE-02124 Issue 1.0	1 Sept. 00

2.2 Reference documents

	Title	Author	Reference	Date
RD1.	FMECA	ECSS	ECSS-Q-30-02A draft	12 Oct 00
RD2.	Instrument level criticality analysis	B. Swinyard	Consortium meeting Cardiff	5/6/7 July 2001
RD3.	Reliability Prediction of Electronic Equipment	US DoD	MIL-HDBK-217F Notice 2	28 Feb 95
RD4.	Recueil de Données de Fiabilité : RDF 2000	UTE	UTE C 80-810	03 July 00

3 Terms and Acronyms

AD	Applicable Document
AF	Adaptation Function
BSM	Beam Steering Mirror
DCU	Detector Control Unit
DF	Design Function
DPU	Data Processing Unit
DRCU	Detector Readout & Control Unit
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
FPU	Focal Plane Unit
FTS	Fourier Transformer Spectrometer
IF	Interaction Function
LIA	Lock-In Amplifier
MCU	Mechanisms Control Unit
MTTF	Mean Time To Failure
N/A	Not Applicable
PSU	Power Supply Unit
RBD	Reliability Block Diagram
RD	Reference Document
SCU	Subsystem Control Unit
TBD	To Be Defined
WIH	Warm Interconnect Harnesses

4 Analysis approach

The Architecture and Reliability Analysis of the DRCU has been performed according to the following approach:

1. Functional description of the subsystem
2. Failure Modes and Effects Analysis
3. Quantitative evaluation of the DRCU reliability level

4.1 Functional description of the subsystem

The first step of the analysis establishes the functional description that constitutes the basis for the architecture and reliability analysis of the DRCU. This description only takes into account the operational phase of the instrument, with satellite on orbit.

It gives:
- Systems and equipment interfacing the DRCU,
- Functions to be performed by the DRCU,
- A breakdown of the DRCU in flow diagrams, showing the different modules of the DRCU and their elementary blocks, and the way they are involved in DRCU functions.

Three types of functions are identified:
- Interaction Functions (IF): these are the main functions of the DRCU, establishing links between two elements (or more) interfacing the DRCU, in order to perform its mission. They correspond to data flows (control and monitoring data).
- Adaptation Functions (AF): these functions show the particular adaptation of the DRCU to its interfacing systems or equipment.
- Design Functions (DF): these are internal functions of the DRCU, representing the design technical choices implemented to perform interaction functions and adaptation functions.

Interaction functions and adaptation functions are broken down to the elementary level necessary for the DRCU failure analysis. These elementary functions attached to each block of the DRCU are used as inputs for the FMEA.

Functional description o DRCU is given in appendix 1.

4.2 Failure Modes and Effects Analysis (FMEA)

A FMEA is performed on the DRCU with the aim of:
- identifying critical items for the DRCU functionality,
- defining the risk of propagation of DRCU elementary failures to other DRCU blocks, to other instrument modules or to satellite equipment,
- highlighting single point failures, that may have critical consequences on the scientific mission.

The results of the FMEA allow to issue recommendations in order to improve the DRCU design and architecture, such as:
- methods for preventing or compensating failure effects of critical items,
- guidelines for the elimination of single point failures,
- detection means of elementary failures.

The DRCU FMEA is performed with a functional approach based on the functional description of the subsystem. The FMEA results are given in appendix 5.

4.3 Quantitative evaluation of the DRCU reliability level

The quantitative evaluation of the DRCU reliability is performed according to the following approach:

- Building of the Reliability Block Diagram of the DRCU, in consistency with the functional breakdown of the subsystem,
- Calculation of the intrinsic reliability of each DRCU module, according to the reliability models defined in the Parts Count reliability prediction method of the MIL-HDBK-217 (RD3),
- Reliability simulation on the analogue parts of the DRCU, in order to highlight ways of optimisation of these parts. This simulation is carried out with the help of Markov graphs.

The reliability evaluation results are given in appendix 2 and 3

5 Main assumptions

5.1 DRCU Mission profile

Hypotheses :

- Herschel overall operational life in orbit: 54 months = 38880 hours (1 month = 720 hours)
- Time shared between 3 instruments :
  - SPIRE is in observation mode during 33% of the mission time
  - SPIRE is non operational 67% of the mission time
- SPIRE observations are shared
  - Photometric mode 67% of SPIRE time
  - Spectrometric mode 33% of SPIRE time

The operational mission profile used for the DRCU reliability evaluation is defined as follows:

DRCU mission phases	Duration (hours)	% mission duration
Observation on photometric mode	8640	22%
Observation on spectrometric mode	4320	11%
Stand-by (no observation: main and redundant chains OFF)	25920	67%
Overall mission	*38880*	*100 %*

5.2 Severity classification of DRCU failure effects

Criticality at DRCU level is based on RD1 and RD2. Some additional hypothesis have been taken.

The failure effects at DRCU level identified in the FMEA are classified according to the following table:

Failure effects	Severity
Loss of DRCU functionality: ▪ Loss of P500 photometric data ▪ Total loss of spectrometric data ▪ Calibration source permanently ON during photometric observation ▪ Loss of cooler(electrectronics) ▪ Loss of power supply	Critical - 2
Degradation of DRCU functionality: ▪ Loss of 16 P500 photometric data ▪ Loss of 16 P250 photometric data ▪ Total loss of 12 spectrometric data (LW or SW) ▪ Loss of calibration source during spectrometric observation	Major - 3
Negligible impact on DRCU functionality: ▪ Loss of 16 P350 photometric data	Negligible - 4

NOTE: *In DRCU FMEA, there is no effect of severity 1S, 1 or 2S.*

5.3 Reliability calculation

Calculation is performed with the "parts count method" of RD3. Only active components are taken into account.
As the assessment aims to compare different configurations and not to give an absolute value, the quality factor π_Q used for the reliability calculation is taken 1, corresponding to Class B category for microcircuits and JANTX category for diodes and transistors.
FPGA failure rate is estimated from the reliability model given in RDF2000 (RD4).

6 Results of the architecture and reliability analysis

DRCU items with failure modes classified as severity 2 are considered as "reliability critical" items, regarding the mission and the functionality of the subsystem. Items classified as severity 2R are not "reliability critical". *(**NOTE:** There is no item classified as severity 1S, 1 or 2S)*

Reliability critical items AND Single points failures of the DRCU are summarised in the tables presented in the following pages.

Reliability critical items of the DRCU

FMEA item	Module	Block	Failure modes	Subsystem effects (DRCU)	Severity	Existing compensating provisions	Corrective actions to be implemented or to be verified
2.9	DCU	BIAS	Heating of a Bias board (nominal or redundant) following internal failure	Loss of all the data of the photometric detectors (IF 1 lost) Risk of propagation of failure (PoF) towards the other boards of the DRCU by thermal propagation (degradation of other DRCU boards). Total loss of the mission (loss of all the scientific data).	2	The Bias boards are redundant. The heating of a BIAS board is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU.	To avoid the thermal propagation towards other boards, it is necessary to insulate the board at fault quickly (cut off its supply via switch ON/OFF controlled by the SCU) and to switch on the redundant chain of the DRCU (except LIA) to recover all detectors data.
2.9 Bis	DCU	BIAS	Heating of a Bias board (nominal or redundant) following internal failure	Loss of all the data of the spectrometric detectors (IF 1 lost) Risk of propagation of failure (PoF) towards the other boards of the DRCU by thermal propagation (degradation of other DRCU boards). Total loss of the mission (loss of all the scientific data)	2	The Bias boards are redundant. The heating of a board BIAS is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU.	To avoid the thermal propagation towards other boards, it is necessary to insulate the board at fault quickly (cut off its supply via switch ON/OFF controlled by the SCU) and to switch on the redundant chain of the DRCU (except LIA) to recover all detectors data.
5.4	SCU	SCU	Failure of T°C probe electronic module : too important bias current following short circuit or reduction in the resistivity of resistor dedicated to the limitation of current	Loss of a temperature monitoring data of the equipment from FPU towards DPU (worst case) (IF 2 lost) Risk of deterioration of the corresponding temperature sensor (worst case: bias current not compatible) Risk of self-heating of probe (thermal dissipation), and consequently heating of the other equipment of FPU. See whether it requires to switch on the redundant chain of the DRCU.	2	Bias currents are individually and by a low level command switched off . A short-circuit at the level of a probe is protected by a current limitation resistor. A reduction in the resistivity is detected a priori by the DPU (non-coherent value of temperature) and must result in insulating the chain.	The rise in temperature of the other equipment of FPU is detected by the DPU, and must lead to a period of setting off the DRCU, so that the equipment go down again in temperature. It is necessary to define the prerogatives of switching on the redundant DRCU according to the loss of only one temperature probe.
5.48	SCU	SCU	Inopportune setting ON of a powering relay (short circuit on coil, stuck contact...)	The DRCU consumes a great quantity of energy, so the satellite will cut off its supply. DRCU is " switched off".	2	Under nominal operation, the relays of powering of the elements of the chain are in position ON (except specific case of supply of LIA P or LIA S). See interface with the MCU	

The failure modes analysed in items 4.5 and 5.50 of the FMEA are considered as potentially "reliability critical", because their severity could not be assessed at the DRCU level:

FMEA item	Module	Block	Failure modes	Subsystem effects (DRCU)	Severity	Existing compensating provisions	Corrective actions to be implemented or to be verified
4.5	PSU	PSU	Too important inrush current at the starting of equipment	Risk of collapse of the power supply bar of the satellite (PoF)	TBD		To be envisaged: a limiting device of inrush current in input of the converter However a progressive powering is considered. Moreover, the position of ON/OFF powering relays must be guaranteed before the powering of the "Primary power line (28V)" at the satellite level; i.e. the powering relays of the equipment must be in position OFF before their powering (see items related to function DF 4).
5.50	SCU	SCU	Powering relays in the not supplied redundant chain of the DRCU remained in position ON [loss of power supply of SCU (SCU_DIG_P5) or loss of the power supply of the powering relays (SCU_REL_P12)]	Risk of collapse of the satellite bar	TBD		See whether it is necessary that the SCU forces all the powering relays on state OFF at the time of their initialisation (starting following the powering of the corresponding relay)

Single points failures

FMEA item	Module	Block	Failure modes	Subsystem effects (DRCU)	Severity	Existing compensating provisions	Corrective actions to be implemented or to be verified
1.1	DCU	LIA P	Loss of PSD + filter (among 32) of a LIA P board (electronic or connector failure)	Loss of a photometric scientific data among a potential of 9*32 data (degraded IF1)	3		Detection of the loss of the data during the analysis by the scientists
1.1 Bis	DCU	LIA S	Loss of PSD + filter (among 24) of a LIA board (electronic or connector failure)	Loss of a spectrometric scientific data among a potential of 3*24 data (degraded IF1)	3		Detection of the loss of the data during the analysis by the scientists
1.2	DCU	LIA P	Failure of a multiplexer 16 > 1 (among 2) of a LIA P board	Loss of 16 photometric scientific data among a potential of 9*32 (degraded IF1)	3		Detection of the loss of the 16 data during the analysis by the scientists If the 3 chains of T/C measure (temperature) are used for the regulation of the bolometers (via control of the cooler), the distribution of the T/C must be such as the loss of a multiplexer 16 > 1 does not lead to the loss of the 3 chains of temperature. This distribution implies 3 distinct analogue channels towards the multiplexers 4 > 1 of DAQ module.
1.2 Bis	DCU	LIA S	Failure of a multiplexer 12 > 1 (among 2) of a LIA board	Loss of 12 spectrometric scientific data among a potential of 3*24 data (degraded IF1)	3		Detection of the loss of the 12 data during the analysis by the scientists
1.3	DCU	LIA P	Short circuit of a component Heating of a LIA P board following internal failure	Loss of 32 photometric scientific data among a potential of 9*32 data (degraded IF1) Risk propagation of failure (PoF) towards the other LIA board by thermal propagation (degradation of the other LIA board) total Loss of the mission Photometer (loss of all the scientific data)	3	The LIA boards are not redundant and cannot be controlled ON/OFF individually. The heating of a LIA board is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU.	If the case of a risk of failure propagation towards the other LIA boards leading to a total loss of the scientific data is confirmed, each analogue module (LIA) must be individually commandable ON/OFF by means of low level commands. If the 3 chains of T/C measure (temperature) are used for the regulation of the bolometers (via control of the cooler), the distribution of the T/C must be such as the loss of a LIA board does not lead to the loss of the 3 chains of temperature.

FMEA item	Module	Block	Failure modes	Subsystem effects (DRCU)	Severity	Existing compensating provisions	Corrective actions to be implemented or to be verified
1.3 Bis	DCU	LIA S	Short circuit of a component Heating of a LIA board following internal failure	Loss of 24 spectrometric scientific data among a potential of 3*24 data (degraded IF1) Risk of propagation of failure (PoF) towards the other LIA board by thermal propagation (degradation of the other LIA board). Total loss of the spectrometric mission (loss of all the scientific data)	3	The LIA board are not redundant and cannot be controlled ON/OFF individually. The heating of a LIA board is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU.	If the case of a risk of failure propagation towards the other LIA boards leading to a total loss of the scientific data is confirmed, each analogue module (LIA) must be individually commandable ON/OFF by means of low level commands.
2.9	DCU	BIAS	Heating of a Bias board (nominal or redundant) following internal failure	Loss of all the data of the photometric detectors (IF 1 lost) Risk of propagation of failure (PoF) towards the other boards of the DRCU by thermal propagation (degradation of other DRCU boards). Total loss of the mission (loss of all the scientific data)	2	The Bias boards are redundant. The heating of a BIAS board is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU.	To avoid the thermal propagation towards other boards, it is necessary to insulate the board at fault quickly (cut off its supply via switch ON/OFF controlled by the SCU) and to switch on the redundant chain of the DRCU (except LIA) to recover all detectors data.
2.9 Bis	DCU	BIAS	Heating of a Bias board (nominal or redundant) following internal failure	Loss of all the data of the spectrometric detectors (IF 1 lost) Risk of propagation of failure (PoF) towards the other boards of the DRCU by thermal propagation (degradation of other DRCU boards). Total loss of the mission (loss of all the scientific data)	2	The Bias boards are redundant. The heating of a BIAS board is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU.	To avoid the thermal propagation towards other boards, it is necessary to insulate the board at fault quickly (cut off its supply via switch ON/OFF controlled by the SCU) and to switch on the redundant chain of the DRCU (except LIA) to recover all detectors data.
4.5	PSU	PSU	Too important inrush current at the starting of equipment	Risk of collapse of the power supply bar of the satellite (PoF)	TBD		To be envisaged: a limiting device of inrush current in input of the converter However a progressive powering is considered. Moreover, the position of ON/OFF powering relays must be guaranteed before the powering of the "Primary power line (28V)" at the satellite level; i.e. the powering relays of the equipment must be in position OFF before their powering (see items related to function DF 4).

FMEA item	Module	Block	Failure modes	Subsystem effects (DRCU)	Severity	Existing compensating provisions	Corrective actions to be implemented or to be verified
5.4	SCU	SCU	Failure of T°C probe electronic module : too important bias current following short circuit or reduction in the resistivity of resistor dedicated to the limitation of current	Loss of a temperature monitoring data of the equipment from FPU towards DPU (worst case) (IF 2 lost) Risk of deterioration of the corresponding temperature sensor (worst case: bias current not compatible) Risk of self-heating of probe (thermal dissipation), and consequently heating of the other equipment of FPU. See whether it requires to switch on the redundant chain of the DRCU.	2	Bias currents are individually and by a low level command switched off . A short-circuit at the level of a probe is protected by a current limitation resistor.	A reduction in the resistivity is detected a priori by the DPU (non-coherent value of temperature) and must result in insulating the chain. The rise in temperature of the other equipment of FPU is detected by the DPU, and must lead to a period of setting off the DRCU, so that the equipment go down again in temperature. It is necessary to define the prerogatives of switching on the redundant DRCU according to the loss of only one temperature probe.
5.48	SCU	SCU	Inopportune setting ON of a powering relay (short circuit on coil, stuck contact...)	The DRCU consumes a great quantity of energy, so the satellite will cut off its supply. DRCU is " switched off ".	2	Under nominal operation, the relays of powering of the elements of the chain are in position ON (except specific case of supply of LIA P or LIA S; see 5.46 item). See interface with the MCU	
5.50.	SCU	SCU	Powering relays in the not supplied redundant chain of the DRCU remained in position ON [loss of power supply of SCU (SCU_DIG_P5) or loss of the power supply of the powering relays (SCU_REL_P12)]	Risk of collapse of the satellite bar	TBD		See whether it is necessary that the SCU forces all the powering relays on state OFF at the time of their initialisation (starting following the powering of the corresponding relay).

7 Conclusion

7.1 Synthesis of the FMEA

DRCU "reliability critical" items

Few "reliability critical" items are issued from the DRCU FMEA, because in most cases of failures classified as severity 2, it is possible to switch the DRCU on the redundant chain. So, only 4 failures are considered as critical for the DRCU reliability:

- Two critical failures involve the overheating of a BIAS board that may result in a thermal propagation towards other DRCU boards. These failures are detected by the internal DRCU housekeeping. In that case, it will be necessary to have the possibility to insulate the board at fault quickly and to switch on the redundant chain.
- One critical failure concerns the temperature probe electronic module of the SCU, that may lead to send a non adapted signal to a FPU temperature detector and risk to deteriorate some FPU equipment. It is necessary to verify if the considered failure can be detected by the DPU, and to implement a procedure to make the temperature of equipment go down. In this case, it is also necessary to define prerogatives of switching the DRCU on the redundant chain.
- The latest critical failure is the inopportune setting ON of a power relay by the SCU, that risks to lead to switch off the DRCU because of an overconsumption of energy.

Moreover, two failures are considered as potentially "reliability critical", because their severity could not be assessed at the DRCU level. One failure concerns the PSU and the other the SCU, but both failures can lead to a risk of collapse of the power supply bar of the satellite. In both cases, the guarantee of position of powering relays involved in the power supply distribution is in question.

As stated above, most of the DRCU items with failures classified as severity 2 are not considered as critical items for the subsystem reliability because of the possibility to use the redundant chain. This acknowledgement highlights the importance of the strategy to be implemented to decide to switch from the main chain to the redundant chain of the DRCU.

Failure propagation

The FMEA has not shown any case of failure propagation outside the DRCU.

However, some cases of internal propagation of failures due to overheating of electronic boards have been identified. In that cases, it will be necessary to have the possibility to detect the considered failures, to insulate the board at fault individually, and to switch the DRCU on the redundant chain.

Consequently, criteria concerning the overheating of electronic boards have to be included in the switching strategy.

Single Point Failures (SPF)

In addition to the critical items described at section 0 that constitute single point failures classified as severity 2, other SPFs concern the analogue modules. SPFs related to LIA boards are classified as severity 3, because they don't lead to a total loss of the DRCU functionality.

However, some risks of thermal propagation also exist for LIA boards. In that cases, it will be necessary to have the possibility to detect the considered failures and to insulate the board at fault individually. Considering that there is no redundancy on analogue parts, in such cases the DRCU will remain in a degraded configuration.

7.2 Synthesis of the quantitative reliability evaluation

Intrinsic reliability level of DRCU boards

The intrinsic reliability calculation that have been performed on the electronic boards has to be considered as a basis for the architecture evaluation of the DRCU, but not as an accurate estimation of the reliability level of each electronic board. So, the reliability figures can be refined by a detailed calculation based on a Parts Stress approach.

Mission reliability

The mission reliability evaluated for the DRCU in its various phases of mission profile highlights the preponderant part of the photometric observation mode in the overall mission reliability of the DRCU.

This evaluation also shows that the impact of the stand-by state is not negligible, considering the assumptions on stand-by failure rates (failure rate OFF = failure rate ON / 10) and the ratio between the observation mode and the "no observation" mode of the instrument. This acknowledgement highlights the importance of dormant failures for the DRCU.

Optimisation of LIA boards configuration

The simulations carried out on the distribution of the various photometric channels on the 9 LIA_P boards show that the best configuration with regard to the risk of loss of DRCU functionality is :

3 X P350 /P500
4 X P250 /P250
1 X P250/P350
1 X P250/P250

However, if operating the DRCU in a degraded mode is acceptable, the configuration that seems to present the better compromise is

4 X P250/P250
3 X P350/ P350
1 X P250 /P500
1 X P500/ P500

Concerning the LIA_S boards, the configuration offering the better reliability level is

1X SLW/SLW
2 X SSW/SSW

Appendix 1. Functional description of DRCU

Appendix 1.1. DRCU overview

The DRCU is an electronic unit housed into two boxes: the FCU and the DCU connected between the FPU and the DPU. This unit along with the DPU and the WIH constitutes the system called “SPIRE Warm Electronics”. The DRCU includes the front-end electronics of the following sub-systems:

- Detector,
- Fourier Transform Spectrometer,
- Beam Steering Mirror,
- Cooler,
- Calibrators,
- Thermometry & analogue Housekeeping,

each sub-system being associated with “cold elements” located in the FPU and high-level control functions located in the DPU OBS.

The DRCU comprises 4 physical sub-units which are:

- the DCU includes the Detector Control Electronics,
- the MCU includes the Mechanisms (FTS+BSM) Control Electronics,
- the SCU includes the Sub-system Control Electronics,
- the PSU includes a multi-outputs SMPS DC/DC converter.

NOTE: *The MCU is out of the scope of the analysis.*

Appendix1 .1. DRCU functions

Three types of functions are defined: Interaction Functions (IF), Adaptation Functions (AF), Design Functions (DF).

List of functions

Appendix 1.1.1. Interaction functions of the DRCU

- IF 1: To ensure the transfer and treatment of information between FPU and DPU modules (control and monitoring of observation data).
  - IF 1.1: To transmit information from FPU towards DPU.
    - IF 1.1.1: To collect, process, transfer the data from FPU towards DAQ
    - IF 1.1.2: To collect, process, transfer the analogue information from LIA towards DPU
  - IF 1.2: To transmit control data from DPU towards FPU.
    - IF 1.2.1: To collect, process, transfer information from DPU towards BIAS
    - IF 1.2.2: To transfer the control data towards the FPU detectors and the JFET box

- IF 2: To ensure the transfer and treatment of monitoring information of equipment between FPU and DPU modules.
  - IF 2.1: To transfer, convert and execute the monitoring control information of the FPU equipment temperatures
  - IF 2.2: To transfer, convert and execute the polarisation control information of the detectors
  - IF 2.3: To transfer, convert and execute the control information of the cooler

Appendix 1.1.2. Adaptation functions of the DRCU

- AF 1: To collect the power supply coming from S/C, to convert it and to distribute it to the whole DRCU modules.
  - AF 1.1 : To collect the electric power coming from S/C

AF 1.2 : To transfer the electric power for distribution to the modules of the DRCU

- AF 2: To transmit monitoring information and controls between DRCU equipment and DPU.
  - AF 2.1 : To take delivery of information of control coming from DPU
  - AF 2.2 : To ensure the return of information in answer to a DPU request

- AF 3: To transmit information from DCU towards DPU and conversely.
  - AF 3.1: To take delivery of the numerical controls coming from the DPU
    - AF 3.1.1 : To collect the numerical data of control coming from DPU
    - AF 3.1.2 : To transfer the numerical data towards the BIAS
    - AF 3.1.3 : To ensure the demodulation of analogue information at the LIA modules level
  - AF 3.2: To transfer the information digitised from DAQ towards DPU
    - AF 3.2.1 : To transfer the digitised data towards DPU
    - AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA

- AF 4: At DCU level, to receive analogue information from FPU and to transmit controls to FPU.
  - AF 4.1: To take delivery of analogue information coming from FPU
    - AF 4.1.1 : To collect the analogue data coming from FPU, to demodulate them and to filter them
    - AF 4.1.2 : To multiplex and transfer the analogue data
  - AF 4.2: To transfer analogue controls towards FPU and JFET box
    - AF 4.2.1 : To transfer the analogue controls data towards the heaters of the JFET box (power supply of the JFET box)
    - AF 4.2.2 : To adapt and transfer the analogue controls data (signal of modulation) towards the photometric or spectrometric detectors
    - AF 4.2.3 : To ensure the transfer of continuous powering control of the JFET Box to allow the return of measurement information

- AF 5: At SCU level, to receive analogue information from FPU and to transmit controls to FPU.
  - AF 5.1 : To make carry out a control of temperature monitoring at the FPU level and ensure the return of corresponding information
  - AF 5.2 : To make carry out a control of calibration of the detectors at the FPU level and ensure the return of corresponding information
  - AF 5.3 : To make carry out a control at the level of the cooler and ensure the return of corresponding information

- AF 6 : To ensure the transfer of power supply towards DCU module
- AF 7 : To ensure the transfer of PSU temperature probes information towards the HK / AD module
- AF 8 : To configure the power supply M/R (Main / Redundant) of the LIA boards of DCU
- AF 9: To transmit housekeeping information from SCU/PSU to DPU.

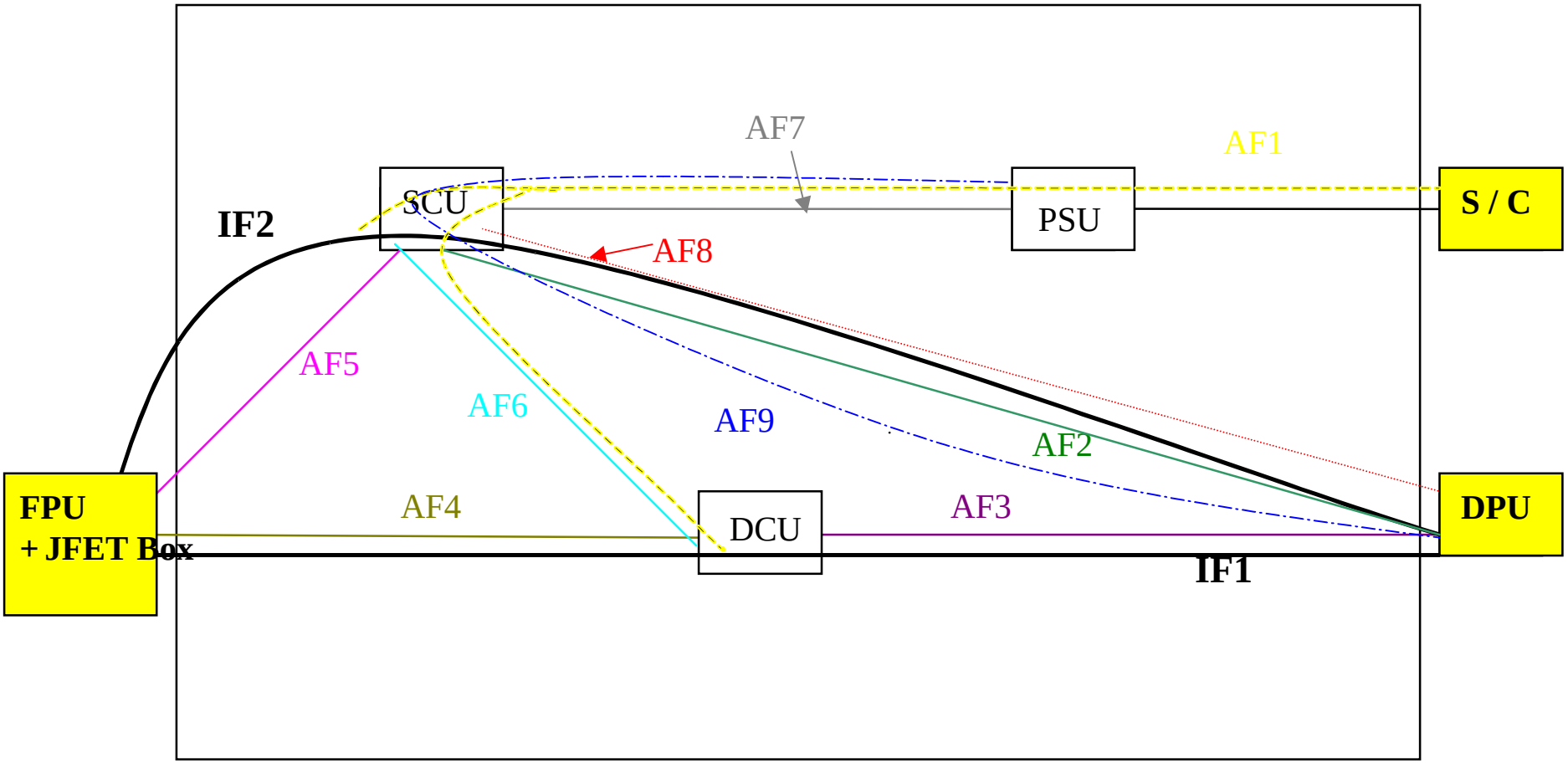
Appendix 1.1.3. Design functions of the DRCU are:

- DF 01 : To transfer the numerical message outgoing from MTIM module towards DAQ I/F
- DF 02 : To transfer the controlling of specific amplitude to each Bias DAC
- DF 03 : To ensure the sorting of information of control coming from DAQ
- DF 04 : To transform and ensure the transfer of the sinusoidal signals towards Bias DACs
- DF 05 : To ensure the transfer of information from the HK A/D module towards the SCU Control Logic module
- DF 06 :To configure the relays of power supply of the DRCU elements
- DF 07 : Transfer of information between cooler control and the SCU control logic module
- DF 08 : Transfer of information between calibration monitoring and SCU Control Logic module
- DF 09 : Transfer of information between the Temperature control electronic module and the SCU control logic
- DF 10 : To ensure the transfer of secondary voltages information towards the HK / AD module
- DF 11 : To ensure the transfer of SCU temperature probes information towards the HK / AD module
- DF 12 : To transmit the setting parameters (sampling rate) of the SCU control logic for the reception of information related to temperature, calibration and cooler
- DF 13 : To transmit the setting parameters (frequency...) of the SCU Control Logic for the reception of information related to secondary voltages and SCU/PSU temperature probes

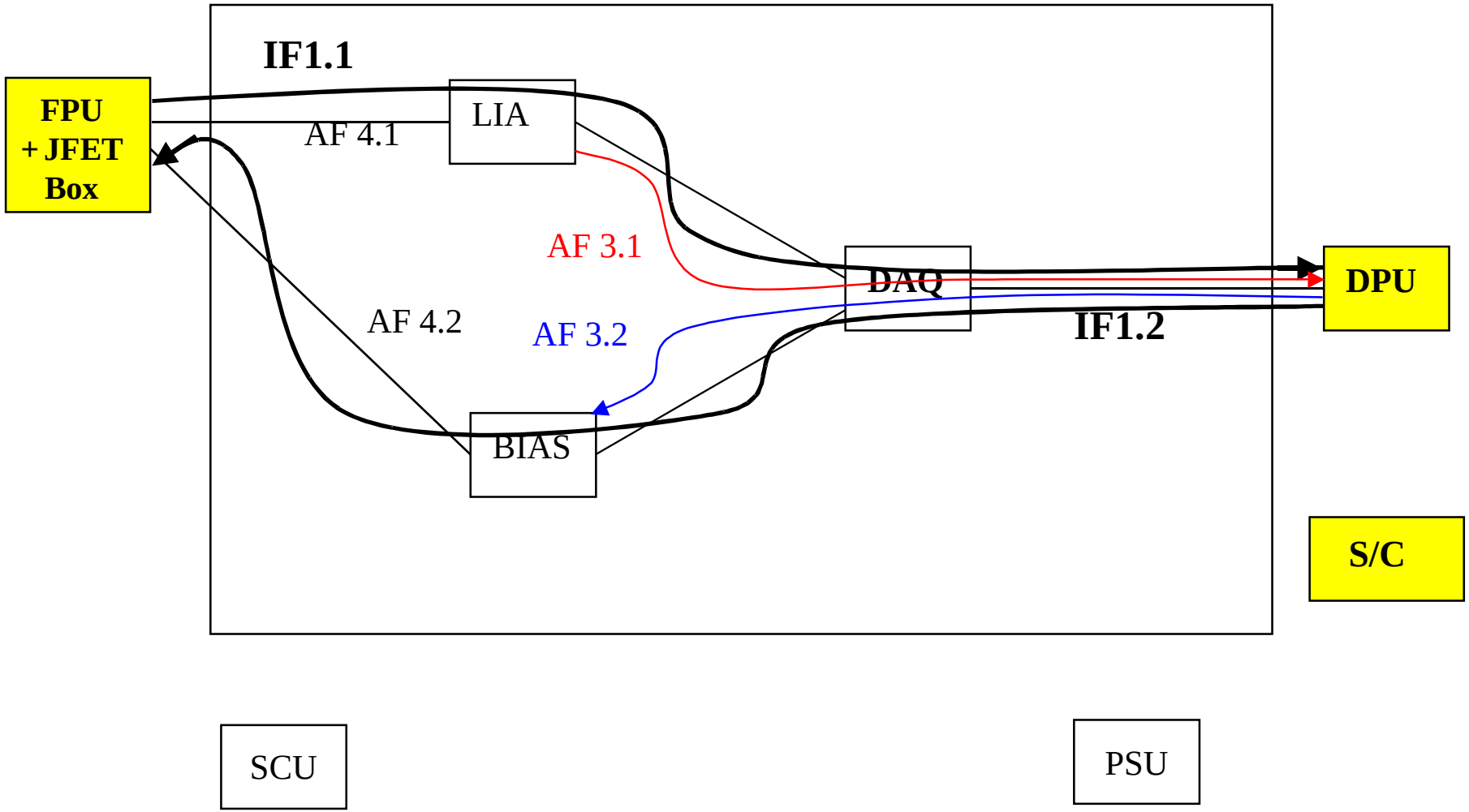
Appendix1 .2. Flow diagrams

- Flow diagram at DRCU level
  - Flow diagram of DCU module
    - Flow diagram of LIA_P block
    - Flow diagram of LIA_S block
    - Flow diagram of DAQ block
    - Flow diagram of BIAS block
  - Flow diagram of SCU module
  - Flow diagram of PSU module

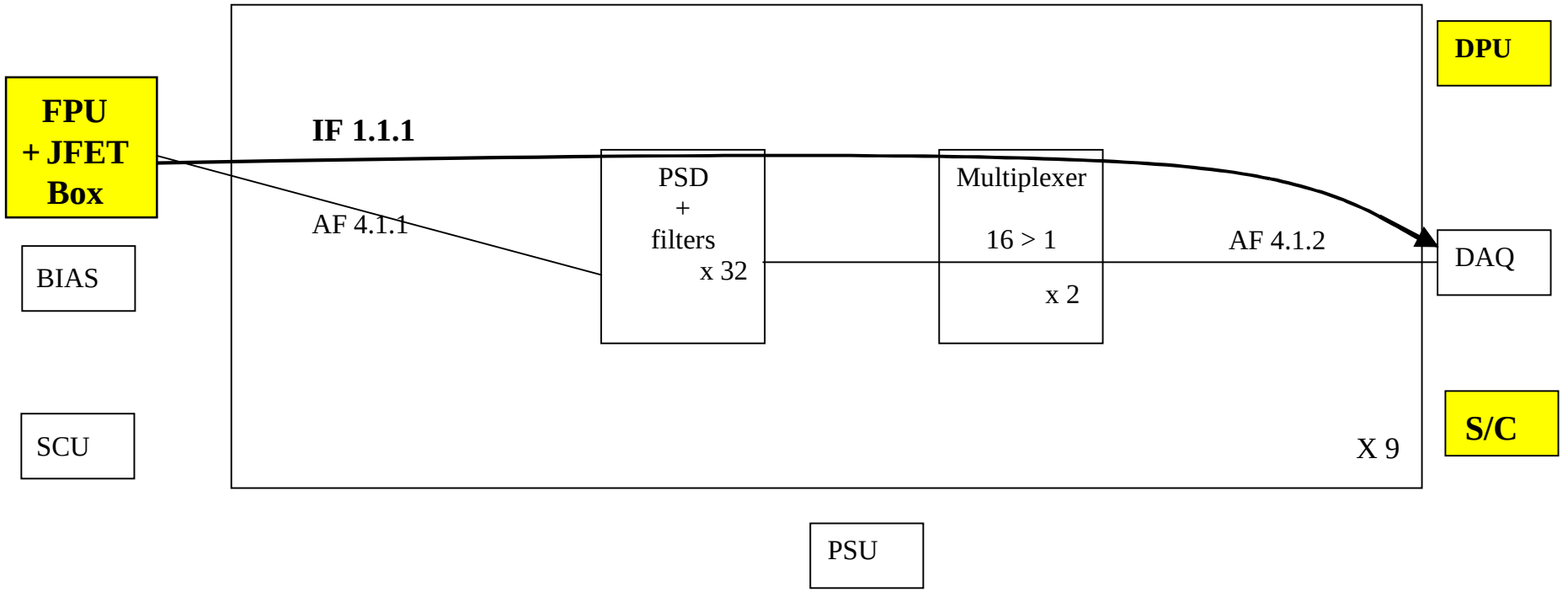
DRCU


AF7
AF1
SCU
PSU
S / C
IF2
AF8
AF5
AF6
AF9
AF2
FPU
+ JFET Box
AF4
DCU
AF3
DPU
IF1

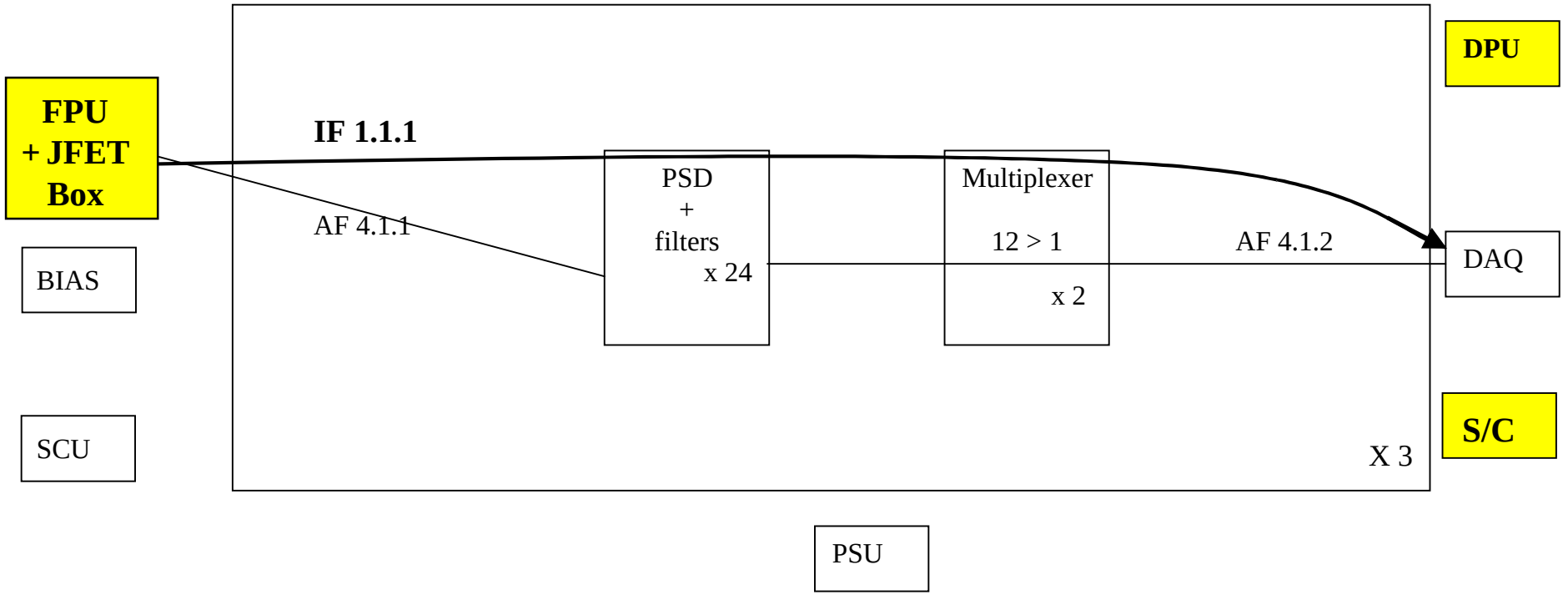
DCU


IF1.1
FPU
+ JFET
Box
LIA
AF 4.1
AF 3.1
DAQ
DPU
IF1.2
AF 4.2
AF 3.2
BIAS
S/C
SCU
PSU

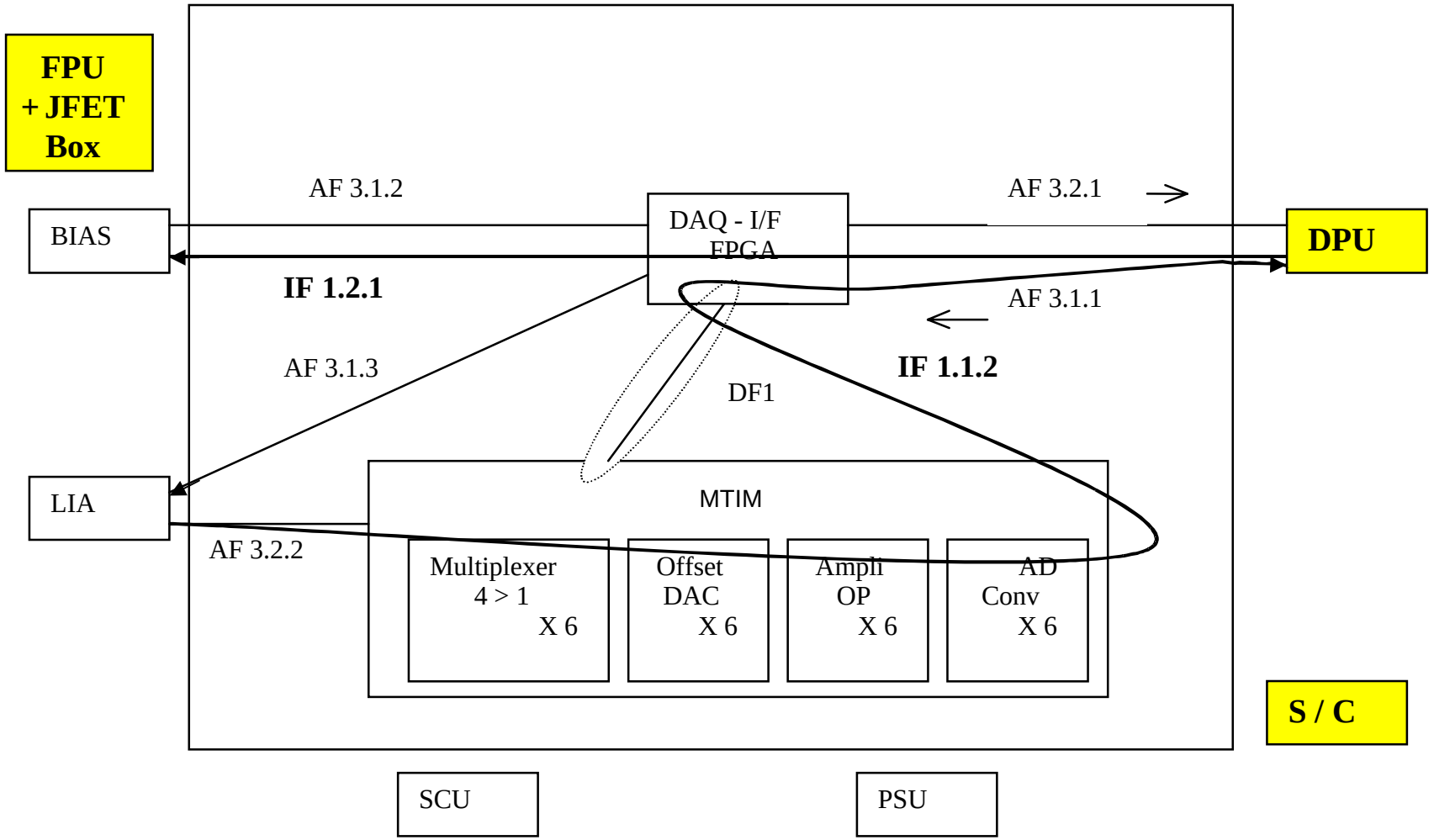
LIA_P


FPU
+ JFET
Box
IF 1.1.1
AF 4.1.1
PSD
+
filters
x 32
Multiplexer
16 > 1
x 2
AF 4.1.2
DPU
DAQ
BIAS
SCU
S/C
X 9
PSU

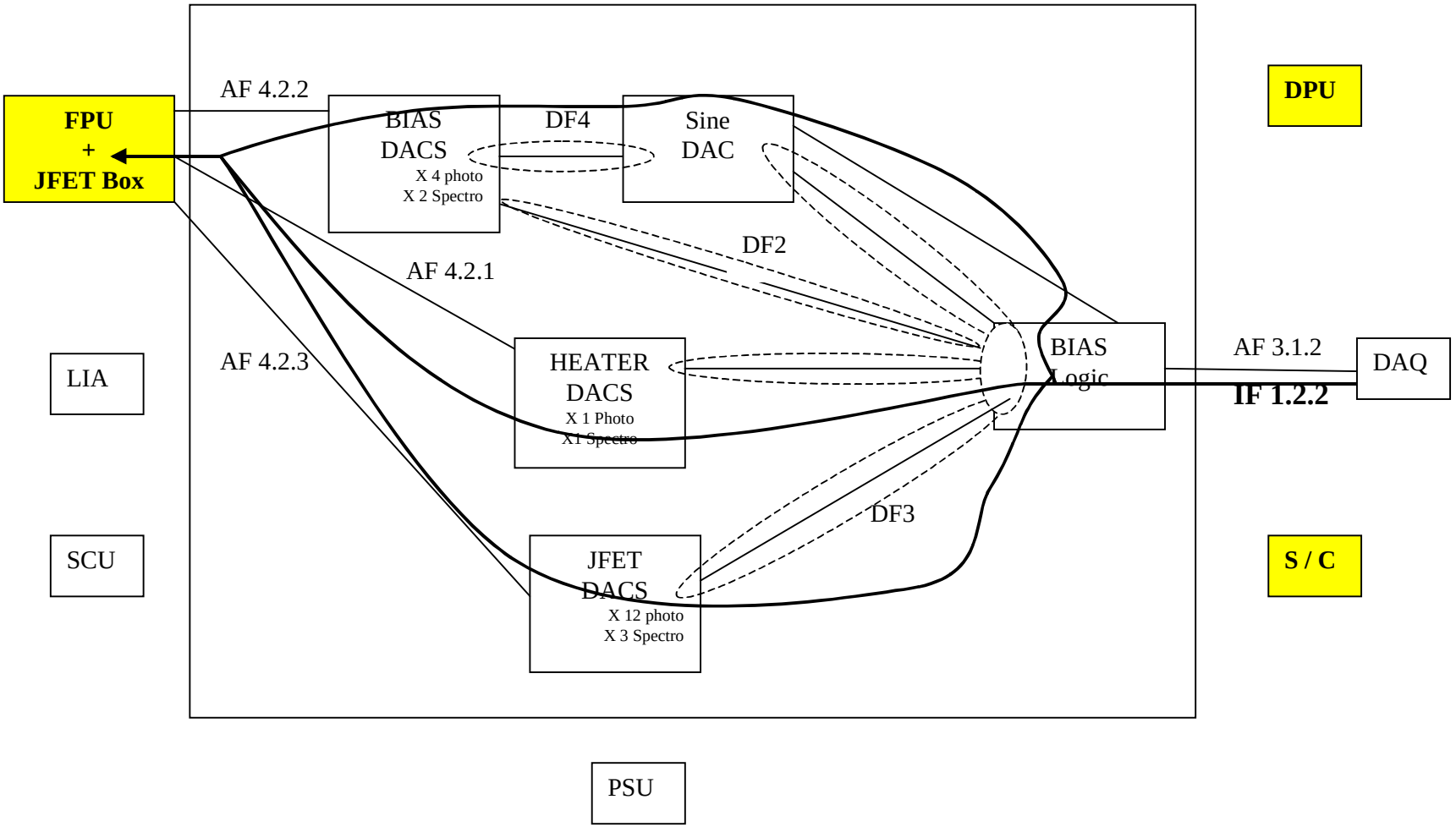
LIA_S


FPU
+ JFET
Box
IF 1.1.1
AF 4.1.1
PSD
+
filters
x 24
Multiplexer
12 > 1
x 2
AF 4.1.2
DPU
DAQ
BIAS
SCU
S/C
X 3
PSU

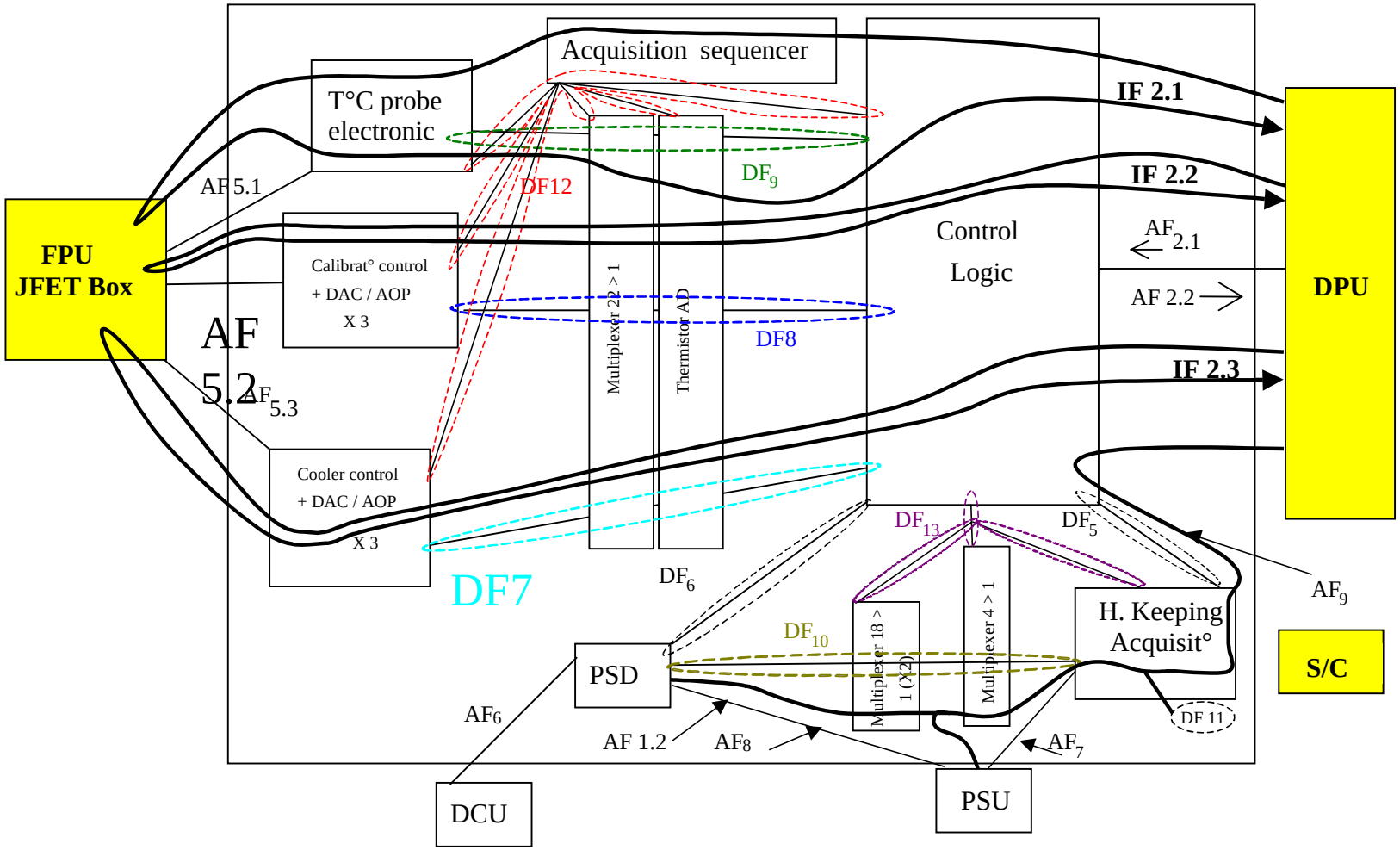
DAQ


FPU
+ JFET
Box
AF 3.1.2
AF 3.2.1
BIAS
DAQ - I/F
FPGA
DPU
IF 1.2.1
AF 3.1.1
AF 3.1.3
IF 1.1.2
DF1
LIA
MTIM
AF 3.2.2
Multiplexer
4 > 1
X 6
Offset
DAC
X 6
Ampli
OP
X 6
AD
Conv
X 6
S / C
SCU
PSU

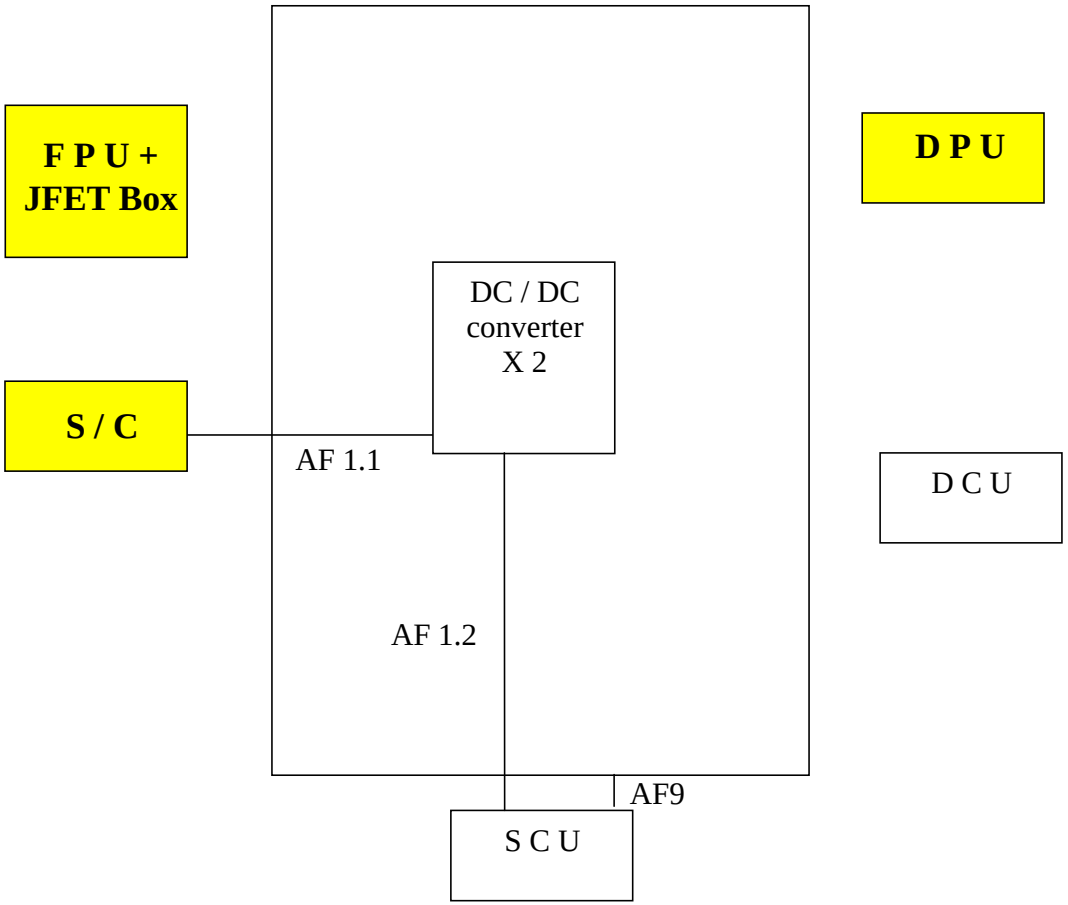
BIAS


FPU
+
JFET Box
AF 4.2.2
BIAS
DACS
X 4 photo
X 2 Spectro
DF4
Sine
DAC
DPU
DF2
AF 4.2.1
AF 4.2.3
LIA
HEATER
DACS
X 1 Photo
X1 Spectro
BIAS
Logic
AF 3.1.2
IF 1.2.2
DAQ
DF3
SCU
JFET
DACS
X 12 photo
X 3 Spectro
S / C
PSU

SCU


Acquisition sequencer
T°C probe electronic
AF 5.1
DF12
DF9
IF 2.1
IF 2.2
FPU JFET Box
Calibrat° control + DAC / AOP X 3
Control Logic
AF 2.1
AF 2.2
DPU
AF 5.2
AF5.3
Multiplexer 22 > 1
Thermistor A/D
DF8
IF 2.3
Cooler control + DAC / AOP X 3
DF13
DF5
DF7
DF6
AF9
DF10
PSD
Multiplexer 18 > 1 (X2)
Multiplexer 4 > 1
H. Keeping Acquisit°
S/C
DF 11
AF6
AF 1.2
AF8
AF7
DCU
PSU

PSU



Appendix1 .3. Functional Analysis Table

Functions				IF										
				1	1.1	1.1.1	1.1.2	1.2	1.2.1	1.2.2	2	2.1	2.2	2.3
Equipement	FPU (EME 1)			X	X	X		X		X	X	X	X	X
	DPU (EME 2)			X	X		X	X	X		X	X	X	X
	S/C (EME 3)													
	DCU			X										
		LIA P			X		X							
			PSD + Filters (X32)			X								
			Multiplexer 16 > 1			X								
		LIA S			X		X							
			PSD + Filters (X24)			X								
			Multiplexer 12 > 1			X								
		DAQ			X	X		X		X		X	X	X
			DAQ-IF FPGA				X		X					
			MTIM				X							
		BIAS						X	X					
			BIAS Logic							X				
			Sine DAC							X				
			BIAS DACs							X				
			JFET DACs							X				
			HEATER DACs							X				
			Offset DAC X 6			X								
	SCU										X			
		Control Logic										X		
		House Keeping Acq												
		PSD												
		Temperatures Probes Elec										X		
		Calibration sources Elec											X	
		Cryocooler Electronics												X
		Acquisition sequencer										X		
		Multiplexer 22 > 1										X	X	X
		Multiplexer 18 > 1												
		Multiplexer 4 > 1												
		Thermistor AD										X	X	X
	PSU													
		DC / DC converter												

Functional Analysis Table (cont'd)

Functions				IF										
				1	1.1	1.1.1	1.1.2	1.2	1.2.1	1.2.2	2	2.1	2.2	2.3
AF	1			X							X			
		1,1		X	X			X			X	X	X	X
		1,2		X	X			X			X	X	X	X
	2										X			
		2,1									X	X	X	X
		2,2									X	X	X	X
	3			X										
		3,1						X						
			3,1,1	X	X			X	X					
			3,1,2	X				X	X	X				
			3,1,3	X	X		X							
		3,2			X									
			3,2,1	X	X		X							
			3,2,2	X	X		X							
	4			X										
		4,1			X									
			4,1,1	X	X	X								
			4,1,2	X	X	X								
		4,2						X						
			4,2,1	X				X		X				
			4,2,2	X				X		X				
			4,2,3	X				X		X				
	5										X			
		5,1									X	X		
		5,2									X		X	
		5,3									X			X
	6			X										
	7													
	8			X	X									
	9													
DF	DF 1			X	X		X							
	DF 2			X				X		X				
	DF 3			X				X		X				
	DF 4			X				X		X				
	DF 5													
	DF 6			X	X			X			X	X	X	X
	DF 7										X	X	X	X
	DF 8										X	X	X	X
	DF 9										X	X	X	X
	DF 10													
	DF 11													
	DF 12										X	X	X	X
	DF 13													

Appendix 2. Intrinsic reliability calculation for each electronic board

Appendix 2.1. Calculation hypothesis

Only active components are taken into account in the reliability calculation: microcircuits, diodes, transistors.

The intrinsic reliability of each DRCU module is calculated according to the reliability models defined in the Parts Count reliability prediction method of the MIL-HDBK-217F Notice 2 (RD3), except for FPGAs. The general mathematical expression for equipment failure rate with this method is:

$$\lambda_{EQUIP} = \sum_{i=1}^{i=n} N_i (\lambda_g . \pi_Q)_i$$

for a given equipment environment where:

- λ_{EQUIP} : total equipment failure rate (failures / 10^6 Hours)
- λ_g : generic failure rate for the i^{th} generic part (failures / 10^6 Hours)
- π_Q : quality factor for the i^{th} generic part
- N_i : quantity of i^{th} generic part
- n : number of different generic part categories in the equipment

The operational environment used for the reliability calculation is "Space, Flight" (SF).

As the assessment aims to compare different configurations and not to give an absolute value, the quality factor π_Q used for the reliability calculation is taken 1, corresponding to Class B category for microcircuits and JANTX category for diodes and transistors.

FPGA failure rate is estimated from the reliability model given in RDF2000 (RD4).

Appendix 2.2. LIA_P

Folio / Block	Qty	Components	Qty	Type	Techno	Section	Kind	λ_g (*10^{-6} h^{-1})	$\lambda_{Component}$ (*10^{-6} h^{-1})
Folio 2	1								
		REF02	2	volt. Ref.	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
		ADG503FBR	4	mux 8 to 1	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,038
		OP400	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		DS90C032	4	Line receiver, quad, CMOS	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,038
		74HC595	2	Shift register	MOS	5.1 Gate/Logic arrays	1 to 100 gates	0,0057	0,0114
Folio 3 à 18	16								
		OP400	3	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,456
		HI303	1	CMOS Analog switches	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,152

λ_{LIA_P} = 0,7239.10^{-6} h^{-1}

Appendix 2.3. LIA_S

Folio / Block	Qty	Components	Qty	Type	Techno	Section	Kind	λ_g (*10^{-6} h^{-1})	$\lambda_{Component}$ (*10^{-6} h^{-1})
Folio 2	1								
		REF02	2	volt. Ref.	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
		ADG503FBR	4	mux 8 to 1	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,038
		OP400	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		DS90C032	4	Line receiver, quad, CMOS	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,038
Folio 3 à 14	12								
		OP400	3	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,342
		HI303	1	CMOS Analog switches	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,114
Folio 15 à 17	3								
		OP400	2	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,057

λ_{LIA_S} = 0,6175.10^{-6} h^{-1}

Appendix 2.4. SCU

Folio / Block	Qty	Components	Qty	Type	Techno	Section	Kind	λ_g (*10^{-6} h^{-1})	$\lambda_{Component}$ (*10^{-6} h^{-1})
Bloc A	1								
		HS-508	6	mux 8 to 1	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,057
Bloc B	1								
		AMP01	1	diff amp	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
Bloc C	1								
		OP400	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		REF02	1	volt. Ref.	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
Bloc D	1								
		HS-508	2	mux 8 to 1	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
Bloc E	1								
		HS-508	2	mux 8 to 1	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
Bloc F	1								
		OP270	1	fast dual AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
Bloc G	1								
		SEI7809RP	3	16-bit ADC	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0285
Bloc H	11								
		OP400	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,1045
		HS-303	1	quad mux 2 to 1	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,1045
		AMP01	1	diff amp	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,1045
Bloc I	1								
		AMP01	1	diff amp	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		OP15	3	FET AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0285
		OP400	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		HS-303	2	quad mux 2 to 1	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
		REF02	1	volt. Ref.	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
Bloc J	2								
		OP484	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
		OP400	2	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,038
		AMP01	6	diff amp	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,114
		AD7545	3	12-bit DAC	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,057

SCU (cont'd)

Folio / Block	Qty	Components	Qty	Type	Techno	Section	Kind	λ_g ($*10^{-6}$ h^{-1})	$\lambda_{Component}$ ($*10^{-6}$ h^{-1})
Bloc K	1								
		54SX32	1	FPGA		Calcul avec RDF 2000		0,09	0,09
		M672061	2	FIFO		Calcul avec RDF 2000		0,009	0,018
		26C31	1	driver 422	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		26C32	1	rec. 422	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		54HC14	1	hex. Inverter	MOS	5.1 Gate/Logic arrays	1 to 100 gates	0,0057	0,0057
		HS9S-117RH	1	volt. Reg	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		CFPX375x	1	crystal	Misc.	19.1 Quartz Crystals		0,016	0,016
Bloc L	9								
		2N5154	2	NPN trans	Bipolar	6.3 Transistors	PNP (f<200 MHz)	0,000073	0,001314
		1N5617	8	diode		6.2 Diodes	Schottky Barrier	0,023	1,656
Bloc M	1								
		OP400	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		AD7545	3	12-bit DAC	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0285
		REF02	1	volt. Ref.	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
Bloc N	1								
		OP400	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		2N2222	3	NPN trans	Bipolar	6.6 Transistors	PNP (f<200 MHz)	0,000073	0,000219
		2N2907	3	PNP trans	Bipolar	6.3 Transistors	PNP (f<200 MHz)	0,000073	0,000219
		1N4148	2	diode		6.1 Diodes	Switching	0,00047	0,00094

$\lambda_{SCU} = 2,6244.10^{-6}\ h^{-1}$

Appendix 2.5. DAQ_I/F

Folio / Block	Qty	Components	Qty	Type	Techno	Section	Kind	λ_g ($*10^{-6}$ h^{-1})	$\lambda_{Component}$ ($*10^{-6}$ h^{-1})
Folio 1	1								
		26C31	1	driver 422	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		26C32	1	rec. 422	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
Folio 2 à 3	2								
		AMP02	12	AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,228
Folio 4 à 5	2								
		ADG503FBR	9	mux 8 to 1	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,171
		REF02	1	volt. Ref.	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
		OP215	6	Dual AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,114
Folio 6	1								
		ADS7309	6	Converter A/D	Bipolar	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,057
Folio 7	1								
		DS90C031	7	Line driver, quad, CMOS	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0665
Folio 8	1								
		DIP14	1	Oscillator programming	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
		XC17128-DDSM	1	Serial mem - 128	MOS	5.2 Memories, PROM	Up to 16K	0,0048	0,0048
		XC4010-208	1	FPGA		Calculated with RDF 2000		0,09	0,09

$\lambda_{DAQ\ I/F} = 0{,}7788.10^{-6}\ h^{-1}$

Appendix 2.6. BIAS

Folio / Block	Qty	Components	Qty	Type	Techno	Section	Kind	λ_g ($*10^{-6}$ h^{-1})	$\lambda_{Component}$ ($*10^{-6}$ h^{-1})
Folio 1	1								
		LM117H	2	Adjustable regul.	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
		DS90C032	2	Line receiver, quad, CMOS	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
		HC595	6	Shift register	MOS	5.1 Gate/Logic arrays	1 to 100 gates	0,0057	0,0342
		HC164	2	Interface serie //	MOS	5.1 Gate/Logic arrays	1 to 100 gates	0,0057	0,0114
Folio 2	1								
		AD7545A	4	12-bit DAC	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,038
		OP400	2	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
		REF02	2	volt. Ref.	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
Folio 3 à 5	3								
		AD7545A	2	12-bit DAC	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,057
		OP400	2	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,057
Folio 6 à 8	3								
		AD7545A	4	12-bit DAC	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,114
		OP400	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0285
Folio 9	1								
		AD7545A	3	12-bit DAC	MOS				0
		OP400	1	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,0095
Folio 10 à 11	2								
		HI303	3	CMOS Analog switches	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,057
		OP400	3	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,057
Folio 12	1								
		HI303	2	CMOS Analog switches	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
		OP400	2	quad AOP	MOS	5.1 Linear Microcircuits	1 to 100 transistors	0,0095	0,019
Folio 13 à 14	2								
		2N2907	1	PNP trans	Bipolar	6.3 Transistors	PNP (f<200 MHz)	0,000073	0,000146
		2N2222	2	NPN trans	Bipolar	6.6 Transistors	PNP (f<200 MHz)	0,000073	0,000292

$\lambda_{BIAS} = 0,5780.10^{-6}\ h^{-1}$

Appendix 3. Reliability evaluation

Appendix 3.1. Intrinsic reliability of electronic boards recapitulative table

Electronic boards	Failure rates ($10^{-6}.h^{-1}$)
LIA_P	0,7239
LIA_S	0,6175
SCU	2,6244
DAQ_I/F	0,7788
BIAS	0,5780
PSU	0,5000 (approximation)

Failure rates listed in the above table are given for boards on operation (failure rate ON). When an electronic board is in stand-by state, its failure rate is considered as: failure rate OFF = failure rate ON / 10.

Appendix 3.2. Mission reliability of the DRCU

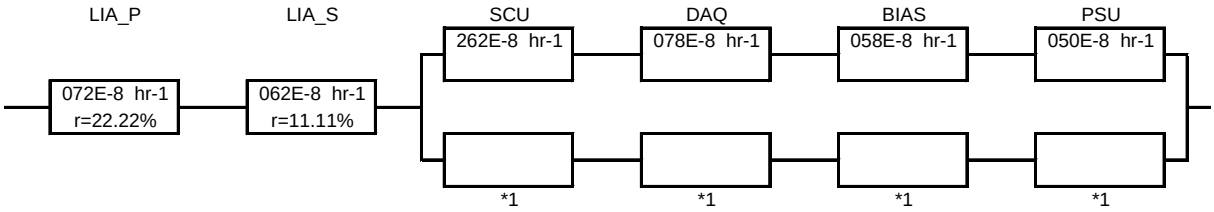
The mission reliability of the DRCU is evaluated by taking into account the following inputs:

- intrinsic reliability figures,
- architecture of the subsystem (main / redundant),
- operations modes: observation on photometric mode, observation on spectrometric mode, stand-by.

The mission reliability evaluated for the DRCU in the various phases of the mission profile described in section 5.1 is as follows:

DRCU mission phases	Duration (hours)	% mission duration	Mission reliability
Observation on photometric mode	8640	22%	0,944499
Observation on spectrometric mode	4320	11%	0,991827
Stand-by (no observation: main and redundant chains OFF)	25920	67%	0,978470
Overall mission	*38880*	*100 %*	*0,900045*

Appendix 3.2.1. Overall mission of the DRCU

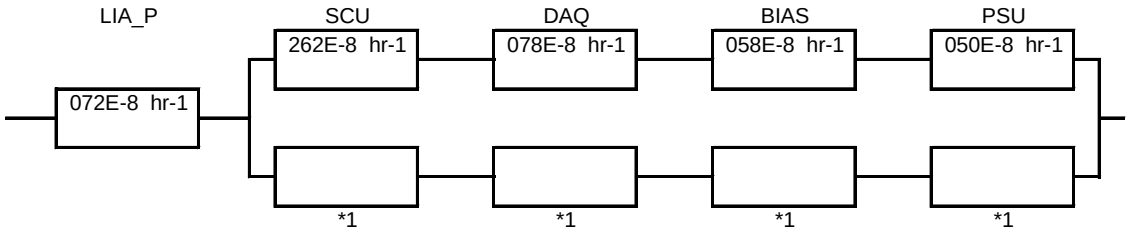


	Série	**Série**		**passive**
	***9**	***3**		***1**
Fiab.	0,92681	0,9857		0,98521

T (hr) = 38880

DRCU boards	**Failure rate ON (hr^{-1})**	**Qty**	**Type of redundancy**	**Failure rate OFF (hr^{-1})**	**Operation ratio**	**Reliability T (hr) = 38880**
LIA_P	7,24E-07	9	Serial		22%	0,926814
LIA_S	6,175E-07	3	Serial		11%	0,985698
SCU	2,62E-06	1				
DAQ	7,79E-07	1				
BIAS	5,78E-07	1				
PSU	5,00E-07	1				
	4,48E-06	1	Passive	4,48E-07	33%	0,985207
DRCU						*0,900045*

Appendix 3.2.2. Observation on photometric mode

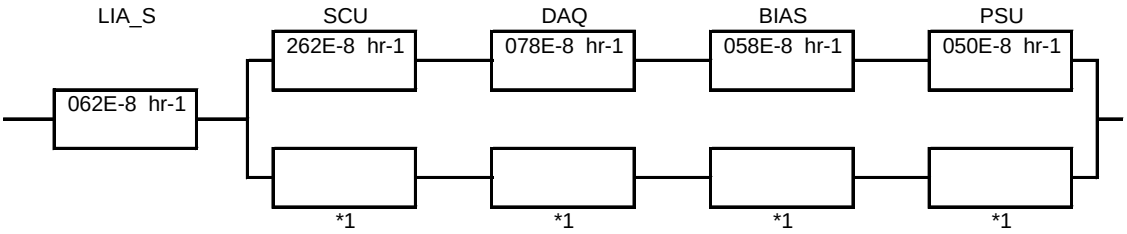


	Série	passive
	*9	*1
Fiab.	0,94526	0,9992

T (hr) = 8640

DRCU boards	Failure rate ON (hr^{-1})	Qty	Type of redundancy	Failure rate OFF (hr^{-1})	Operation ratio	Reliability T (hr) = 8640
LIA_P	7,24E-07	9	Serial			0,945257
SCU	2,62E-06	1				
DAQ	7,79E-07	1				
BIAS	5,78E-07	1				
PSU	5,00E-07	1				
	4,48E-06	1	Passive	4,48E-07		0,999198
DRCU						*0,944499*

Appendix 3.2.3. Observation on spectrometric mode

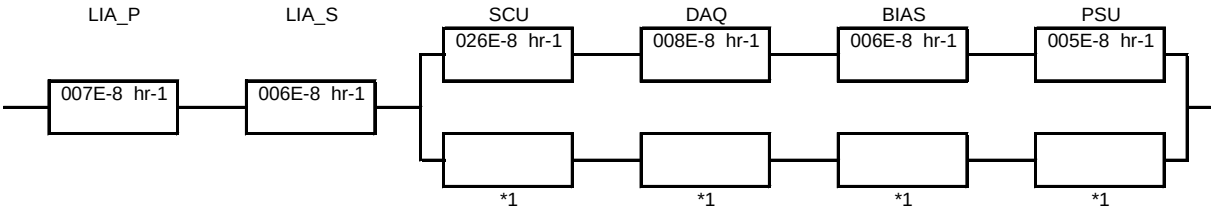


	Série	**passive**
	***3**	***1**
Fiab.	0,99203	0,9998

T (hr) = 4320

DRCU boards	**Failure rate ON (hr^{-1})**	**Qty**	**Type of redundancy**	**Failure rate OFF (hr^{-1})**	**Operation ratio**	**Reliability T (hr) = 8640**
LIA_S	6,18E-07	3	Série			0,992029
SCU	2,62E-06	1				
DAQ	7,79E-07	1				
BIAS	5,78E-07	1				
PSU	5,00E-07	1				
	4,48E-06	1	passive	4,48E-07		0,999797
DRCU						*0,991827*

Appendix 3.2.4. Stand-by (no observation)



	Série	**Série**		**passive**
	***9**	***3**		***1**
Fiab.	0,98325	0,99521		0,99993

T (hr) = 25920

DRCU boards	**Failure rate OFF (hr^{-1})**	**Qty**	**Type of redundancy**	**Operation ratio**	**Reliability T (hr) = 8640**
LIA_P	7,24E-08	9	Série		0,983252
LIA_S	6,175E-08	3	Série		0,995210
SCU	2,62E-07	1			
DAQ	7,79E-08	1			
BIAS	5,78E-08	1			
PSU	5,00E-08	1			
	4,48E-07	1	passive		0,999926
DRCU					*0,978470*

Appendix 4. Ways of optimisation of analogue parts

Appendix 4.1. Optimisation hypotheses

Analogue parts of the DRCU (LIA_P and LIA_S) are not redounded. Besides, the mission reliability evaluation in each observation mode (photometric, spectrometric) highlights that the corresponding LIA module is the weak point of the DRCU. Consequently, this part of the analysis focuses on the configuration of analogue modules of the DRCU, in order to identify some ways of optimisation of LIA_P and LIA_S modules on a reliability point of view.

Two ways of optimisation are considered, taking into account the following criteria:

Ways of optimisation	Criteria
Improvement of the reliability level with respect to the loss of DRCU functionality.	Loss of DRCU functionality due to LIA failure: ▪ Loss of LIA_P500 (3*16 channels) ▪ Loss of all LIA_S (42 SW and 24 LW)
Improvement of the reliability level with respect to the degradation of DRCU functionality.	Degradation of DRCU functionality due to LIA failure: ▪ Loss of 16 LIA_P500 ▪ Loss of 16 LIA_P250 ▪ Loss of 16 LIA_P350 ▪ Loss of 12 S_LW ▪ Loss of 12 S_SW

Several configurations are proposed for analogue modules, considering that:

- distributing the various types of data channels (photometry: P500, P250, P350; spectrometry: SW, LW) among the LIA boards allows to get a better reliability level with regard to the loss of DRCU functionality,
- grouping the various types of data channels on LIA boards allows to optimise the reliability level with regard to the operation of the DRCU in a degraded mode.

Appendix 4.2. LIA_P configurations

Five configurations are proposed to distribute the various photometric channels on the 9 LIA_P boards.

NOTE: each LIA_P board gathers 2*16 photometric channels.

Configuration 1 :

⇨ "maximum splitting" of P500 and "medium grouping" of P250

3	P350 / P500	+ 3	P250 / P350	+ 3	P250 / P250			

Configuration 2 :

⇨ "maximum splitting" of P500 and "maximum grouping" of P250

3	P350 / P500	+ 4	P250 / P250	+ 1	P250 / P350	+ 1	P350 / P350			

Configuration 3 :

⇨ "maximum splitting" of P500 and "maximum splitting" of P250

3	P250 / P500	+ 6	P250 / P350		

Configuration 4 :

⇨ grouping of P500, P250 and P350 (current configuration)

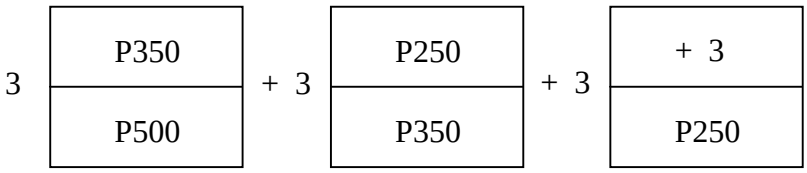
4	P250 / P250	+ 3	P350 / P350	+ 1	P250 / P500	+ 1	P500 / P500			

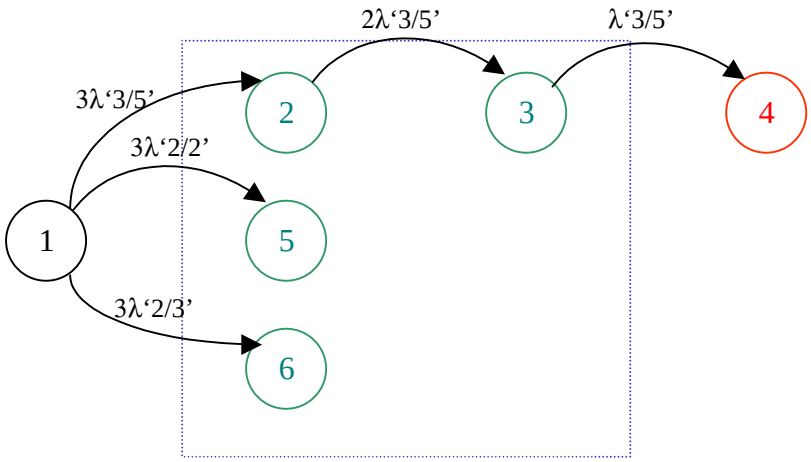
Configuration 5 :

⇨ grouping of P500 and P250, splitting of P350 (separation of P250 and P500)

4	P250 / P250	+ 2	P350 / P350	+ 1	P350 / P500	+ 1	P500 / P500	+ 1	P500 / P500			

Appendix 4.2.1. LIA_P: configuration 1





Given that: $\lambda'2/2' = \lambda\ '2/3' = \lambda\ '3/5' = \lambda_{LIA\_P} = 0{,}7239.10^{-6}\ h^{-1}$

$P_{loss\ ofmission} = P4 = 2{,}4.10^{-7}$

$P_{degraded\ mode} = P2 + P3 + P5 + P6 = 0{,}0547$

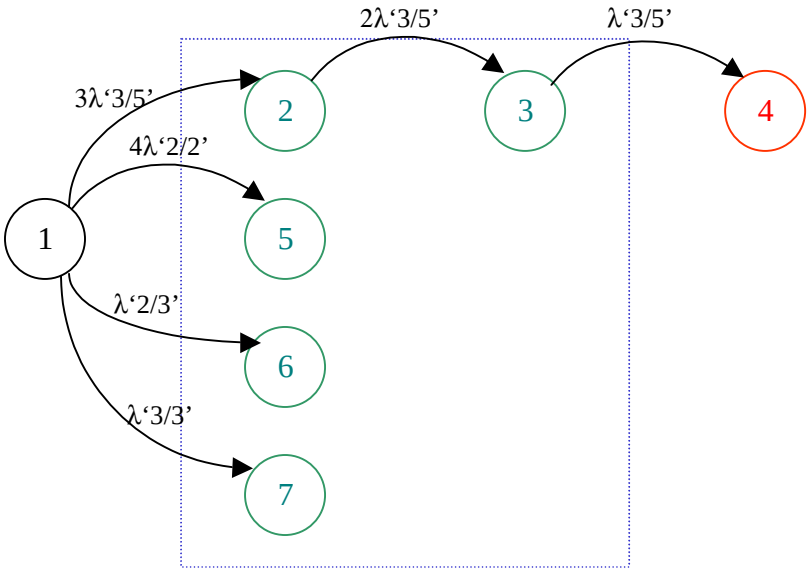
$P_{loss\ of\ P500} = P2 + P3 = 0{,}0182$

$P_{loss\ of\ P250} = P5 + P6 = 0{,}0365$

$P_{loss\ of\ P350} = P2 + P6 = 0{,}0364$

Appendix 4.2.2. LIA_P: configuration 2

3	P350 / P500	+ 4	P250 / P250	+ 1	P250 / P350	+ 1	P350 / P350	



Given λ‘2/2’ = λ ‘2/3’ = λ ‘3/5’ = λ ‘3/3’ = $\lambda_{LIA\_P} = 0{,}7239.10^{-6}\ h^{-1}$

$P_{loss\ ofmission} = P4 = 2{,}4.10^{-7}$

$P_{degraded\ mode} = P2 + P3 + P5 + P6 + P7 = 0{,}0547$

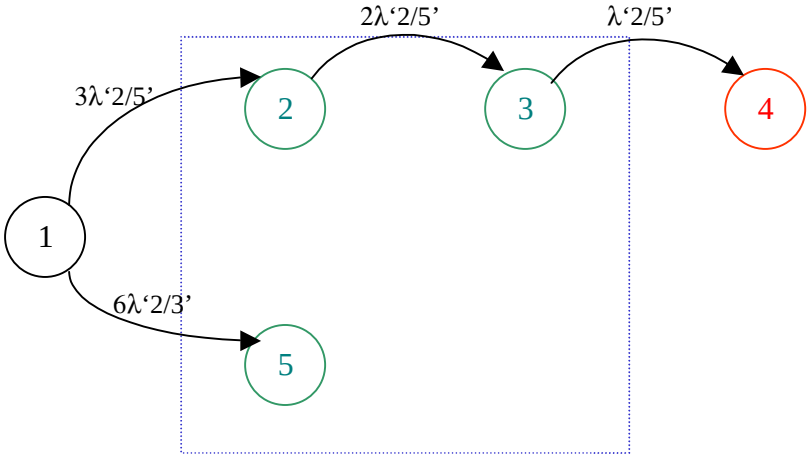
$P_{loss\ of\ P500} = P2 + P3 = 0{,}0182$

$P_{loss\ of\ P250} = P5 + P6 = 0{,}0304$

$P_{loss\ of\ P350} = P2 + P6 + P7 = 0{,}0303$

Appendix 4.2.3. LIA_P: configuration 3

3	P250	+	6	P250
	P500			P350



Given λ‘2/3’ = λ ‘2/5’ = λ_{LIA_P} = 0,7239.10^{-6} h^{-1}

$P_{loss\ ofmission}$ = P4 = 2,4.10^{-7}

$P_{degraded\ mode}$ = P2 + P3 + P5 = 0,0547

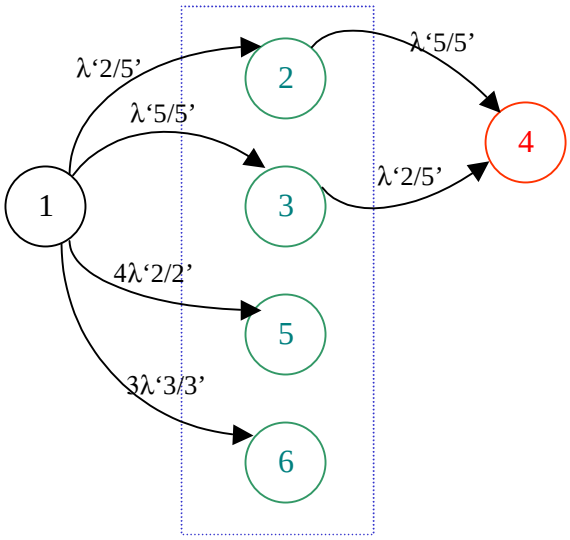
$P_{loss\ of\ P500}$ = P2 + P3 = 0,0182

$P_{loss\ of\ P250}$ = P2 + P5 = 0,0546

$P_{loss\ of\ P350}$ = P5 = 0,0365

Appendix 4.2.4. LIA_P: configuration 4

4	P250 / P250	+	3	P350 / P350	+	1	P250 / P500	+ 1	P500 / P500



Given λ‘2/2’ = λ ‘2/5’ = λ ‘3/3’ = λ ‘5/5’ = λ_{LIA_P} = 0,7239.10^{-6} h^{-1}

$P_{loss\ ofmission}$ = P4 = 3,82.10^{-5}

$P_{degraded\ mode}$ = P2 + P3 + P5 + P6 = 0,0547

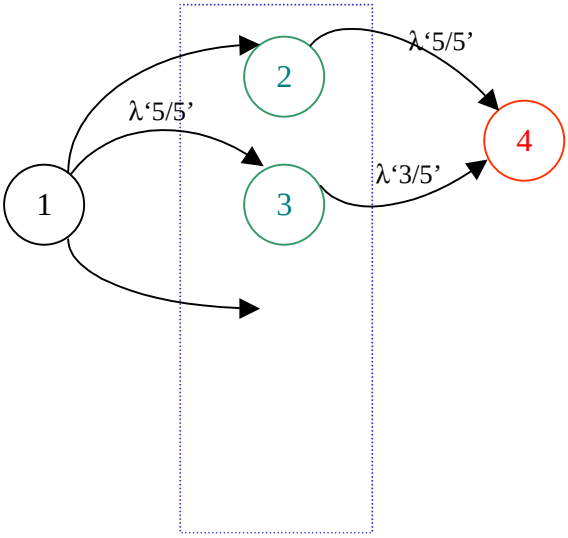
$P_{loss\ of\ P500}$ = P2 + P3 = 0,0121

$P_{loss\ of\ P250}$ = P2 + P5 = 0,0304

$P_{loss\ of\ P350}$ = P6 = 0,0182

Appendix 4.2.5. LIA_P: configuration 5

4	P250 P250	+ 2	P350 P350	+ 1	P350 P500	+ 1	P500 P500	+ 1	P500 P500



Appendix 4.3. LIA_S configurations

Two configurations are proposed to distribute the various spectrometric channels on the 3 LIA_S boards.

NOTE: each LIA_S board gathers 2*12 spectrometric channels.

Configuration 1 :

⇨ grouping of SW and LW

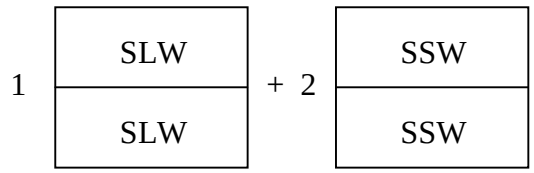
1	SLW	+ 2	SSW	
	SLW		SSW	

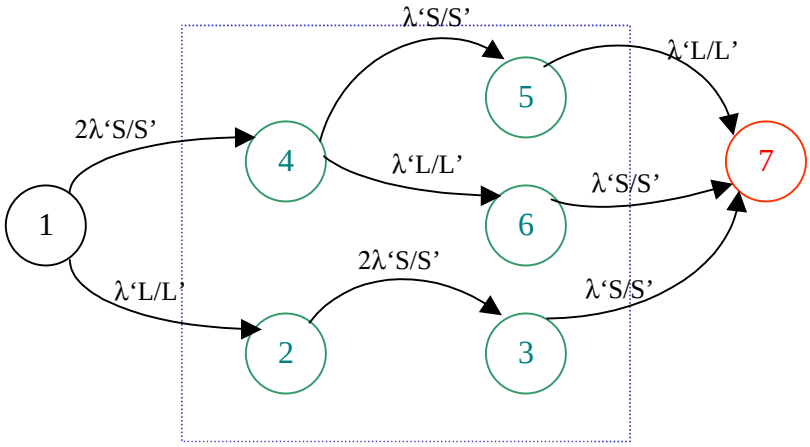
Configuration 2 :

⇨ splitting of SW and LW

2	SLW	+ 1	SSW	
	SSW		SSW	

Appendix 4.3.1. LIA_S: configuration 1





Given that: λ'L/L' = λ 'S/S' = λ_{LIA_S} = 0,6175.10^{-6} h^{-1}

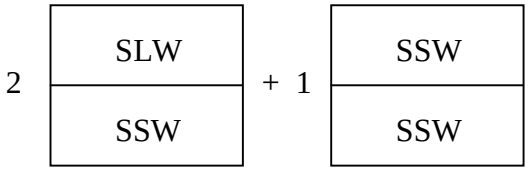
$P_{loss\ ofmission}$ = P7 = 1,891.10^{-8}

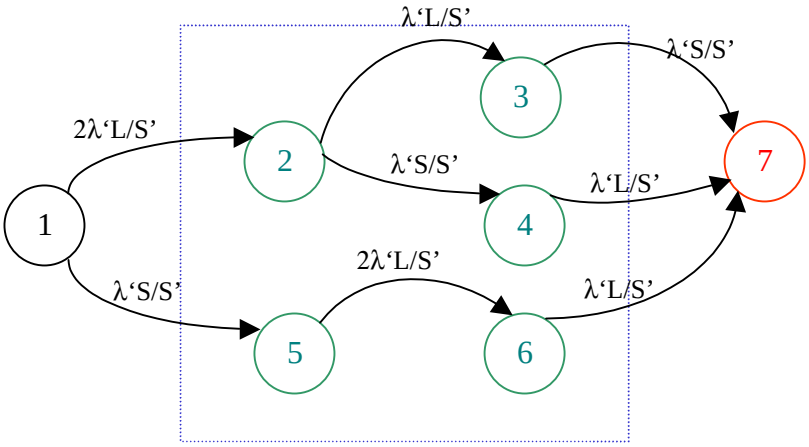
$P_{degraded\ mode}$ = P2 + P3 + P4 + P5 + P6 = 0,00797

$P_{loss\ of\ 'L'}$ = P2 = 0,00265

$P_{loss\ of\ 'S'}$ = P4 = 0,0053

Appendix 4.3.2. LIA_S: configuration 2





Given that λ'L/S' = λ 'S/S' = λ_{LIA_S} = 0,6175.10^{-6} h^{-1}

$P_{loss\ ofmission}$ = P7 = 1,891.10^{-8}

$P_{degraded\ mode}$ = P2 + P3 + P4 + P5 + P6 = 0,00797

$P_{loss\ of\ 'L'}$ = P2 = 0,0053

$P_{loss\ of\ 'S'}$ = P2 + P5 = 0,00795

Appendix 4.4. Mission reliability of LIA modules in the various proposed configurations

The calculation of probabilities associated with each state of the graphs is carried out with the following inputs:

Board	Failure rate ($10^{-6}.h^{-1}$)	Operating time (hours)
LIA_P (2*16 photometric channels)	0,7239	8640
LIA_S (2*12 spectrometric channels)	0,6175	4320

Probabilities issued from Markov graphs for each configiration:

LIA_P

Configuration	Loss of mission (loss of all P500)	Degraded mode (*)	Loss of 16 P500	Loss of 16 P250	Loss of 16 P350
1	$2,4.10^{-7}$	0,0547	0,0182	0,0365	0,0365
2	$2,4.10^{-7}$	0,0547	0,0182	0,0304	0,0303
3	$2,4.10^{-7}$	0,0547	0,0182	0,0546	0,0365
4	$3,82.10^{-5}$	0,0547	0,0121	0,0304	0,0182
5	$3,82.10^{-5}$	0,0547	0,0121	0,0304	0,0243

LIA_S

Configuration	Loss of mission (loss of all S datas	Degraded mode (*)	Loss of 12 S_LW	Loss of 12 S_SW
1	$1,891.10^{-8}$	0,00797	0,00265	0,0053
2	$1,891.10^{-8}$	0,00797	0,0053	0,00795

(*) Degraded mode = Sum of the probabilities corresponding to failed states of the DRCU, except "loss of mission".

Appendix 5. FMEA tables

Appendix 5.1. Description of the FMEA worksheet

The columns of the FMEA are described in the following table :

Item	Reference number of the FMEA item.
Module	Identification of the DRCU module, as defined in the DRCU functional description.
Block	Identification of the functional block of the considered DRCU module.
Functions	Description of the block functions, as defined in the DRCU functional description.
Failure modes	Description of the potential failure modes of the function under analysis.
Local effects	Impact of the failure modes on the block function under analysis.
Module effects	Impact of the failure modes on the DRCU module under analysis.
Subsystem effects (DRCU)	Impact of the failure modes at the DRCU level, in consistency with the high level functions (IF, AF) defined in the DRCU functional description.
Remarks	Complementary information on failure modes, failure effects, detection means, compensating provisions or corrective actions.
Classification of the effects at DRCU level	Severity class of the failure effects at DRCU level, according to the severity categories defined in RD1 at subsystem level (see details at section Appendix 5.2).
Classification of the effects at instrument level	Severity class of the failure effects at instrument level, according to the severity categories defined in RD1 at system level.

Appendix 5.2. Failure effect severity

The severity of each subsystem failure effect is evaluated, in order to establish the failure criticality for the DRCU. The consequences of DRCU failures are then to be assessed at instrument level (system level), according to their impact on the scientific mission and/or on the satellite functions.

Severity	***Definition at subsystem level***
Catastrophic 1S	▪ Loss of life, life threatening or permanently disabling injury or occupational illness, loss of an element of an interfacing manned flight system. ▪ Loss of launch site facilities. ▪ long term detrimental environmental effects.
Catastrophic 1	▪ Propagation of failure to other subsystems/assemblies/equipment.
Critical 2S	▪ Temporary disabling but not life threatening injury, or temporary occupational illness. ▪ Loss of, or major damage to other flight systems, major flight elements or ground facilities. ▪ Loss of, or major damage to public or private property. ▪ Short term detrimental environmental effects.
Critical 2	▪ Loss of functionality.
Major 3	▪ Degradation of functionality.
Negligible 4	▪ Any other effect.

Severity categories are assigned without consideration of existing compensating provisions, to provide a qualitative measure of the worst potential consequences resulting from item failure. The number identifying the severity category is followed by a suffix in the following cases:

1. The suffix S is used to indicate safety impacts.
2. The suffix R is used to indicate redundancy.

For example while 3 indicates that the item failure mode under consideration can lead to the consequences listed in category 3, 3R indicates that such consequences can occur only after the failure of all the redundant items.

Appendix 5.3. Failure effect list

The effects of DRCU failures are defined in regard with their impact on DRCU high-level functions. The undesirable events identified at DRCU level are classified according to the severity categories defined at section 5.2.

Possibilities of switching on the redundant chain are not taken into account in the following list.

DRCU functions	Failure effects	Severity	FMEA items
IF 1: To ensure the transfer and treatment of information between FPU and DPU modules (control and monitoring of observation data).	Loss of IF 1 (photometric data)	Critical - 2	2.9; 3.1; 3.2; 3.5; 4.1; 4.2; 4.3; 4.4; 5.14; 5.47; 5.48; 5.49; 5.51
	Loss of IF 1 (spectrometric data)	Critical - 2	2.9 Bis; 3.1 Bis; 3.2 Bis; 3.5 Bis; 4.1; 4.2; 4.3; 4.4; 5.46; 5.48; 5.49; 5.51
	Degradation of IF 1 (photometric data)	Major - 3	1.1; 1.2; 1.3; 2.1; 2.2; 2.3; 2.4; 2.5; 2.6; 2.8; 3.3; 3.4; 3.6; 3.7; 3.8; 3.9; 3.1; 3.11; 3.12
	Degradation of IF 1 (spectrometric data)	Major - 3	1.1 Bis; 1.2 Bis; 1.3 Bis; 2.1 Bis; 2.2 Bis; 2.3 Bis; Bis; 2.5 Bis; 2.6 Bis; 2.8 Bis; 3.3 Bis; 3.4 Bis; 3.6 Bis; 3.7 Bis; 3.8 Bis; 3.9 Bis; 3.10 Bis; 3.11 Bis; 3.12 Bis; 5.14 Bis
IF 2: To ensure the transfer and treatment of monitoring information of equipment between FPU and DPU modules.	Loss of IF 2	Critical - 2	4.1; 4.2; 4.3; 4.4; 5.1; 5.2; 5.3; 5.4; 5.5; 5.7; 5.8; 5.9; 5.1; 5.18; 5.19; 5.21; 5.22; 5.28; 5.29; 5.31; 5.32; 5.47
	Degradation of IF 2	Major - 3	5.7; 5.11; 5.12; 5.13; 5.15; 5.16; 5.17; 5.2; 5.23; 5.25; 5.26; 5.27; 5.28; 5.31
AF 5.2: To execute a calibration control of detectors at FPU level and to receive associated information	Loss of AF 5.2	Critical - 2	5.12; 5.14; 5.15
	Degradation of AF 5.2	Major - 3	5.13; 5.14 Bis; 5.16; 5.17
AF 5.3: To execute a control of the cooler at FPU level and to receive associated information	Loss of AF 5.3	Critical - 2	5.23; 5.26
	Degradation of AF 5.3	Major - 3	5.24; 5.25; 5.27; 5.28
AF 9: To transmit housekeeping information from SCU/PSU to DPU.	Loss of AF 9	Major - 3	5.1; 5.37; 5.39; 5.4; 5.41; 5.42; 5.43; 5.44
	Degradation of AF 9	Major - 3	5.34; 5.35; 5.36; 5.38; 5.45
All functions	Failure propagation inside DRCU	Major - 3	1.3; 1.3 Bis; 2.6; 2.6 Bis; 2.9; 2.9 Bis; 5.34; 5.37; 5.44; 5.49

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
1,1	DCU	LIA P	AF4.1.1 : To collect the analogue data coming from FPU, to demodulate them and to filter them	Loss of PSD + filter (among 32) of a LIA P board (electronic or connector failure)	Loss of a photometric scientific data sent to the DAQ (degraded IF1.1.1)	Reception by the DAQ of one of the 32 analogue channels degraded for treatment (digitalisation) and sending to the DPU (degraded IF1.1)	Loss of a photometric scientific data among a potential of 9*32 data (degraded IF1)	9 photometric LIA board Detection of the loss of the data during the analysis by the scientists	3	
1,1 Bis	DCU	LIA S	AF4.1.1 : To collect the analogue data coming from FPU, to demodulate them and to filter them	Loss of PSD + filter (among 24) of a LIA board (electronic or connector failure)	Loss of a spectrometric scientific data sent to the DAQ (degraded IF1.1.1)	Reception by the DAQ of one of the 24 analogue channels degraded for treatment (digitalisation) and sending to the DPU (degraded IF1.1)	Loss of a spectrometric scientific data among a potential of 3*24 data (degraded IF1)	3 spectrometric LIA board Detection of the loss of the data during the analysis by the scientists	3	
1,2		LIA P	AF4.1.2 : To multiplex and transfer the analogue data	Failure of a multiplexer 16 > 1 (among 2) of a LIA P board	Loss of 16 photometric scientific data sent to the DAQ (degraded IF1.1.1)	Loss of one of the 32 analogue channels (not sent to the DPU) (degraded IF1.1)	Loss of 16 photometric scientific data among a potential of 9*32 (degraded IF1)	2 multiplexers 16 > 1 per LIA P board Detection of the loss of the 16 data during the analysis by the scientists If the 3 chains of T/C measure (temperature) are used for the regulation of the bolometers (via control of the cooler), the distribution of the T/C must be such as the loss of a multiplexer 16 > 1 does not lead to the loss of the 3 chains of temperature. This distribution implies 3 distinct analogue channels towards the multiplexers 4 > 1 of DAQ module.	3	
1,2 Bis		LIA S	AF4.1.2 : To multiplex and transfer the analogue data	Failure of a multiplexer 12 > 1 (among 2) of a LIA board	Loss of 12 spectrometric scientific data sent to the DAQ (degraded IF1.1.1)	Loss of one of the 24 analogue channels (not sent to the DPU) (degraded IF1.1)	Loss of 12 spectrometric scientific data among a potential of 3*24 data (degraded IF1)	2 multiplexers 12 > 1 per LIA S board Detection of the loss of the 12 data during the analysis by the scientists	3	
1,3	DCU	LIA P	AF4.1.1 : To collect the analogue data coming from FPU, to demodulate them and to filter them AF4.1.2 : To multiplex and transfer the analogue data	Short circuit of a component Heating of a LIA P board following internal failure	Loss of 32 photometric scientific data sent to the DAQ (degraded IF1.1.1)	Loss of 2 of the 32 analogue channels (not sent to the DPU) (degraded IF1.1)	Loss of 32 photometric scientific data among a potential of 9*32 data (degraded IF1) Risk propagation of failure (PoF) towards the other LIA board by thermal propagation (degradation of the other LIA board) total Loss of the mission Photometer (loss of all the scientific data)	The LIA board are not redundant and cannot be controlled ON/OFF individually. The heating of a LIA board is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU. If the case of a risk of failure propagation towards the other LIA boards leading to a total loss of the scientific data is confirmed, each analogue module (LIA) must be individually commandable ON/OFF by means of low level commands. If the 3 chains of T/C measure (temperature) are used for the regulation of the bolometers (via control of the cooler), the distribution of the T/C must be such as the loss of a LIA board does not lead to the loss of the 3 chains of temperature.	3	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
1,3 Bis	DCU	LIA S	AF4.1.1 : Collect the analogue data coming from FPU, demodulate them and filter them AF4.1.2 : Multiplex and transfer the analogue data	Short circuit component Heating of a LIA board following internal failure	Loss of 24 spectrometric scientific data sent to the DAQ (degraded IF1.1.1)	Loss of 2 of the 24 analogue channels (not sent to the DPU) (degraded IF1.1)	Loss of 24 spectrometric scientific data among a potential of 3*24 data (degraded IF1) Risk of propagation of failure (PoF) towards the other LIA board by thermal propagation (degradation of the other LIA board). Total loss of the spectrometric mission (loss of all the scientific data)	The LIA board are not redundant and cannot be controlled ON/OFF individually. The heating of a LIA board is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU. If the case of a risk of failure propagation towards the other LIA boards leading to a total loss of the scientific data is confirmed, each analogue module (LIA) must be individually commandable ON/OFF by means of low level commands.	3	
2,1	DCU	BIAS	AF 4.2.2 : To adapt and transfer the analogue controls data (signal of modulation) towards the photometric or spectrometric detectors	Failure of one of the 4 Bias DAC dedicated to the photometric detectors: no transfer no adaptation of the signal (amplitude, frequency, gain)	No generation of corresponding analogue controls (degraded IF1.2.2)	No sending of analogue control to the photometric detectors of the FPU (degraded IF1.2)	Loss of all the data from the photometric detectors of the FPU towards the DPU (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Detection of the loss of the data during the analysis by the scientists The switching is carried out by the switching of supply " Primary power line " (28 V) at the satellite level. The switching procedure must be performed safely (shut off the blocks before switching of power supply). Potential problems with the Bistable relays.	3R	
2,1Bis	DCU	BIAS	AF 4.2.2 : To adapt and transfer the analogue controls data (signal of modulation) towards the photometric or spectrometric detectors	Failure of one of the 2 Bias DAC dedicated to the spectrometric detectors: no transfer no adaptation of the signal (amplitude, frequency, gain)	No generation of corresponding analogue controls (degraded IF1.2.2)	No sending of analogue control to the spectrometric detectors of the FPU (degraded IF1.2)	Loss of all the data from the spectrometric detector of the FPU towards the DPU (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Detection of the loss of the data during the analysis by the scientists The switching is carried out by the switching of supply " Primary power line " (28 V) at the satellite level. The switching procedure must be performed safely (shut off the blocks before switching of power supply). Potential problems with the Bistable relays.	3R	
2,2		BIAS	AF 4.2.2 : To adapt and transfer the analogue controls data (signal of modulation) towards the photometric or spectrometric detectors	Failure of one of the 4 Bias DAC dedicated to the photometric detectors: bad adaptation (amplitude), bad interpretation of the amplitude parameter emitted by the DAQ - I/F	No adaptation of the sinusoidal signal emitted by Sine DAC (amplitude of the signal corresponding to that of Sine DAC)	Transmission of a signal not adapted to the photometric detectors of the FPU (degraded IF1.2)	Loss of all the data from the photometric detectors of the FPU towards the DPU Risk of deterioration of the corresponding detectors (worst case; non compatible amplitude: double failure) (lost IF1)	Amplitude parameters sent by the DAQ - I/F in each Bias Dac are returned to the DPU (Housekeeping parameters). The value of amplitude issued from Bias DAC is not a Housekeeping parameter. In the case of the non adaptation of the signal is not compatible with detectors and lead to their deterioration, the second reading of the value of amplitude issued from Bias Dac and returned to DAQ I/F must lead to re-sent the nominal amplitude parameter towards Bias DAC at fault.	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
2,2 Bis		BIAS	AF 4.2.2 : To adapt and transfer the analogue controls data (signal of modulation) towards the photometric or spectrometric detectors	Failure of one of the 2 Bias DAC dedicated to the spectrometric detectors: bad adaptation (amplitude), bad interpretation of the amplitude parameter emitted by the DAQ - I/F	No adaptation of the sinusoidal signal emitted by Sine DAC (amplitude of the signal corresponding to that of Sine DAC)	Transmission of a signal not adapted on the spectrometric detectors of the FPU (degraded IF1.2)	Loss of all the data from the spectrometric detectors of the FPU towards the DPU Risk of deterioration of the corresponding detectors (worst case; non compatible amplitude: double failure) (lost IF1)	Amplitude parameters sent by the DAQ - I/F in each Bias Dac are returned to the DPU (Housekeeping parameters). The value of amplitude issued from Bias DAC is not a Housekeeping parameter. In the case of the non adaptation of the signal is not compatible with detectors and lead to their deterioration, the second reading of the value of amplitude issued from Bias Dac and returned to DAQ I/F must lead to re-sent the nominal amplitude parameter towards Bias DAC at fault.	3R	
2,3		BIAS	DF 3 : To ensure the sorting of information of control coming from DAQ	Failure of Bias Logic (no sorting, no transmission) dedicated to the photometric detectors	No generation of numerical controls relating to photometric detections towards: Sine Dac for modulation signal towards the detectors Bias DAC for the amplitude parameters Heater DACs for heating of the JFET box when starting JFET DACs for power supply of the JFET (lost IF1.2.2)	No sending towards the FPU of the analogue controls of modulation signal towards the detectors, value of amplitude, heating of the JFET box and power supply of the JFET (degraded IF1.2)	Loss of all the data from the photometric detectors of the FPU towards the DPU (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Idem item 2.1	3R	
2,3 Bis		BIAS	DF 3 : To ensure the sorting of information of control coming from DAQ	Failure of Bias Logic (no sorting, no transmission) dedicated to the spectrometric detectors	No generation of numerical controls relating to photometric detections towards: Sine Dac for modulation signal towards the detectors Bias DAC for the amplitude parameters Heater DACs for heating of the JFET box when starting JFET DACs for power supply of the JFET (lost IF1.2.2)	No sending towards the FPU of the analogue controls of signal of modulation towards the detectors, value of amplitude, heating of the JFET box and power supply of the JFET (degraded IF1.2)	Loss of all the data from the spectrometric detectors of the FPU towards the DPU (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Idem item 2.1	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
2,4		BIAS	DF 2 : To transfer the controling of specific amplitude to each Bias DAC	Failure of an output of Bias Logic: no transmission of an amplitude parameter relating to the signal of modulation of the photometric detectors	No generation of a numerical control relating to the photometric detectors towards Bias DAC (IF 1.2.2 degraded)	No sending towards the FPU of an analogue control of modulation signal towards the photometric detectors (degraded IF1.2)	Loss of all the data from the photometric detectors of the FPU towards the DPU (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	DAQ I/F transfers to each Bias DAC via Bias Logic, the value of amplitude of the signal to be generated for the modulation of the photometric detectors. It is considered that not sending the amplitude parameter by DAQ I/F in Bias DAC is interpreted like a null demand by corresponding Bias DAC. A bad interpretation of the demand by Bias DAC is treated at item 2.2 Detection and switching (idem item 2.1)	3R	
2,4 Bis		BIAS	DF 2 : To transfer the controling of specific amplitude to each Bias DAC	Failure of an output of Bias Logic: no transmission of an amplitude parameter relating to the signal of modulation of the spectrometric detectors	No generation of a numerical control relating to the spectrometric detectors towards Bias DAC (IF 1.2.2 degraded)	No sending towards the FPU of an analogue control of modulation signal towards the spectrometric detectors (degraded IF1.2)	Loss of all the data from the spectrometric detectors of the FPU towards the DPU (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	DAQ I/F transfers to each Bias DAC via Bias Logic, the value of amplitude of the signal to be generated for the modulation of the spectrometric detectors. It is considered that not sending the amplitude parameter by DAQ I/F in Bias DAC is interpreted like a null demand by corresponding Bias DAC. A bad interpretation of the demand by Bias DAC is treated at item 2.2 Detection and switching (idem item 2.1)	3R	
2,5	DCU	BIAS	AF 4.2.1 : To transfer the analogue controls data towards the heaters of the JFET box (power supply of the JFET box)	Failure of photometric Heater DAC: no signal, setting OFF inopportune	No generation of analogue controls towards the JFET Box (no power supply of the heaters) (degraded IF1.2.2)	No heating of the JFET Box during the starting of a sequence of acquisition (degraded IF1.2)	Loss of all the data from the photometric detectors of the FPU towards the DPU (worst case) (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Detection of non heating by the Housekeeping parameters of SCU Each heater is individually commandable ON/OFF by means of low level commands	3R	
2,5 Bis	DCU	BIAS	AF 4.2.1 : To transfer the analogue controls data towards the heaters of the JFET box (power supply of the JFET box)	Failure of spectrometric Heater DAC: no signal, setting OFF inopportune	No generation of analogue controls towards the JFET Box (no power supply of the heaters) (degraded IF1.2.2)	No heating of the JFET Box during the starting of a sequence of acquisition (degraded IF1.2)	Loss of all the data from the spectrometric detectors of the FPU towards the DPU (worst case) (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Detection of non heating by the Housekeeping parameters of SCU Each heater is individually commandable ON/OFF by means of low level commands	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
2,6	DCU	BIAS	AF 4.2.1 : To transfer the analogue controls data towards the heaters of the JFET box (power supply of the JFET box)	Failure of photometric Heater DAC: permanent signal	Permanent generation of the analogue controls towards the JFET Box (permanent power supply of the heaters) (degraded IF1.2.2)	Permanent heating of the JFET Box during the sequences of acquisition (degraded IF1.2)	Loss of all the data from the photometric detectors of the FPU towards the DPU (worst case) (lost IF1) Risk of loss of all the data of the FPU towards DPU by thermal propagation (IF 1 lost) Switching on the redundant chain of the DRCU to recover all information detectors	An excessive temperature at the level of the JFET box is detected by the Housekeeping parameters of SCU Each heater bias must be commandable ON/OFF independantly by means of low level commands (control envisaged).	3R	
2,6 Bis	DCU	BIAS	AF 4.2.1 : To transfer the analogue controls data towards the heaters of the JFET box (power supply of the JFET box)	Failure of spectrometric Heater DAC: permanent signal	Permanent generation of the analogue controls towards the JFET Box (permanent power supply of the heaters) (degraded IF1.2.2)	Permanent heating of the JFET Box during the sequences of acquisition (degraded IF1.2)	Loss of all the data from the spectrometric detectors of the FPU towards the DPU (worst case) (lost IF1) Risk of loss of all the data of the FPU towards DPU by thermal propagation (IF 1 lost) Switching on the redundant chain of the DRCU to recover all information detectors	An excessive temperature at the level of the JFET box is detected by the Housekeeping parameters of SCU Each heater bias must be commandable ON/OFF independantly by means of low level commands (control envisaged).	3R	
2,7		BIAS	AF 4.2.3 : To ensure the transfer of continuous powering control of the JFET Box to allow the return of measurement information	Failure of a JFET DACs (no power supply, insufficient power supply, setting OFF inopportune)	No generation of continuous power supply or generation of an insufficient continuous power supply (IF 1.2.2 degraded)	No power supply or insufficient power supply of 24 channels of 2 JFET corresponding to the photometric detectors (IF 1.2 degraded)	Loss of 24 scientific data among a potential of 12*24 data (degraded IF1) switching on the redundant chain of the DRCU to recover all information detectors	Each return channel of a detector is composed of 2 JFET (amplifying of current) A JFET DAC (12 photometric) supplies 24 channels of detectors Detection of the loss of the data during the analysis by the scientists Each JFET power channel is individually commandable ON/OFF by means of low level commands (protection against the failures of a JFET box)	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
2,7 Bis		BIAS	AF 4.2.3 : To ensure the transfer of continuous powering control of the JFET Box to allow the return of measurement information	Failure of a JFET DACs (no power supply, insufficient power supply, setting OFF inopportune)	No generation of continuous power supply or generation of an insufficient continuous power supply (IF 1.2.2 degraded)	No power supply or insufficient power supply of 24 channels of 2 JFET corresponding to the spectrometric detectors (IF 1.2 degraded)	Loss of 24 scientific data among a potential of 3*24 data (degraded IF1) switching on the redundant chain of the DRCU to recover all information detectors	Each return channel of a detector is composed of 2 JFET (amplifying of current) A JFET DAC (3 spectrometric) supplies 24 channels of detectors Detection of the loss of the data during the analysis by the scientists Each JFET power channel is individually commandable ON/OFF by means of low level commands (protection against the failures of a JFET box)	3R	
2,8	DCU	BIAS	DF 4 : To transform and ensure the transfer of the sinusoidal signals towards Bias DACs	Failure of Sine DAC: No generation of an analogue signal Bad adaptation (amplitude, frequency, gain)	No analogue generation of control towards the BIAS DACs corresponding to the photometric detectors (lost AF 4.2.2; IF 1.2.2 degraded)	No sending of analogue control to the photometric detector of the FPU (IF 1.2 degraded)	Loss of all the data from the photometric detectors of the FPU towards the DPU (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Detection of the loss of the data during the analysis by the scientists The switching is carried out by the switching of power supply " Primary power line " (28 V) at the satellite level The switching procedure must be performed safely (shut off the blocks before switching of power supply).	3R	
2,8 Bis	DCU	BIAS	DF 4 : To transform and ensure the transfer of the sinusoidal signals towards Bias DACs	Failure of Sine DAC: No generation of an analogue signal Bad adaptation (amplitude, frequency, gain)	No analogue generation of control towards the BIAS DACs corresponding to the spectrometric detectors (lost AF 4.2.2; IF 1.2.2 degraded)	No sending of analogue control to the spectrometric detector of the FPU (IF 1.2 degraded)	Loss of all the data from the spectrometric detectors of the FPU towards the DPU (lost IF1) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Detection of the loss of the data during the analysis by the scientists The switching is carried out by the switching of power supply " Primary power line " (28 V) at the satellite level The switching procedure must be performed safely (shut off the blocks before switching of power supply).	3R	
2,9		BIAS	DF 4 : To transform and ensure the transfer of the sinusoidal signals towards Bias DACs	Heating of a Bias board (nominal or redundant) following internal failure	No generation of the numerical controls relating to the photometric detectors (IF 1.2.2 lost)	No sending towards the FPU of the analogue controls of modulation signal towards the photometric detectors (lost IF1.2)	Loss of all the data of the photometric detectors (IF 1 lost) Risk of propagation of failure (PoF) towards the other boards of the DRCU by thermal propagation (degradation of other DRCU boards). Total loss of the mission (loss of all the scientific data)	The Bias boards are redundant. The heating of a BIAS board is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU. To avoid the thermal propagation towards other boards, it is necessary to insulate the board at fault quickly (cut off its supply via switch ON/OFF controlled by the SCU) and to switch on the redundant chain of the DRCU (except LIA) to recover all detectors data	2	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
2,9 Bis		BIAS	DF 4 : To transform and ensure the transfer of the sinusoidal signals towards Bias DACs	Heating of a Bias board (nominal or redundant) following internal failure	No generation of the numerical controls relating to the spectrometric detectors (IF 1.2.2 lost)	No sending towards the FPU of the analogue controls of modulation signal towards the spectrometric detectors (lost IF1.2)	Loss of all the data of the spectrometric detectors (IF 1 lost) Risk of propagation of failure (PoF) towards the other boards of the DRCU by thermal propagation (degradation of other DRCU boards). Total loss of the mission (loss of all the scientific data)	The Bias boards are redundant. The heating of a BIAS board is detected by a specific temperature measurement (Housekeeping parameters) returned towards the DPU. To avoid the thermal propagation towards other boards, it is necessary to insulate the board at fault quickly (cut off its supply via switch ON/OFF controlled by the SCU) and to switch on the redundant chain of the DRCU (except LIA) to recover all detectors data	2	
3,1		DAQ	AF 3.1.1 : To collect the numerical data of control coming from DPU	Failure of the DAQ - I/F (electronic or connector failure)	No reception of numerical information coming from DPU (IF 1.2.1 lost)	No generation of numerical controls relating to photometric detections towards the corresponding BIAS (Sine DAC, Heater DACs and JFET DACs) (IF 1.2 lost) No reception of the treated data (digitalisation) relating to the photometric detectors (IF 1.1 lost)	Loss of the 288 photometric scientific data of FPU towards DPU (IF 1 lost) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	Idem item 2.1	2R	
3,1Bis		DAQ	AF 3.1.1 : To collect the numerical data of control coming from DPU	Failure of the DAQ - I/F (electronic or connector failure)	No reception of numerical information coming from DPU (IF 1.2.1 lost)	No generation of numerical controls relating to spectrometric detections towards the corresponding BIAS (Sine DAC, Heater DACs and JFET DACs) (IF 1.2 lost) No reception of the treated data (digitalisation) relating to the spectrometric detectors (IF 1.1 lost)	Loss of the 72 spectrometric scientific data of FPU towards DPU (IF 1 lost) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	Idem item 2.1Bis	2R	
3,2	DCU	DAQ	AF 3.1.2 : To transfer the numerical data towards the BIAS	Failure of the DAQ - I/F (electronic or connector failure)	No generation of numerical controls towards Bias Logic of BIAS module (Sine DAC, Heater DACs and JFET DACs) (IF 1.2.1 lost)	No sending towards the FPU of the analogue modulation controls towards the detectors, heating controls of the JFET Box and power supply controls of the JFET (IF 1.2 lost)	Loss of the 288 photometric scientific data of FPU towards DPU (IF 1 lost) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	Idem item 2.1	2R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
3,2 bis	DCU	DAQ	AF 3.1.2 : To transfer the numerical data towards the BIAS	Failure of the DAQ - I/F (electronic or connector failure)	No generation of numerical controls towards Bias Logic of BIAS module (Sine DAC, Heater DACs and JFET DACs) (IF 1.2.1 lost)	No sending towards the FPU of the analogue modulation controls towards the detectors, heating controls of the JFET Box and power supply controls of the JFET (IF 1.2 lost)	Loss of the 72 spectrometric scientific data of FPU towards DPU (IF 1 lost) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	Idem item 2.1	2R	
3,3		DAQ	AF 3.1.2 : To transfer the numerical data towards the BIAS	Failure of DAQ I/F: bad amplitude parameter sent towards Bias DAC	Generation of an erroneous amplitude demand towards photometric Bias DAC (IF 1.2.1 degraded)	Transmission of a signal not adapted to a photometric detector of the FPU (degraded IF1.2)	Loss of all the data from the photometric detectors of the FPU towards the DPU (lost IF1) Risk of deterioration of the corresponding detectors (worst case; not compatible amplitude) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Amplitude parameters sent by the DAQ - I/F to each Bias Dac are returned to the DPU (Housekeeping parameters) following a DPU request . It should be noted that according to the failure mode (failure of output stages of DAQ I/F), the sending of a null amplitude demand by the DPU towards DAQ I/F is without effect	3R	
3,3 bis		DAQ	AF 3.1.2 : To transfer the numerical data towards the BIAS	Failure of DAQ I/F: bad amplitude parameter sent towards Bias DAC	Generation of an erroneous amplitude demand towards spectrometric Bias DAC (IF 1.2.1 degraded)	Transmission of a signal not adapted to a spectrometric detector of the FPU (degraded IF1.2)	Loss of all the data from the spectrometric detectors of the FPU towards the DPU (lost IF1) Risk of deterioration of the corresponding detectors (worst case; not compatible amplitude) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Amplitude parameters sent by the DAQ - I/F to each Bias Dac are returned to the DPU (Housekeeping parameters) following a DPU request . It should be noted that according to the failure mode (failure of output stages of DAQ I/F), the sending of a null amplitude demand by the DPU towards DAQ I/F is without effect	3R	
3,4		DAQ	AF 3.1.3 : To ensure the demodulation of analogue information at the LIA modules level	Loss or degradation of one of the 4 demodulation signals (failure of the DAQ - I/F; electronic or connector failure)	No sending of the demodulation signal towards LIA for the photometric detectors (IF 1.1.2 degraded)	No demodulation of the data received from the FPU relating to the photometric detectors (IF 1.1 degraded)	Loss of the data from the photometric detectors of the FPU towards the DPU (IF 1 degraded) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Idem item 2.1	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
3,4 Bis		DAQ	AF 3.1.3 : To ensure the demodulation of analogue information at the LIA modules level	Loss or degradation of one of the 2 demodulation signals (failure of the DAQ - I/F; electronic or connector failure)	No sending of the demodulation signal towards LIA for the spectrometric detectors (IF 1.1.2 degraded)	No demodulation of the data received from the FPU relating to the spectrometric detectors (IF 1.1 degraded)	Loss of the data from the spectrometric detectors of the FPU towards the DPU (IF 1 degraded) Need for switching on the redundant chain of the DRCU (except LIA) to recover all detectors data	Idem item 2.1	3R	
3,5		DAQ	AF 3.2.1 : To transfer the digitized data towards DPU	Failure of the DAQ - I/F (electronic or connector failure)	No numerical data processing for transfer to the DPU (IF 1.1.2 lost)	No transfer of the numerical data towards the DPU (IF 1.1 lost)	Loss of the 288 photometric scientific data from FPU towards DPU (IF 1 lost) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	Idem item 2.1	2R	
3,5 Bis		DAQ	AF 3.2.1 : To transfer the digitized data towards DPU	Failure of the DAQ - I/F (electronic or connector failure)	No numerical data processing for transfer to the DPU (IF 1.1.2 lost)	No transfer of the numerical data towards the DPU (IF 1.1 lost)	Loss of the 72 spectrometric scientific data from FPU towards DPU (IF 1 lost) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	Idem item 2.1	2R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
3,6	DCU	DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of a multiplexer 4 > 1 (among 6)	Loss of 3 analogue channels of 16 photometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 3 analogue channels of data among 18 (IF 1.1 degraded)	Loss of 48 photometric data among 288 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	6 multiplexers of 4 analogue channels of 16 data each (9 channels for P250, 6 for P350, 3 for P500, 4 for SW and 2 for LW; i.e. a total of 24 channels). Spectrometric channels are distributed on the 6 multiplexers. According to the distribution of the photometric analogue channels in input of the multiplexer, the loss of a multiplexer can lead to the loss of all the data of a type of detector (ex: loss of all the data of P500, if the 3 P500 channels are on the same multiplexer). A judicious distribution of the analogue channels could make possible to preserve data of each type of detector without switching on the redundant chain. The distribution will be carried out according to the priorities fixed by the scientists. If the 3 chains of T/C measuring (temperature) are used for the regulation of bolometers (via control of the cooler) and if each chain is segregated at the analogue channels level (see item 1.2), the distribution of the 3 analogue channels must be such as the loss of a multiplexer 4 > 1 does not lead to the loss of the 3 chains of temperature.	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
3,6 Bis	DCU	DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of a multiplexer 4 > 1 (among 6)	Loss of an analogue channel of 16 spectrometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 1 analogue channel of data among 6 (IF 1.1 degraded)	Loss of 16 spectrometric data among 72 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	6 multiplexers of 4 analogue channels of 16 data each (9 channels for P250, 6 for P350, 3 for P500, 4 for SW and 2 for LW; i.e. a total of 24 channels). Spectrometric channels are distributed on the 6 multiplexers. According to the distribution of the photometric analogue channels in input of the multiplexer, the loss of a multiplexer can lead to the loss of all the data of a type of detector (ex: loss of all the data of P500, if the 3 P500 channels are on the same multiplexer). A judicious distribution of the analogue channels could make possible to preserve data of each type of detector without switching on the redundant chain. The distribution will be carried out according to the priorities fixed by the scientists. If the 3 chains of T/C measuring (temperature) are used for the regulation of bolometers (via control of the cooler) and if each chain is segregated at the analogue channels level (see item 1.2), the distribution of the 3 analogue channels must be such as the loss of a multiplexer 4 > 1 does not lead to the loss of the 3 chains of temperature.	3R	
3,7	DCU	DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an OFFSET of an analogue channel among 6	No reduction of the noise relating to the 3 analogue channels of 16 photometric data Digitalisation of an analogue signal " disturbed " by the coder after amplification (IF 1.1.2 degraded)	Transfer of degraded numerical data towards the DPU (IF 1.1 degraded)	Sending of degraded data from FPU towards DPU: 48 photometric data among 288 (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	1 OFFSET by analogue / numerical coder	3R	
3,7 Bis	DCU	DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an OFFSET of an analogue channel among 6	No reduction of the noise relating to the 3 analogue channels of 16 spectrometric data Digitalisation of an analogue signal " disturbed " by the coder after amplification (IF 1.1.2 degraded)	Transfer of degraded numerical data towards the DPU (IF 1.1 degraded)	Sending of degraded data from FPU towards DPU: 16 spectrometric data among 72 (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	1 OFFSET by analogue / numerical coder	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
3,8		DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an OFFSET of an analogue channel among 6 : no transmission of the signal	Loss of 3 analogue channels of 16 photometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 3 analogue channels of data among 18 (IF 1.1 degraded)	Loss of 48 photometric data among 288 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission		3R	
3,8 Bis		DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an OFFSET of an analogue channel among 6 : no transmission of the signal	Loss of 3 analogue channels of an analogue channel of 16 spectrometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 1 analogue channel of data among 6 (IF 1.1 degraded)	Loss of 16 spectrometric data among 72 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission		3R	
3,9	DCU	DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an amplifier of an analogue channel among 6: bad amplification	Transfer for digitalisation of a " low " signal relating to the 3 analogue channels of 16 photometric data Digitalisation of an analogue signal badly amplified by the coder (IF 1.1.2 degraded)	Transfer of numerical data degraded towards the DPU (IF 1.1 degraded)	Sending of degraded data from FPU towards DPU: 48 photometric data among 288 (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	1 amplifier by analogue / numerical coder Non amplification of the signal leads to its non digitalisation (signal not in the dynamic range of the coder) and, consequently to the loss of the data (see item 3.10)	3R	
3,9 Bis	DCU	DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an amplifier of an analogue channel among 6: bad amplification	Transfer for digitalisation of a " low " signal relating to the analogue channel of 16 spectrometric data Digitalisation of an analogue signal badly amplified by the coder (IF 1.1.2 degraded)	Transfer of numerical data degraded towards the DPU (IF 1.1 degraded)	Sending of degraded data of FPU towards DPU: 16 spectrometric data among 72 (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	1 amplifier by analogue / numerical coder Non amplification of the signal leads to its non digitalisation (signal not in the dynamic range of the coder) and, consequently to the loss of the data (see item 3.10)	3R	
3,10.		DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an amplifier of an analogue channel among 6: no transmission of the signal	Loss of 3 analogue channels of 16 photometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 3 analogue channels of data among 18 (IF 1.1 degraded)	Loss of 48 photometric data among 288 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission		3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
3,10 Bis		DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an amplifier of an analogue channel among 6: no transmission of the signal	Loss of an analogue channel of 16 spectrometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 1 analogue channel of data among 6 (IF 1.1 degraded)	Loss of 16 spectrometric data among 72 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission		3R	
3,11	DCU	DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an analogue / numerical coder among 6 (no digitalisation of the data detector)	Loss of 3 analogue channels of 16 photometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 3 analogue channels of data among 18 (IF 1.1 degraded)	Loss of 48 photometric data among 288 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission		3R	
3,11Bis	DCU	DAQ	AF 3.2.2 : To collect the analogue data demodulated, filtered and multiplexed by LIA	Failure of an analogue / numerical coder among 6 (no digitalisation of the data detector)	Loss of an analogue channel of 16 spectrometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 1 analogue channel of data among 6 (IF 1.1 degraded)	Loss of 16 spectrometric data among 72 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission		3R	
3,12		DAQ	DF 1 : To transfer the numerical message outgoing from MTIM module towards DAQ I/F	Failure of an analogue / numerical coder (no transfer of the digitized data) or failure of a DAQ - I/F input	Loss of 3 analogue channels of 16 photometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 3 analogue channels of data among 18 (IF 1.1 degraded)	Loss of 48 photometric data among 288 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	At the level of the DAQ - I/F, the 6 inputs relating to the 6 A/D converters are distinct	3R	
3,12 Bis		DAQ	DF 1 : To transfer the numerical message outgoing from MTIM module towards DAQ I/F	Failure of an analogue / numerical coder (no transfer of the digitized data) or failure of a DAQ - I/F input	Loss of an analogue channel of 16 spectrometric data (IF 1.1.2 degraded)	No transfer of the numerical data relating to 1 analogue channel of data among 6 (IF 1.1 degraded)	Loss of 16 spectrometric data among 72 from FPU towards DPU (IF 1 degraded) Require switching on the redundant chain of the DRCU (except LIA) to recover the mission	At the level of the DAQ - I/F, the 6 inputs relating to the 6 A/D converters are distinct	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
4,1	PSU	PSU	AF1.1 : To collect the electric power coming from S/C	Failure of a protection of the power supply bar, feeder or primary of the converter (open circuit)	Loss of power supply of a DC/DC converter of equipment (LIA-S, LIA-P, BIA-S, BIA-P, DAQ or SCU)	Loss of power supply of a module of the DCU (LIA, BIA, DAQ) (IF 1.1 and/or IF 1.2 lost) Loss of power supply of SCU module (IF 2.1, IF 2.2 and/or IF 2.3 lost)	Loss of all the scientific data issued from a type of detector of the FPU towards the DPU (lost IF1) Loss of the control functions (Housekeeping monitorings, calibration...) of DPU towards FPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover the lost functions	Each PSU DC/DC converter shall have an independant electrical interface with the satellite power bus The short circuit located upstream of the secondary leads to the release of the protection of the power supply bar (module S/C) The loss of a secondary voltage is detected by the SCU (Housekeeping parameters) The switching is carried out by the switching of power supply " Primary power line " (28V) at the satellite level.	2R	
4,2		PSU	AF 1.2 : To transfer the electric power for distribution to the modules of the DRCU	Failure of the secondary of the transformer (open circuit)	Loss of power supply of equipment (LIA-S, LIA-P, BIA-S, BIA-P, DAQ or SCU)	Idem item 4.1	Idem item 4.1	Idem item 4.1	2R	
4,3	PSU	PSU	AF 1.2 : To transfer the electric power for distribution to the modules of the DRCU	Failure of the secondary of the transformer (short-circuit)	Loss of power supply of equipment (LIA-S, LIA-P, BIA-S, BIA-P, DAQ or SCU)	Idem item 4.1	Idem item 4.1	The power supply bar must be protected from short-circuit of a converter. This protection will be located as upstream as possible (preferably in specific equipment near to the generation / regulation / storage part).	2R	
4,4	PSU	PSU	AF 1.2 : To transfer the electric power for distribution to the modules of the DRCU	Overvoltage at output of the converter (short circuit of coils of the secondary)	Degradation of equipment following an overvoltage at output of converter	Deterioration of equipment of DCU module (LIA, BIA, DAQ) (IF 1.1 and/or IF 1.2 lost) Deterioration of equipment of SCU module (IF 2.1, IF 2.2 and/or IF 2.3 lost)	Loss of all the scientific data issued from a type of detector of the FPU towards the DPU (lost IF1) Loss of the control functions (Housekeeping monitorings, calibration...) from DPU towards FPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover the lost functions The deterioration of the LIA blocks (9 photometric or 3 spectrometric) leads to the final loss of the corresponding data.	An overvoltage at output of the converter is detected by the secondary voltages (Housekeeping parameters of SCU). The detection of the secondary voltages could be located upstream of ON/OFF powering relays in order to guarantee the nominal voltage before the setting ON of the equipment. This implies that the DPU requests for the interrogation of the secondary voltages before controling (via the SCU) the powering relays of the equipment. There is an overvoltage detection corresponding to nominal +10 %.	2R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
4,5	PSU	PSU	AF 1.2 : To transfer the electric power for distribution to the modules of the DRCU	Too important inrush current at the starting of equipment	/	/	Risk of collapse of the power supply bar of the satellite (PoF)	To be envisaged: a limiting device of inrush current in input of the converter However a progressive powering is considered. Moreover, the position of ON/OFF powering relays must be guaranteed before the powering of the "Primary power line (28V)" at the satellite level; i.e. the powering relays of the equipment must be in position OFF before their powering (see items related to function DF 4).	TBD	
5,1	SCU	SCU	AF 2.1 : To take delivery of information of control coming from DPU	Failure of the SCU Control Logic (failure of the input stage)	No reception of numerical information coming from DPU No generation of controls towards the support functions	No generation of numerical control relative: with the calibration (IF 2.2 lost) with the cooler (IF 2.3 lost) No generation of analogue control relative: with the temperatures of equipment FPU (IF 2.1 lost) with the secondary voltage and SCU/PSU temperature probes (lost AF 9) with switching ON/OFF of the equipment	Loss of the control functions (housekeeping, calibration, cooler...) from DPU towards FPU Loss of monitoring information of the equipment from FPU towards DPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover the control and monitoring information	The failure of a SCU control logic is detected by the loss of all information at the DPU level: calibration, cooler, secondary voltages, housekeeping parameters. The switching on the redundant chain is carried out by the switching of power supply " Primary power line " (28 V) at the satellite level .	3R	
5,2		SCU	AF 2.2 : To ensure the return of information in answer to a DPU request	Failure of the SCU Control Logic (failure of the output stage towards DPU)	No transfer of monitoring information from the FPU, PSU and internal information of SCU, towards DPU	No sending of monitoring information relative to: the temperatures of equipment FPU (IF 2.1 lost) the calibration (IF 2.2 lost) the cooler (IF 2.3 lost) the secondary voltage and SCU/PSU temperature probes (lost AF 9) towards the DPU	Loss of monitoring information of the equipment from FPU towards DPU (IF 2 lost) Loss of Housekeeping information towards DPU (lost AF 9) Need for switching on the redundant chain of the DRCU to recover monitoring information	The failure of a SCU control logic is detected by the loss of all information at the DPU level: calibration, cooler, secondary voltages, housekeeping parameters.	3R	
5,3	SCU	SCU	AF 5.1 : To make carry out a control of temperature monitoring at the FPU level and ensure the return of corresponding information	Failure of T°C probe electronic module (intrinsic failure, inopportune switching off by a low level command, no power supply of probes, open circuit on a current limitation resistor)	No reception of one or more temperature measurements (among 16)	No sending of temperature information towards DPU (IF 2.1 lost)	Loss of the temperature monitoring information of the equipment from FPU towards DPU (worst case) (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover temperature information	The controls of temperature monitoring are systematic. The temperature sensors are supplied by the SCU harness. Bias currents are individually and by a low level command switched off. The loss of temperature monitoring information is detected by the DPU.	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,4	SCU	SCU	AF 5.1 : To make carry out a control of temperature monitoring at the FPU level and ensure the return of corresponding information	Failure of T°C probe electronic module : too important bias current following short circuit or reduction in the resistivity of resistor dedicated to the limitation of current	Transmission of a signal not adapted towards a temperature sensor	Transmission of a signal not adapted towards a temperature sensor (IF 2.1 lost)	Loss of a temperature monitoring data of the equipment from FPU towards DPU (worst case) (IF 2 lost) Risk of deterioration of the corresponding temperature sensor (worst case: bias current not compatible) Risk of self-heating of probe (thermal dissipation), and consequently heating of the other equipment of FPU. See whether it requires to switch on the redundant chain of the DRCU.	Bias currents are individually and by a low level command switched off . A short-circuit at the level of a probe is protected by a current limitation resistor. A reduction in the resistivity is detected a priori by the DPU (non-coherent value of temperature) and must result in insulating the chain. The rise in temperature of the other equipment of FPU is detected by the DPU, and must lead to a period of setting off the DRCU, so that the equipment go down again in temperature. It is necessary to define the prerogatives of switching on the redundant DRCU according to the loss of only one temperature probe.	2	
5,5		SCU	DF 9 : Transfer of information between the Temperature control electronic module and the SCU control logic	Failure of T°C probe electronic module (intrinsic failure, failure of output stages towards DPU)	No sending of information of temperature towards the multiplexer 25 > 1	No sending of information of temperature towards DPU (IF 2.1 lost)	Loss of a temperature monitoring data of the equipment from FPU towards DPU (worst case) (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover information of temperature	The loss of temperature monitoring information is detected by the DPU.	3R	
5,6	SCU	SCU	DF 9 : Transfer of information between the Temperature control electronic module and the SCU control logic	Failure of the multiplexer 25>1	No sending of information related to temperature, calibration and cooler, towards thermistor A/D for digitalisation (lost DF 7 and DF 8)	No sending of information related to temperature, calibration and cooler, towards DPU (IF 2.1, IF 2.2, IF 2.3 lost)	Loss of monitoring information of the equipment from FPU towards DPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover monitoring information.	The loss of temperature monitoring information is detected by the DPU.	3R	
5,7		SCU	DF 9 : Transfer of information between the Temperature control electronic module and the SCU control logic	Failure of the amplifier located downstream from the multiplexer 25 > 1: bad amplification	Transfer for digitalisation by thermistors A/D of a " low " signal relating to the 25 analogue channels (16 temperature, 6 calibration and 3 cooler) (degraded DF 7 and DF 8) Digitalisation of an analogue signal badly amplified by the coder	Transfer of degraded numerical monitoring data towards DPU (IF 2.1, IF 2.2, IF 2.3 degraded)	Sending of degraded monitoring information from FPU towards DPU (degraded IF2) Need for switching on the redundant chain of the DRCU to recover monitoring information.	The degraded reception of monitoring information is detected by the DPU.	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,8		SCU	DF 9 : Transfer of information between the Temperature control electronic module and the SCU control logic	Failure of the amplifier located downstream from the multiplexer 25 > 1: no transmission of the signal	No sending of information related to temperature, calibration and cooler, towards thermistor A/D for digitalisation (lost DF 7 and DF 8)	No sending of information related to temperature, calibration and cooler, towards DPU (IF 2.1, IF 2.2, IF 2.3 lost)	Loss of monitoring information of the equipment from FPU towards DPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover monitoring information.	The loss of monitoring information is detected by the DPU. Non amplification of the signal leads to its non digitalisation (signal out of the dynamic range of the coder), and consequently to the loss of the data (see item 5.9)	3R	
5,9	SCU	SCU	DF 9 : Transfer of information between the Temperature control electronic module and the SCU control logic	Failure of the N/A converter of thermistors AD (no digitalisation of information related to temperature, calibration and cooler, or no transfer to the SCU Control Logic) Failure of the SCU Control Logic (failure of the input stage associated with thermistors A/D)	Loss of information related to the monitoring of temperatures, calibration and cooler (lost DF 7 and DF 8)	No sending of information related to temperature, calibration and cooler, towards DPU (IF 2.1, IF 2.2, IF 2.3 lost)	Loss of monitoring information of the equipment from FPU towards DPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover monitoring information.	The loss of monitoring information is detected by the DPU. The failures of the SCU Control Logic components in interface with the DPU are analysed in items 5.1 and 5.2	3R	
5,10.		SCU	DF 12 : To transmit the setting parameters (sampling rate) of the SCU control logic for the reception of information related to temperature, calibration and cooler	Failure of the Acquisition Sequencer module (no transmission of the sample rate)	No sending of information related to temperature, calibration and cooler towards the multiplexer 25 > 1	No sending of information related to temperature, calibration and cooler, towards DPU (IF 2.1, IF 2.2, IF 2.3 lost)	Loss of monitoring information of the equipment from FPU towards DPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover monitoring information.	The packages of measurements are sent to the SCU according to the sample rate following a DPU request. All the acquisition chains are sampled at the same rate.	3R	
5,11	SCU	SCU	DF 12 : To transmit the setting parameters (sampling rate) of the SCU control logic for the reception of information related to temperature, calibration and cooler	Failure of the Acquisition Sequencer module (erroneous sample rate)	Sending of information related to temperature, calibration and cooler towards the multiplexer 25 > 1 with an erroneous sample rate	Sending of information related to temperature, calibration and cooler towards DPU with a sample rate different from that expected (IF 2.1, IF 2.2, IF 2.3 degraded)	Risk of use of erroneous information of equipment monitoring, from FPU towards DPU (IF 2 degraded) Risk of late detection of an anomaly on equipment of the FPU (if sample rate lower than that specified) (IF 2 degraded)	The sample rate is sent by the SCU following a DPU request. All the chains of acquisition are sampled at the same rate. The DPU can acquire information with a sample rate not corresponding to its request, but it cannot diagnose the anomaly. The DPU detects the loss of expected information. In this case, it is necessary to switch on the redundant chain of the DRCU to recover all information. A too high acquisition frequency which could lead to a risk of overflow, can disturb the treatment of the tasks and their realization by the DPU.	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,12	SCU	SCU	AF 5.2 : To make carry out a control of calibration of the detectors at the FPU level and ensure the return of corresponding information	Failure of a DAC (among 3) of the calibration module (no generation of an analogue signal)	No generation of control towards a calibration heater (1 photometric and 2 spectrometric)	No generation of analogue control relating to a calibration heater (IF 2.2 degraded)	Loss of the controls and the monitoring information of a calibration heater from DPU towards FPU (IF 2 degraded) Need for switching on the redundant chain of the DRCU to recover information of calibration Degradation of the spectrometric mission because of lack of reference (PoF)	For photometer calibrator, bias power is controlled by a low level command. For spectrometer calibrators, bias current are controlled by means of a low level command. The controls of calibration monitoring are systematic. Each DAC receives a demand of numerical current issued from the SCU following a DPU request. The loss of information (U and I) of calibration monitoring is detected by the DPU.	2R	
5,13		SCU	AF 5.2 : To make carry out a control of calibration of the detectors at the FPU level and ensure the return of corresponding information	Failure of a DAC (among 3) of the calibration module (bad adaptation, bad interpretation of the demand)	Sending of a current not adapted towards the corresponding amplifier	Sending of a current not adapted to a heater calibrator of the FPU (IF 2.2 degraded)	Loss of the controls and the monitoring information of a calibration heater from DPU towards FPU (IF 2 degraded) Need for switching on the redundant chain of the DRCU to recover information of calibration	The sending of a current not adapted towards a heater calibrator is detected by the DPU. The value of analogue current is retransmitted to the DPU (consistency check between the demand and the reread value). If a bad adaptation of the non compatible current of a heater leads to its deterioration, the rereading of the the current value must lead to the sending of a null current demand by the DPU. There is a limitation of current on the calibrators.	3R	
5,14	SCU	SCU	AF 5.2 : To make carry out a control of calibration of the detectors at the FPU level and ensure the return of corresponding information	Failure of an AOP or a DAC (among 3) of the calibration module (sending of a constant demand of setting ON of the Photometric calibrator)	Permanent control ON on the output of the calibration control module	Sending of a uninterrupted current on a heater calibrator of the FPU (IF 2,2 degraded)	Permanent calibration of the photometric detectors. Impossible measurement (IF 1 Lost)	Loss of the photometric mission because the detectors are masked by the source of calibration (PoF). Need for envisaging a control of setting OFF the source of calibration.	2R	
5,14 Bis	SCU	SCU	AF 5.2 : To make carry out a control of calibration of the detectors at the FPU level and ensure the return of corresponding information	Failure of an AOP or a DAC (among 3) of the calibration module (no generation of an analogue signal to the Spectrometric calibrator)	Permanent control OFF on the output of the calibration control module	No generation of an analogue control relating to a calibration heater (IF 2.2 degraded)	Slow degradation of the calibration of the Spectrometric detectors. (IF 1 degraded)		3R	
5,15	SCU	SCU	AF 5.2 : To make carry out a control of calibration of the detectors at the FPU level and ensure the return of corresponding information	Failure of an AOP (among 3) of the calibration module (No generation of an analogue signal)	Idem item 5.12	Idem item 5.12	Idem item 5.12	Idem item 5.12	2R	
5,16		SCU	AF 5.2 : To make carry out a control of calibration of the detectors at the FPU level and ensure the return of corresponding information	Failure of an AOP (among 3) of the calibration module (bad adaptation, bad interpretation of the demand)	Idem item 5.13	Idem item 5.13	Idem item 5.13	Idem item 5.13	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,17		SCU	AF 5.2 : To make carry out a control of calibration of the detectors at the FPU level and ensure the return of corresponding information	Failure of a DAC/AOP (among 3) of the calibration module (failure of the input stage in interface with FPU)	No reception of the tension and current measurement of a heater calibrator	No sending of information of a heater calibrator towards DPU (IF 2.2 degraded)	Loss of 2 monitoring information of a heater calibrator (IF 2 degraded) Need for switching on the redundant chain of the DRCU to recover the 2 information of a heater calibrator		3R	
5,18	SCU	SCU	DF 8 : Transfer of information between calibration monitoring and SCU Control Logic module	Failure of the calibration control module (intrinsic failure, failure of the output stage in interface with DPU)	No sending of calibration information towards the multiplexer 25 > 1	No sending of calibration information towards DPU (IF 2.2 lost)	Loss of monitoring information of the FPU calibration towards DPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover information of temperature	The loss of calibration information is detected by the DPU.	3R	
5,19		SCU	DF 8 : Transfer of information between calibration monitoring and SCU Control Logic module	Failure of the multiplexer 25>1	Idem item 5.6 (DF 9 also lost)	Idem item 5.6	Idem item 5.6	Idem item 5.6	3R	
5,20.		SCU	DF 8 : Transfer of information between calibration monitoring and SCU Control Logic module	Failure of the amplifier located downstream from the multiplexer 25 > 1: bad amplification	Idem item 5.7 (DF 9 also lost)	Idem item 5.7	Idem item 5.7	Idem item 5.7	3R	
5,21		SCU	DF 8 : Transfer of information between calibration monitoring and SCU Control Logic module	Failure of the amplifier located downstream from the multiplexer 25 > 1: no transmission of the signal	Idem item 5.8 (DF 9 also lost)	Idem item 5.8	Idem item 5.8	Idem item 5.8	3R	
5,22	SCU	SCU	DF 8 : Transfer of information between calibration monitoring and SCU Control Logic module	Failure of the N/A converter of thermistors AD (no digitalisation of information related to temperature, calibration and cooler, or no transfer to the SCU Control Logic) Failure of the SCU Control Logic (failure of the input stage associated with thermistors A/D)	Idem item 5.9 (DF 9 also lost)	Idem item 5.9	Idem item 5.9	Idem item 5.9	3R	
5,23	SCU	SCU	AF 5.3 : To make carry out an control on the level of the cooler and ensure the return of corresponding information	Failure of a DAC / AOP (among 3) of the cooler control module (no generation of an analogue signal)	No generation of a ON control control towards HSE	No generation of an control to the cooler (control ON of HSE) (AF 5.3 lost)	Loss of the cryocooler functionality. Loss of all observation data. (IF 1 lost) Need for switching on the redundant chain of the DRCU to recover the control of the cooler	Redundancy of coolers. The controls of control of the cooler are systematic. Each DAC receives an demand of numerical current issued from the SCU following a request DPU. The loss of the monitoring voltage information of each heater of the cooler is detected by the DPU.	2R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,24	SCU	SCU	AF 5.3 : To make carry out an control on the level of the cooler and ensure the return of corresponding information	Failure of a DAC / AOP (among 3) of the cooler control module (no generation of an analogue signal)	No generation of a OFF control control towards HSE	No generation of an control to the cooler (control OFF of HSE) (AF 5.3 lost)	Recycling impossible to perform at the cooler level: reduction of the mission duration. Degradation of observation data. (IF 1 degraded) Need for switching on the redundant chain of the DRCU to recover the control of the cooler	The controls of control of the cooler are systematic. Each DAC receives an demand of numerical current issued from the SCU following a request DPU. The loss of the monitoring voltage information of each heater of the cooler is detected by the DPU.	3R	
5,25	SCU	SCU	AF 5.3 : To make carry out an control on the level of the cooler and ensure the return of corresponding information	Failure of a DAC / AOP (among 3) of the cooler control module (no generation of an analogue signal)	No generation of a ON control control towards HSP	No generation of an control to the cooler (control ON of HSP) (AF 5.3 lost)	Recycling impossible to perform at the cooler level: reduction of the mission duration. Degradation of observation data. (IF 1 degraded) Need for switching on the redundant chain of the DRCU to recover the control of the cooler	The controls of control of the cooler are systematic. Each DAC receives an demand of numerical current issued from the SCU following a request DPU. The loss of the monitoring voltage information of each heater of the cooler is detected by the DPU.	3R	
5,26	SCU	SCU	AF 5.3 : To make carry out an control on the level of the cooler and ensure the return of corresponding information	Failure of a DAC / AOP (among 3) of the cooler control module (no generation of an analogue signal)	No generation of a OFF control control towards HSP	No generation of an control to the cooler (control OFF of HSP) (AF 5.3 lost)	Loss of the cryocooler functionality. Loss of all observation data. (IF 1 lost) Need for switching on the redundant chain of the DRCU to recover the control of the cooler	Redundancy of coolers. The controls of control of the cooler are systematic. Each DAC receives an demand of numerical current issued from the SCU following a request DPU. The loss of the monitoring voltage information of each heater of the cooler is detected by the DPU.	2R	
5,27	SCU	SCU	AF 5.3 : To make carry out an control on the level of the cooler and ensure the return of corresponding information	Failure of a DAC / AOP (among 3) of the cooler control module (no generation of an analogue signal)	Sending of a current not adapted towards the corresponding HSE or HSP amplifier	Sending of a current not adapted on Heater cooler of the FPU (IF 2.2 degraded)	Loss of the control and the monitoring information of a heater of the cooler from DPU towards FPU (IF 2 degraded) Need for switching on the redundant chain of the DRCU to recover the control of the cooler	The sending of a current not adapted towards Heater of the cooler is detected by the DPU (consistency check between the demand of current and the reread voltage value). If a bad adaptation of the non compatible current of a heater leads to its deterioration, the rereading of the voltage value must lead to the sending of a null current demand by the DPU. There is an absence of variation in temperature of the sorption pump because a detection is included in the algorithm of the recycling control.	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,28	SCU	SCU	AF 5.3 : To make carry out a control at the level of the cooler and ensure the return of corresponding information	Failure of a DAC/AOP (among 3) of the cooler module (failure of the input stage in interface with FPU)	No reception of the voltage measurement of a cooler heater	No sending of the information of a cooler heater towards DPU (IF 2.3 degraded)	Loss of the monitoring information of a cooler heater (IF 2 degraded) Need for switching on the redundant chain of the DRCU to recover information of a cooler heater		3R	
5,29		SCU	DF 7 : Transfer of information between cooler control and the SCU control logic module	Failure of the cooler control module (intrinsic failure, failure of the output stage in interface with DPU)	No sending of cooler information towards the multiplexer 25 > 1	No sending of cooler information towards DPU (IF 2.3 lost)	Loss of monitoring information of the cooler from FPU towards DPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover cooler information	The loss of cooler information is detected by the DPU.	3R	
5,30.		SCU	DF 7 : Transfer of information between cooler control and the SCU control logic module	Failure of the multiplexer 25>1	Idem item 5.6 (DF 9 also lost)	Idem item 5.6	Idem item 5.6	Idem item 5.6	3R	
5,31		SCU	DF 7 : Transfer of information between cooler control and the SCU control logic module	Failure of the amplifier located downstream from the multiplexer 25 > 1: bad amplification	Idem item 5.7 (DF 9 also lost)	Idem item 5.7	Idem item 5.7	Idem item 5.7	3R	
5,32		SCU	DF 7 : Transfer of information between cooler control and the SCU control logic module	Failure of the amplifier located downstream from the multiplexer 25 > 1: no transmission of the signal	Idem item 5.8 (DF 9 also lost)	Idem item 5.8	Idem item 5.8	Idem item 5.8	3R	
5,33	SCU	SCU	DF 7 : Transfer of information between cooler control and the SCU control logic module	Failure of the N/A converter of thermistors AD (no digitalisation of information related to temperature, calibration and cooler, or no transfer to the SCU Control Logic) Failure of the SCU Control Logic (failure of the input stage associated with thermistors A/D)	Idem item 5.9 (DF 9 also lost)	Idem item 5.9	Idem item 5.9	Idem item 5.9	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,34		SCU	DF 10 : To ensure the transfer of secondary voltages information towards the HK / AD module	Failure of a multiplexer 18 > 1 (among 2)	No sending of 18 secondary voltages information towards the HK A/D module for digitalisation	No sending of 18 secondary voltages information towards DPU (degraded IF3)	Loss of 18 monitoring information of the PSU equipment towards FPU, among a potential of 36 (degraded AF 9) Risk of non detection of an overvoltage at the converter output, which can lead to the deterioration of equipment Risk of non detection of a loss of equipment supply	The controls of secondary voltages monitoring are performed on request. See item 4.4 for the risk of overvoltage at the converter output. The loss of equipment supply not detected by the secondary voltage information can be diagnosed by other parameters (ex: loss of power supply of a SCU board by non reception of information related to calibration, cooler and temperature by the DPU) .	3R	
5,35	SCU	SCU	DF 10 : To ensure the transfer of secondary voltages information towards the HK / AD module	Failure of the amplifier located downstream from the 2 multiplexers 18 > 1: bad amplification	Transfer for digitalisation by the HK A/D module of a low signal relating to 36 secondary voltages information	Transfer of degraded numerical information of secondary voltages towards DPU (degraded AF 9)	Sending of degraded information of equipment monitoring from PSU towards DPU (degraded AF 9) Need for switching on the redundant chain of the DRCU to recover monitoring information	The degraded reception of secondary voltages information is detected by the DPU following a request	3R	
5,36		SCU	DF 10 : To ensure the transfer of secondary voltages information towards the HK / AD module	Failure of the amplifier located downstream from the 2 multiplexers 18 > 1: no transmission of the signal	No sending of secondary voltages information towards the HK A/D module for digitalisation	No sending of secondary voltages information towards DPU (degraded IF3)	Loss of monitoring information of the PSU equipment towards FPU (degraded AF 9)	The loss of monitoring information is detected by the DPU following a request Non amplification of the signal leads to non digitalisation (signal is out of the dynamic range of the coder), and consequently to the loss of the data (see item 5.40)	3R	
5,37	SCU	SCU	DF 10 : To ensure the transfer of secondary voltages information towards the HK / AD module	Failure of the multiplexer 4>1	No sending of secondary voltages information towards the HK A/D module for digitalisation (AF 7 and DF 11 also lost)	No sending of information related to secondary voltages, SCU temperature and PSU temperature towards DPU (lost AF 9)	Loss of monitoring information related to the equipment of PSU and SCU towards FPU (lost AF 9) Risk of non detection of a rise in temperature of SCU equipment non compatible with the mission (thermal propagation which can lead to a degradation of the bolometric data)	The monitoring controls of secondary voltages and SCU temperature probes are performed on request. See item 5.34, 5.35 and 5.36 for secondary voltages information.	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,38		SCU	DF 10 : To ensure the transfer of secondary voltages information towards the HK / AD module	Failure of the amplifier located downstream from the multiplexer 4 > 1: bad amplification	Transfer for digitalisation by the HK A/D module of a low signal relating to 36 secondary voltages information (also lost AF 7 and DF 11)	Transfer of degraded numerical information related to secondary voltages, SCU temperature and PSU temperature, towards DPU (degraded AF 9)	Sending of degraded monitoring information of PSU and SCU equipment towards DPU (degraded AF 9) Need for switching on the redundant chain of the DRCU to recover monitoring information	The degraded reception of information related to secondary voltages and SCU temperatures is detected by the DPU following a request	3R	
5,39	SCU	SCU	DF 10 : To ensure the transfer of secondary voltages information towards the HK / AD module	Failure of the amplifier located downstream from the multiplexer 4 > 1: no transmission of the signal	No sending of secondary voltages information towards the HK A/D module for digitalisation (AF 7 and DF 11 also lost)	No sending of information related to secondary voltages, SCU temperature and PSU temperature towards DPU (lost AF 9)	Loss of monitoring information related to the equipment of PSU and SCU towards FPU (lost AF 9)	The loss of monitoring information is detected by the DPU following a request Non amplification of the signal leads to non digitalisation (signal is out of the dynamic range of the coder), and consequently to the loss of the data (see item 5.40)	3R	
5,40.		SCU	DF 10 : To ensure the transfer of secondary voltages information towards the HK / AD module	Failure of the numerical analogue converter (no digitalisation of the data)	Loss of information of secondary voltage and SCU temperature probes (AF 7 and DF 11 also lost)	No sending of information related to secondary voltages, SCU temperature and PSU temperature towards DPU (lost AF 9)	Loss of monitoring information related to the equipment of PSU and SCU towards FPU (lost AF 9)	The loss of information is detected by the DPU	3R	
5,41		SCU	DF 5 : To ensure the transfer of information from the HK A/D module towards the SCU Control Logic module	Failure of A/D converter (no transfer to the SCU Control Logic) Failure of SCU Control Logic (failure of the input stage associated with HK A/D)	Loss of information related to secondary voltages, SCU temperature and PSU temperature	No sending of information related to secondary voltages, SCU temperature and PSU temperature towards the DPU (lost AF 9)	Loss of monitoring information related to the equipment of PSU and SCU towards FPU (lost AF 9)	The loss of information is detected by the DPU The failures of the SCU control logic components in interface with the DPU are analysed at items 5.1 and 5.2	3R	
5,42		SCU	DF 13 : To transmit the setting parameters (frequency...) of the SCU Control Logic for the reception of information related to secondary voltages and SCU/PSU temperature probes	Failure of the Acquisition Sequencer module (no transmission of the sample rate)	No sending of information related to secondary voltages, SCU temperature and PSU temperature towards the multiplexer 4 > 1	No sending of information related to secondary voltages, SCU temperature and PSU temperature towards the DPU (lost AF 9)	Loss of monitoring information related to the equipment of PSU and SCU towards FPU (lost AF 9) Need for switching on the redundant chain of the DRCU to recover monitoring information.	The sample rate is sent by the SCU following a DPU request. All the acquisition chains are sampled at the same rate.	3R	
5,43	SCU	SCU	DF 13 : To transmit the setting parameters (frequency...) of the SCU Control Logic for the reception of information related to secondary voltages and SCU/PSU temperature probes	Failure of the Acquisition Sequencer module (erroneous sample rate)	Sending of information related to secondary voltages, SCU temperature and PSU temperature towards the multiplexer 4 > 1 with an erroneous sample rate	Sending of information related to secondary voltages, SCU temperature and PSU temperature towards the DPU with a sample rate different from expected (lost AF 9)	Risk of use of erroneous information related to PSU and SCU monitoring towards DPU (lost AF 9) Risk of late detection of an anomaly on PSU or SCU equipment (if sample rate lower than specified) (lost AF 9)	Idem item 5.11	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,44		SCU	AF 7 : To ensure the transfer of PSU temperature probes information towards the HK / AD module		See items 5.37 to 5.40	See items 5.37 to 5.40	See items 5.37 to 5.40	The loss of monitoring information is detected by the DPU following a request The equipment supporting function AF 7 are identical to those associated with function DF 10 (multiplexer 4 > 1 and HK A/D module). The failures of these equipment are analysed at items 5.37 to 5.40 The failures of the SCU control logic components in interface with the DPU are analysed at items 5.1 and 5.2 The PSU is not part of the SCU. It is considered that temperature information of PSU module will be retransmitted as housekeeping parameters.	3R	
5,45		SCU	DF 11 : To ensure the transfer of SCU temperature probes information towards the HK / AD module		See items 5.37 to 5.40	See items 5.37 to 5.40	See items 5.37 to 5.40	The loss of monitoring information is detected by the DPU following a request The 3 temperatures at the SCU level correspond to the 3 boards which constitute it. The equipment supporting function DF 11 are identical to those associated with function DF 10 (multiplexer 4 > 1 and HK A/D module). The failures of these equipment are analysed at items 5.37 to 5.40. The failures of the SCU control logic components in interface with the DPU are analysed at items 5.1 and 5.2.	3R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,46	SCU	PSD	AF 6 : To ensure the transfer of power supply towards DCU module	Failure of "external harness" connector (pin failure, open circuit...) Failure of the distribution line (open circuit) Galvanic insulation failure	No transfer of power supply towards an element of the DCU (LIA P, LIA S, BIAS, DAQ)	Loss of power supply of DCU equipment (BIAS, DAQ or LIA)	Loss of all the data from the detectors (photometric or spectrometric) (worst case: loss of power supply of LIA P or LIA S board) (IF 1 lost) The loss of power supply of a BIAS or DAQ must lead to the switching on the redundant chain DRCU to recover all detectors data.	The photometric and spectrometric modes detection are exclusive modes. In photometric mode (resp. spectrometric), the 3 LIA_S boards are not supplied (resp. the 9 LIA_P boards). The choice of the mode is carried out by the DPU. Distribution of power supply (+ 5.2 and? 9 V) of LIA is carried out by 2 relays in series. A ON/OFFrelay is controled by the SCU following a DPU request (see function DF 6). The other relay is directly controled by the choice of Primary Power Line (28 V) supply at the satellite level (see function AF 8). The supply of the DCU elements is carried out via an external harness. The failures related to the converters are analysed at items 4.2 to 4.5.	2R	
5,47	SCU	SCU	DF 6 :To configure the relays of power supply of the DRCU elements	No setting ON of a powering relay (coil burn out, failed contact, loss of 12 V " SCU_REL_P12 ",...) Inopportune setting OFF of a powering relay (short circuit on coil, stuck contact...)	No power supply or loss of supply of DRCU equipment	Loss of power supply of a module of the DCU (LIA, BIAS, DAQ) (IF 1.1 and / or IF 1.2 lost) Loss of power supply of SCU module (IF 2.1, IF 2.2 and/or IF2.3 lost)	Loss of all the scientific data issued from a type of detector (photometric or spectrometric) from FPU towards DPU (lost IF1) Loss of the monitoring functions (Housekeepink, calibration, cooler) from DPU towards FPU (IF 2 lost) Need for switching on the redundant chain of the DRCU to recover to the lost function(s).	The control of the powering relays ("bistable" type relay) is carried out by SCU following a DPU request. When DRCU is in state OFF, all the relays are in state OFF. The loss of power supply of a DCU or SCU module is detected by the DPU, by the loss of information relating to the equipment not supplied (loss of the scientific data if loss of DCU supply, and loss of the monitoring data if loss of SCU supply). Moreover, according to the implementation of secondary voltages detection (see item 4.4), the loss of power supply can be detected by the "Secondary voltages" Housekeeping parameters.	2R	
5,48	SCU	SCU	DF 6 :To configure the relays of power supply of the DRCU elements	Inopportune setting ON of a powering relay (short circuit on coil, stuck contact...)	Accidental power supply of an element of the DRCU		The DRCU consumes a great quantity of energy, so the satellite will cut off its supply. DRCU is " switched off ".	Under nominal operation, the relays of powering of the elements of the chain are in position ON (except specific case of supply of LIA P or LIA S; see 5.46 item). See interface with the MCU	2	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,49	SCU	SCU	DF 6 :To configure the relays of power supply of the DRCU elements	No setting OFF of powering relay (coil burn out, failed contact, short circuit downstream, heating, loss of 12 V " SCU_REL_P12 "...)	No power supply cut-off of an element of the DRCU	No switching of detection mode (from photometric to spectrometric and vice versa) No insulation of the DRCU equipment following internal failure (overheating, short circuit...)	Loss of all the scientific data issued from a type of detector (photometric or spectrometric) (IF 1 lost) Need for switching on the redundant chain of the DRCU to recover the detectors data. Permanent consumption and risk of propagation of failure by thermal dissipation. Risk of total loss of the mission.	If possible, dimension the protections to make acceptable the thermal dissipation generated by any short-circuit downstream. Dimension the circuit of setting OFF (resistance to heating) and the response time of the monitoring with respect to the risk of propagation of failure by thermal dissipation. If necessary, make reliable the setting OFF of equipment that consumes the most. The photometric and spectrometric modes are exclusive (see item 5.46). If LIA P and LIA S are supplied simultaneously, a double control of DPU allows the setting ON of a type of LIA and the setting OFF the other type.	2R	
5,50.	SCU	SCU	DF 6 :To configure the relays of power supply of the DRCU elements	Powering relays in the not supplied redundant chain of the DRCU remained in position ON [loss of power supply of SCU (SCU_DIG_P5) or loss of the power supply of the powering relays (SCU_REL_P12)]	Incoherent configuration of the powering relays in regard with the chain of the DRCU (not supplied chain)	Too important inrush current at the the starting of equipment following the switching on the corresponding chain (chain in which all the powering relays of are in position ON)	Risk of collapse of the satellite bar	See whether it is necessary that the SCU forces all the powering relays on state OFFat the time of their initialization (starting following the powering of the corresponding relay)	TBD	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,51	SCU	SCU	AF 8 : To configure the power supply M/R (Main / Redundant) of the LIA boards of DCU	Failure of the power on pulse generators or failure of a M/R configuration relay	Misconfiguration of the relay in regard with the power supply bar (relay on Main position whereas Redundant 28 V is present)	No power supply of LIA_P or LIA_S modules (IF 1.1 lost)	Loss of all the scientific data (photometric or spectrometric) from FPU towards DPU (lost IF1) Need for switching on the redundant chain of the DRCU to recover the lost function(s)	Distribution of power supply (+ 5.2 and 9 V) of LIA boards is carried out by 2 relays in series. A ON/OFFrelay is controled by the SCU following a DPU request (see function DF 8). The other relay is directly controled by the choice of Primary Power Line (28 V) supply at the satellite level. This relay avoids to create a common point between the secondaries of power supply of redundant LIA and main LIA associated with spectrometers and photometers. This relay is positioned in the configuration M or R by means of a pulsed detector (power on pulse generators) implemented on the power supply line of 5 V SCU. The pulse is effective following the voltage presence at the level of the 5 V SCU (voltage obtained by the satellite power supply bar ; Main or Redundant). Piloting these relays requires the 12V dedicated to controls (SCU_REL_P12).	2R	
5,51	SCU	SCU	AF 8 : To configure the power supply M/R (Main / Redundant) of the LIA boards of DCU (cont'd - 1)					If the voltage rising of 12 V (SCU_REL_P12) for controling the relays is slower than the voltage rising 5 V SCU (SCU_DIG_P5), and consequently of the pulse duration of the voltage presence detector, the relays of configuration M/R of the LIA boards will not move. To guarantee the position of relays M/R, it is necessary either that the pulse duration is compatible of the voltage rising of 12 V for relay control, or that voltage presence detectors are implemented (power pulse-on generators) on the line of 12 V for relays (SCU_REL_P12) (the pulse will be effective when 12 V is nominal).	2R	

Item	Module	Block	Functions	Failure modes	Local effects	Module effects	Subsystem effects (DRCU)	Remarks	Classification of the effects at DRCU level	Classification of the effects at instrument level
5,51	SCU	SCU	AF 8 : To configure the power supply M/R (Main / Redundant) of the LIA boards of DCU (cont'd - 2)					It should be noted that the loss of a voltage presence detector (power pulse-on generators) leads to the loss of the possibility of switching on the redundant chain of the DRCU, and constitutes a dormant failure not detected before switching. See whether it is necessary to redundate the voltage presence detectors. See whether it is necessary to set up a detection relating to the correct operation of these detectors. However it is necessary to find a compromise between the addition of equipment and the loss of reliability they can generate.	2R	