**Software Requirements Specification (SRS)**

**Version 2.1**

**Solar Orbiter Mission**

**RPW INVESTIGATION**

**MEB (Main Electronic Box) Instrument**

**LFR (Low Frequency Receiver) Sub-Instrument**

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**Change Record**

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| 1 | 2 |  | PLE | TM/TC tables updated |
| 1 | 3 | 15 nov. 12 | GSA | -Updated Scope according to the “ECSS-E-ST-40C\_6March2009” reference document.-Update of the RPW-SYS-SSS-00013-LES\_Iss1\_Rev1\_ 21/09/2012 document (RPW Instrument - Software System Specification)-Taking into account the RPWSSS-142 and RPWSSS-138 remarks of the JIRA “Bug tracking tool”.-Updated according to RID\_SRSV1.3.-Multiple format changes to use Tramway (TOPCASED). |
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| 1 | 6 | 10-Mar-14 | GSA | Update from RPW-SYS-SSS-00013-LES-Iss2\_Rev0 (13/11/2013), RPW-SYS-SSS-00013-LES\_Issue:2 Rev.:1 (20/01/2014),RPW-SYS-SSS-00013-LES Issue: 2 Rev.: 2(10/03/2014) |
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| 1 | 8 | 15-aug-14 | BKA/VBO | Update/corrections from JIRA issues :RPWSWR-341, RPWSWR-119, RPWSWR-116, RPWSWR-432Update of §7 Traceability : removal of closed/fixed issues |
| 1 | 9 | 20-oct-15 | BKA/VBO | Tab 5.2 updated to include new R3 TCAD18 updatedRD01 addedRD02 addedRD03 addedREQ-LFR-SRS-5100\_Ed1 REQ-LFR-SRS-5230\_Ed1 REQ-LFR-SRS-5231\_Ed1 REQ-LFR-SRS-5232\_Ed1 REQ-LFR-SRS-5242\_Ed1 deletedTBD deleted from 5.2.1REQ-LFR-SRS-5289 REQ-LFR-SRS-5590, REQ-LFR-SRS-5591, REQ-LFR-SRS-5580 , REQ-LFR-SRS-5581 REQ-LFR-SRS-5582 REQ-LFR-SRS-5583 REQ-LFR-SRS-5584 REQ-LFR-SRS-5592, REQ-LFR-SRS-5599 addedREQ-LFR-SRS-5570 REQ-LFR-SRS-5547 deletedREQ-LFR-SRS-5230, REQ-LFR-SRS-5231, REQ-LFR-SRS-5232, REQ-LFR-SRS-5407, REQ-LFR-SRS-5552, REQ-LFR-SRS-5553, REQ-LFR-SRS-5555, REQ-LFR-SRS-5564, REQ-LFR-SRS-5556, REQ-LFR-SRS-5558, REQ-LFR-SRS-5569, REQ-LFR-SRS-5533 REQ-LFR-SRS-5218 REQ-LFR-SRS-5219 REQ-LFR-SRS-5220 REQ-LFR-SRS-5503 REQ-LFR-SRS-5504 REQ-LFR-SRS-5505 REQ-LFR-SRS-5506 REQ-LFR-SRS-5567 REQ-LFR-SRS-5238 REQ-LFR-SRS-5546 REQ-LFR-SRS-5533 REQ-LFR-SRS-5520 updatedREQ-LFR-SRS-5559 and REQ-LFR-SRS-5560 verification method changed from Test to InspectionREQ-LFR-SRS-5212 , REQ-LFR-SRS-5548, REQ-LFR-SRS-5549, REQ-LFR-SRS-5550, REQ-LFR-SRS-5500 REQ-LFR-SRS-5501 from Design to TestAppendix C updated |
| 2 | 0 | 10-feb-2016 | BKA/VBO | Minor fixes related to JIRA issue RPWSWR-616AD19 addedRD01 updatedREQ-LFR-SRS-5800 addedREQ-LFR-SRS-5230\_Ed1 REQ-LFR-SRS-5231\_Ed1 REQ-LFR-SRS-5232\_Ed1 re-introduced§5.2.4 updatedREQ-LFR-SRS-5599 deletedREQ-LFR-SRS-5289 tagged as TestREQ-LFR-SRS-5210, REQ-LFR-SRS-5218, REQ-LFR-SRS-5236, REQ-LFR-SRS-5533, REQ-LFR-SRS-5536, REQ-LFR-SRS-5540, REQ-LFR-SRS-5541, REQ-LFR-SRS-5542, REQ-LFR-SRS-5544, REQ-LFR-SRS-5545, REQ-LFR-SRS-5546, REQ-LFR-SRS-5514, REQ-LFR-SRS-5580, REQ-LFR-SRS-5561, REQ-LFR-SRS-5565, REQ-LFR-SRS-5566, REQ-LFR-SRS-5571, REQ-LFR-SRS-5569, REQ-LFR-SRS-5409, REQ-LFR-SRS-5289 updatedSeveral requirements changed from Design to Test :REQ-LFR-SRS-5534, REQ-LFR-SRS-5536, REQ-LFR-SRS-5540, REQ-LFR-SRS-5541, REQ-LFR-SRS-5542, REQ-LFR-SRS-5545, REQ-LFR-SRS-5546, REQ-LFR-SRS-5508, REQ-LFR-SRS-5513, REQ-LFR-SRS-5514, REQ-LFR-SRS-5516, REQ-LFR-SRS-5206, REQ-LFR-SRS-5210, REQ-LFR-SRS-5202, REQ-LFR-SRS-5214, REQ-LFR-SRS-5241, REQ-LFR-SRS-5237, REQ-LFR-SRS-5407, REQ-LFR-SRS-5409REQ-LFR-SRS-5410 changed from Design to InspectionREQ-LFR-SRS-5544 changed to “Test and Design” |
| 2 | 1 | 20-apr-2017 | BKA/VBO | Major updates for R3++ compliancy :- Applicable and Reference documents updated- Abbreviations updatedREQ-LFR-SRS-5533, REQ-LFR-SRS-5522, REQ-LFR-SRS-5409, REQ-LFR-SRS-5564, REQ-LFR-SRS-5569 updated§5.5.10 and §5.5.11 addedREQ-LFR-SRS-6000, REQ-LFR-SRS-6020, REQ-LFR-SRS-6001, REQ-LFR-SRS-6002, REQ-LFR-SRS-6003, REQ-LFR-SRS-6004, REQ-LFR-SRS-6005, REQ-LFR-SRS-6006, REQ-LFR-SRS-6100, REQ-LFR-SRS-6101, REQ-LFR-SRS-6102, REQ-LFR-SRS-6103, REQ-LFR-SRS-6104, REQ-LFR-SRS-6105 added |
| 2 | 2 | 7-nov-2018 | BKA/VBO | No more lines in red .Updated REQ-LFR-SRS-5204, REQ-LFR-SRS-5207, REQ-LFR-SRS-5208, REQ-LFR-SRS-5232, REQ-LFR-SRS-5241, REQ-LFR-SRS-5409, REQ-LFR-SRS-5533, REQ-LFR-SRS-5534, REQ-LFR-SRS-5540.Updated Appendix C  |

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# Introduction

The LFR is one of the 3 analyzers of the RPW consortium, which is a part of the Solar Orbiter instrument suite. The other ones are TNR-HFR and TDS.

The LFR SRS (Software Requirements Specification) is a major constituent of the technical specification (TS). It describes the functional and non-functional requirements applicable to the flight software of the LFR. The SRS scope and content are described in the ECSS-E-ST-40C.

## REQUIREMENT STRUCTURE

The structure of a SRS requirement is the following (ensure the specific style for Topcased treatment):

|  |
| --- |
| **Requirement ID***Verification Method: “Test” (preferably), “Design”, “Inspection”, “Analyse” (for example: mechanical).*Requirement BodyDependencies |

The section Dependencies gives the list of the upper level requirements that come from the AD1 applicable document.

# Applicable and reference documents

|  |  |  |  |
| --- | --- | --- | --- |
|  | Reference | Issue/Rev | Title |
| AD1 | RPW-SYS-SSS-00013-LES | Issue4 Rev3 | Software System Specification |
| AD2 | RPW-SYS-MEB-LFR-ICD-00097 | Issue4Rev3 | RPW LFR SOFTWARE ICD |
| AD3 | [IR-20] SO-ESC-RS-05002,Is.1,Draft,20100331\_Solar\_Orbiter\_Generic\_frame\_and\_packet\_structure | Iss.1Draft20100331 | Solar Orbiter Generic Frame and Packet Structure |
| AD4 | [NR-27] SO-ESC-RS-05001, Issue 1r6, 20110824 \_Solar Orbiter OIRD\_.signed | Issue 1r620110824 | Solar Orbiter Operations Requirements Document |
| AD5 | ECSS-Q-ST-80C | C | Space product assurance / Software product assurance |
| AD6 | ECSS-E-ST-40C | C | Space Engineering / Software |
| AD7 | ECSS-E-70-41A | A | Space engineering / Ground systems and operations – Telemetry and telecommands packet utilization |
| AD8 | ECSS-E-ST-50-12C | C | Space engineering / SpaceWire – Links, nodes, routers and networks |
| AD9 | ECSS-E-ST-50-53C | C | Space engineering / SpaceWire – CCSDS packet transfer protocol |
| AD10 | SOL.S.ASTR.TN.00079\_03\_Solar Orbiter TM-TC and Packet Structure ICD | Issue 3 | SOL.S.ASTR.TN.00079 - Solar Orbiter Space to Ground ICD Vol. 2: Frame and Packet Structure and Packet Utilisation Standard |
| AD11 | RPW-SYS---ICD-00067-LES | Issue3rev11 | RPW IDB PARAMETER DEFINITION |
| AD12 | RPW FDIR | V2.2 | RPW-SYS-MEB-###-FMC-000207-LES\_Issue2\_Rev2\_FDIR\_Analysis |
| AD13 | GRLIB IP Core User’s Manual |  | Aeroflex Gaisler. Version 1.1–0 - B4104 |
| AD14 | SOL-EST-RCD-0050 |  | Solar Orbiter Experiment Interface Document – Part A (EID-A) |
| AD15 | RPW-SYS-MEB-DPS-ICD-00065-LES |  | RPW DPU Boot Software TM Packet Definition |
| AD16 | RPW-SYS-MEB-DPS-ICD-00084-LES |  | RPW DPU Application Software TM Packet Definition |
| AD17 | RID\_SRSV1.3\_D3 |  | Report ID about SRS 1.3 |
| AD18 | RPW-MEB-LFR-SPC-00061 | 1-8 | FPGA\_Architecture\_Design |
| AD19 | RPW-SYS-MEB-MGT-QAD-000405-LES |  |  |
| RD01 | RPW-MEB-LFR-RPT-00094-LPP | 2.3 | LFR FSW Verification Report |
| RD02 | RPW-MEB-LFR-SPC-00003 | 1.12 | LFR technical specification |
| RD03 | RPW-MEB-LFR-SDD-00039 | 1.3 | LFR Software Design Document |
| RD04 | RPW-MEB-LFR-NTT-000123-LPP | 1.4 | LFR Software User Manual |

Applicable and reference documents prevail in case of contradiction with the SRS present document (see §7:Traceability about opened item).

# Terms, definitions and abbreviated terms

| **Abbreviation** | **Mean** |
| --- | --- |
| Ack | Acknowledgement |
| AIT | Assembly, Integration and Test |
| AMBA | Advanced Microcontroller Bus Architecture |
| APID | Application Process Identifier |
| ASM | Averaged spectral matrix |
| BIAS | Biasing Unit (RPW) |
| BP | Basic parameters |
| CCSDS | Consultative Committee for Space Data Systems |
| CPU | Central processing unit |
| CRC | Cyclic Redundancy Code |
| CTR | Central Time Reference |
| CUC | CCSDS Unsegmented time Code |
| CWF | Continuous waveforms |
| DAC | Digital-to-Analogue Converter |
| DAS | DPU Application Software |
| DBS | DPU Boot Software |
| DMS | Data Management System |
| DPU | Data/Digital Processing Unit |
| ECSS | European Cooperation on Space Standardization |
| EDAC | Error Detection And Correction |
| EEPROM | Electrically Erasable Programmable Read-Only Memory |
| EID | Experiment Interface Document |
| EXE | Execution |
| FDIR | Failure Detection Isolation and Recovery |
| FFT | Fast Fourier transform |
| FPGA | Field Programmable Gate Array |
| FSW | Flight Software |
| GRLIB | Gaisler Research Library |
| HK | Housekeeping |
| HW | Hardware |
| ICD | Interface Control Document |
| ID | Identifier |
| IP | Internet Protocol |
| LF | Low Frequency |
| LFM | LFM mode=RPW backup mode of TDS |
| LFR | Low Frequency Receiver |
| LSB | Least Significant Bit |
| MEB | Main Electronics Box |
| MSB | Most Significant Bit |
| PAS | Proton-Alpha Sensor (SWA-PAS) |
| PDR | Preliminary Design Review |
| PID | Process Identifier |
| PUS | Packet Utilization Service/Standard |
| REQ | Requirement |
| RID | Report ID |
| RMAP | Remote Memory Access Protocol |
| ROM | Read Only Memory |
| RPW | Radio and Plasma Waves |
| RW | Reaction Wheel |
| RTAX | Radiation-tolerant Axcelerator |
| S/C | SpaceCraft |
| SBM | Selected Burst Mode |
| SBM1 | Selected Burst Mode1 (interplanetary shock measurement) |
| SBM2 | Selected Burst Mode2 (In-situ Type III measurements) |
| SCET | SpaceCraft Elapsed Time |
| SCM | Search Coil Magnetometer |
| SEU | Single Event Upset |
| SID | Structure Identifier |
| SoC | System on Chip |
| SpW | SpaceWire |
| SRS | Software Requirements Specification |
| SSS | System Software Specification |
| SW | Software |
| SWF | Waveform snapshots |
| TBD | To Be Defined |
| TC | TeleCommand |
| TDS | Time Domain Sampler |
| TM | TeleMetry |
| TNR-HFR | Thermal Noise Receiver - High Frequency receive |
| TS | Technical specification |
|  |  |

# Software overview

## Function and purpose

The purpose of the LFR FSW is to drive the appropriate LFR scientific modes upon TC received from the RPW DPU.

The LFR FSW main functions are the following:

* Communication with the RPW DPU: telecommands interpretation, telemetry products packaging and transmission to the DPU.
* Configuration of the LFR sampling strategy and pre-processing abilities following the reception of telecommands and of appropriate parameter sets coming from the RPW DPU.
* Time keeping.
* Computation of a given set of scientific products: the Basic Parameters.
* Housekeeping data collection and housekeeping reporting to the DPU.

The LFR FSW is made of one only product that implements all of the requirements related to the LFR instrument scientific modes as described in the SSS.

## Environmental considerations

The LFR FSW will be executed on the Leon3 soft processor instantiated in the FPGA of the LFR board. It will be connected to an AMBA SoC bus around which several coprocessors and hardware drivers will also be deployed. The LFR FSW will be able to configure the entities connected to the AMBA bus. It will also be able to get data from the coprocessors, to do further processing on it, to build the science telemetry packets and to send the packets to the DPU.

## Relation to other systems

The LFR FSW has a direct relation with the DPU board through a fully redundant SpaceWire link. The LFR is also synchronized with other RPW sub-systems. There will be no ROM onboard the LFR. The analyzer will be booted via RMAP by the DPU. The LFR FSW will be stored by the DPU in an EEPROM.

The LFR sub-system is an integrated HW-SW product. An overview of the HW of the LFR is presented on Figure 1. 11 analog channels coming from three RPW sub-systems, SCM, BIAS Unit and TDS, are routed by analog switches towards 8 ADCs. In addition to the scientific data inputs, one outside temperature probe is monitoring the SCM temperature and two inside temperature probes are monitoring the LFR board and FPGA. The LFR has one analog output used to send a calibration signal to SCM.



Figure 1: LFR sub-system overview.

The digitized data streams are sent to the LFR FPGA for further processing. Inside the FPGA, several modules are organized around an AMBA bus. Among them are pre-processing modules and driver modules.



Figure 2: LFR FPGA block diagram. Modules are organized around an AMBA SoC bus.

## Constraints

The size of the LFR FSW is limited by the onboard memory and by the space allocated for the LFR FSW in the DPU EEPROM. The maximum size for the LFR FSW is ~400 KBytes.

# Requirements

## General

Requirements are extracted from the AD1 document. The present SRS document:

-gives the needed details of LFR specific equipment implementation.

-provides answers to problems traced in the RID.

## Functional requirements

Preliminary note about counters: Implemented counters are coded on a finite number of bits. So, when maximum value is reached, such counters will restart nominally from 0.

### Commands management

#### Command management

|  |
| --- |
| REQ-LFR-SRS-5200\_Ed1TestThe LFR FSW shall receive and process the command packets sent by the DPU.SSS-CP-FS-020 |
| REQ-LFR-SRS-5201\_Ed1DesignThe LFR FSW shall always process the received command packets as soon as possible (ie when it is available).SSS-CP-FS-030 |
| REQ-LFR-SRS-5233\_Ed1TestThe LFR Flight Software shall be able to receive, to process and to execute the command packets without affecting its other running independent processes.SSS-CP-FS-031 |
| REQ-LFR-SRS-5234\_Ed1TestThe execution of every telecommand shall be verifiable through a resulting change in the value of a Telemetry parameter.SSS-CP-FS-032 |
| REQ-LFR-SRS-5235\_Ed1DesignEach command packet shall contain one and only one command function, as specified in [AD10].SSS-CP-FS-033 |
| REQ-LFR-SRS-5242\_Ed1DeletedSSS-GEN-FS-024 |

#### Command start/progress stage

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| --- |
| REQ-LFR-SRS-5202\_Ed1TestAccording to the [AD4] and to [AD10] documents, the LFR FSW shall not generate reports (neither failure nor success reports) concerning the start or the progress of telecommand executions. The acknowledgement flag in the telecommand packet header related to the start of execution or to the progress execution shall be ignored.SSS-CP-FS-100 |

From the LFR FSW point of view, the commands are always seen as immediate commands.

#### Command acceptance stage

|  |
| --- |
| REQ-LFR-SRS-5203\_Ed2TestThe LFR FSW shall validate the received commands prior to their execution (acceptance stage).SSS-CP-FS-040 |
| REQ-LFR-SRS-5204\_Ed1TestUpon the reception of any command packet, the LFR FSW shall verify if the packet can be accepted by:* Checking the following items in this specific order :
	+ APID (PID, CAT)
	+ Length of the received packet should match packet\_length field contained in packet header
	+ service type and service subtype
	+ source ID
	+ Length\_packet field value is relevant with expected length considering definition of the sub-type.
	+ packet error control (CRC). The algorithm to compute the packet error control is specified in the [AD10], appendix 6.

If at least one of this criteria fails, TM\_LFR\_EXE\_CORRUPTED packet is emitted with failure code 42005* Checking that the command is allowed in the current mode (see tab 5.2) and/or state of the instrument.
* No check of the packet sequence counter shall be made.

 : should be*Note :* command packet which the length is too long (SY\_LFR\_TC\_MAX\_SIZE)) or too short (CCSDS\_TC\_PKT\_MIN = 16 bytes) doesn’t not be verified by the acceptance stage.*Note :* should be[]shouldSSS-CP-FS-050 |

|  |
| --- |
|  |
|  REQ-LFR-SRS-5236\_Ed1TestThe LFR Flight Software shall compute the CRC on the CCSDS Telecommand Source Packet part of the received packet i.e. LFR flight sofware should be able to detect the validity of received CRC.SSS-CP-FS-055 |
|  REQ-LFR-SRS-5205\_Ed3TestIf the acceptance of the command fails, the LFR FSW shall systematically generate one Telecommand Execution Completed Failure Report (TM\_LFR\_TC\_EXE\_CORRUPTED or TM\_LFR\_TC\_EXE\_NOT\_EXECUTABLE) conforming to the PUS telecommand verification service [AD10], whatever the value of the acknowledgment flag in the command packet header.This requirement does not apply to the following packets: TC\_LFR\_UPDATE\_INFO, TC\_LFR\_UPDATE\_TIME.SSS-CP-FS-065 |

The soft parses the bytes in the order of arrival:

1. CSDS\_VERSION\_NUMBER
2. PACKET\_TYPE
3. DATA\_FIELD\_HEADER\_FLAG
4. PROCESS\_ID
5. PACKET\_CATEGORY
6. SEGMENTATION\_GROUPING\_FLAG
7. SEQUENCE\_CNT
8. PACKET\_LENGTH
9. CCSDS\_SECONDARY\_HEADER\_FLAG
10. PUS\_VERSION
11. ACK\_EXECUTION\_COMPLETION
12. ACK\_EXECUTION\_PROGRESS
13. ACK\_EXECUTION\_START
14. ACK\_ACCEPTANCE
15. SERVICE\_TYPE
16. SERVICE\_SUBTYPE
17. SOURCE\_ID
18. ...
19. CRC

If TC is not (explicitly) rejected before the analysis of SERVICE\_TYPE, SERVICE\_SUBTYPE, then only if SERVICE\_TYPE, SERVICE\_SUBTYPE are consistent with TC\_LFR\_UPDATE\_INFO or TC\_LFR\_UPDATE\_TIME, FSW LFR will not sent acknowledgment.

If the acceptance of the command fails, the LFR FSW shall systematically generate one Telecommand Execution Completed Failure Report into one TM\_LFR\_TC\_EXE\_CORRUPTED.

|  |
| --- |
| REQ-LFR-SRS-5206\_Ed1TestThe LFR Flight Software shall start the execution of the commands only if they have been accepted, otherwise the commands shall be discarded.SSS-CP-FS-075 |

#### Command execution stage

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| --- |
| REQ-LFR-SRS-5207\_Ed2TestIf the execution of the command fails, the LFR FSW shall generate one Telecommand Execution Completed Failure Report conforming to the PUS telecommand verification service [AD7] (type=1, subtype=8) even if this has not been requested in the execution acknowledgement flag in the telecommand packet header. See “LFR TM PACKETS” table 10 in APPENDIX C.This requirement does not apply to the following packets: TC\_LFR\_UPDATE\_INFO, TC\_LFR\_UPDATE\_TIME.SSS-CP-FS-080 |

The DAS filters: it accepts the TC\_LFR\_xxx commands and forwards them to the LFR analyzer.

The LFR has fewer constraints:

|  |  |  |
| --- | --- | --- |
|  | Current mode |  |
|  | STANDBY | NORMAL | BURST | SBM1 | SBM2 |  |
| TC\_LFR\_RESET | yes | yes | yes | yes | yes |  |
| TC\_LFR\_LOAD\_COMMON\_PAR | yes | yes | yes | yes | yes | SSS-CP-DAS-524 |
| TC\_LFR\_LOAD\_NORMAL\_PAR | yes | NO | yes | NO | NO | SSS-CP-DAS-525, -977, -978 |
| TC\_LFR\_LOAD\_BURST\_PAR | yes | yes | NO | yes | yes | SSS-CP-DAS-526 |
| TC\_LFR\_LOAD\_SBM1\_PAR | yes | yes | yes | NO | yes |  |
| TC\_LFR\_LOAD\_SBM2\_PAR | yes | yes | yes | yes | NO |  |
| TC\_LFR\_DUMP\_PAR | yes | yes | yes | yes | yes | SSS-CP-DAS-529SSS-CP-EQS-328 |
| TC\_LFR\_ENTER\_MODE | Yes only if CP\_LFR\_MODE<>current mode |  |
| TC\_LFR\_ENABLE\_CALIBRATION | yes | yes | yes | yes | yes | SSS-CP-EQS-250 |
| TC\_LFR\_DISABLE\_CALIBRATION | yes | yes | yes | yes | yes | SSS-CP-EQS-250 |
| TC\_LFR\_UPDATE\_TIME | yes | yes | yes | yes | yes |  |
| TC\_LFR\_UPDATE\_INFO | yes | yes | yes | yes | yes | SSS-CP-EQS-351 |
| TC\_LFR\_LOAD\_FBINS\_MASK | yes | yes | yes | yes | yes | SSS-CP-EQS-527 |
| TC\_LFR\_LOAD\_KCOEFFICIENTS | yes | yes | yes | yes | yes | SSS-CP-EQS-529 |
| TC\_LFR\_DUMP\_KCOEFFICIENTS | yes | yes | yes | yes | yes | SSS-CP-EQS-531 |
| TC\_LFR\_LOAD\_FILTER\_PAR | yes | yes | ues | yes | yes | SSS-CP-EQS-753 |

Tab 5.2

So, above nominal TC shall be accepted and executed in the ‘yes’ cases, except for TC\_LFR\_ENTER\_MODE packets; LFR shall reject CP\_LFR\_MODE if equal to the current mode.

LFR FSW shall reject TC\_LFR\_ENTER\_MODE packets when a mode transition is already managed by LFR (until TIME of LFR reaches CP\_LFR\_ENTER\_MODE\_TIME of the previous TC\_LFR\_ENTER\_MODE).

|  |
| --- |
| REQ-LFR-SRS-5208\_Ed1TestThe LFR FSW shall manage the following criteria that can be the cause of the failure of the command execution:* If TC has a wrong or inconsistent data field (section APPLICATION\_DATA) e.g. the command parameters are not correctly encoded nor within their range of values or non coherent with another value : a TM\_LFR\_TC\_EXE\_INCONSISTENT is emitted. This is only applicable to those following TC : TC\_LFR\_LOAD\_NORMAL\_PAR, TC\_LFR\_LOAD\_BURST\_PAR, TC\_LFR\_LOAD\_SBM1\_PAR, TC\_LFR\_LOAD\_SBM2\_PAR, TC\_LFR\_ENTER\_MODE, TC\_LFR\_LOAD\_FILTER\_PAR,TC\_LFR\_LOAD\_KCOEFFICIENTS

For more details on acceptable values : see [AD02].* The command cannot be executed at this time or the commands parameters are not valid for the current mode (see tab 5.2) : a TM\_LFR\_TC\_EXE\_NOT\_EXECUTABLE is emitted.
* A malfunction or an error is detected during the execution : a TM\_LFR\_TC\_EXE\_ERROR is emitted.

Note : if command execution fails for TC\_LFR\_UPDATE\_xxx, no error TM\_LFR\_TC\_EXE is emitted and TC is not executed.See “LFR TM PACKETS” table 10 in APPENDIX C.SSS-CP-FS-085 |
| REQ-LFR-SRS-5209\_Ed2TestWhen a command has been properly executed, the LFR FSW shall generate one report of successful completion for the execution stage conforming to the PUS telecommand verification service (Telecommand Execution Completed Report – Success, type=1, subtype=7) systematically, whatever the value of the acknowledgement flag in the command packet header (this flag shall be ignored).This requirement does not apply to the following packets: TC\_LFR\_UPDATE\_INFO, TC\_LFR\_UPDATE\_TIME.SSS-CP-FS-090 |
| REQ-LFR-SRS-5210\_Ed1TestThe LFR FSW shall produce one single acknowledgement report including the acceptance step and the execution step except for TC\_LFR\_UPDATE\_INFO and TC\_LFR\_UPDATE\_TIME (see REQ-LFR-SRS-5205, REQ-LFR-SRS-5207 and REQ-LFR-SRS-5209 ).The TM (1,7) -TC Completion Report Success- telemetry service reports to the command source the successful execution of the TC sent to the addressed APID.SSS-CP-FS-095  |

The full and detailed list of failure code and possible parameters will be given in the AD11 and in the RPW Technical TM Packet Definition Document (AD15 and AD16).

#### Content of the verification reports

|  |
| --- |
| REQ-LFR-SRS-5211\_Ed1TestThe TC acceptance / execution success report (=TM) shall contain:* a copy of the TC Packet ID field.
* a copy of the TC Packet Sequence Control field.

SSS-CP-FS-110 |
| REQ-LFR-SRS-5212\_Ed1TestThe TC acceptance / execution failure report (=TM with (1,8)) shall contain:* a copy of the TC Packet ID field (PA\_RPW\_TELECOMMAND\_PKT\_ID).
* a copy of the TC Packet Sequence Control field (PA\_RPW\_SEQ\_CONTROL).
* a failure code: the failure code, which is an identifier for interpreting the failure, is mandatory (PA\_RPW\_TC\_FAILURE\_CODE). See Table 10
* optional parameters (auxiliary data) to identify the nature and cause of the TC failure (PA\_RPW\_TC\_SERVICE and PA\_RPW\_TC\_SUBTYPE ). Extra parameters are set for TM\_LFR\_TC\_EXE\_INCONSISTENT,TM\_LFR\_TC\_EXE\_NOT\_IMPLEMENTED, TM\_LFR\_TC\_EXE\_CORRUPTED .

SSS-CP-FS-120 |

Table 1: Source data field structure of a TC acceptance / execution success report

|  |  |
| --- | --- |
| **TC Packet ID** | **Packet Sequence Control** |
| 2 bytes | 2 bytes |

Table 2: Source data field structure of a TC acceptance / execution failure report

|  |  |  |  |
| --- | --- | --- | --- |
| **TC Packet ID** | **Packet Sequence Control** | **Code** | **Parameters** |
| 2 bytes | 2 bytes | Enumerated | Any |

#### Summary

The Table 3 below summarizes the different sub-services of the PUS Telecommand Verification Service (service type 1) which shall be implemented by the LFR FSW.

Table 3: PUS Telecommand Verification Service

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sub-service name** | **Subtype** | **Category** | **DPU** | **LFR** |
| Telecommand Acceptance Report - Success | 1 | Report | Yes, only if requested in the TC ack flags | No |
| Telecommand Acceptance Report – Failure | 2 | Report | Yes | No |
| Telecommand Execution Completed Report - Success | 7 | Report | Yes, only if requested in the TC ack flags | Yes |
| Telecommand Execution Completed Report - Failure | 8 | Report | Yes | Yes |

The LFR FSW will not implement the following sub-services of the PUS Telecommand Verification Service:

* TC Execution Started Report – Success (subtype=3, report)
* TC Execution Started Report – Failure (subtype=4, report)
* TC Execution Progress Report – Success (subtype=5, report)
* TC Execution Progress Report – Failure (subtype=6, report)

A diagram given in APPENDIX B. Telecommand verification service, describes the telecommand verification process that shall be implemented by the LFR.

### Housekeeping reporting

#### HK reporting

|  |
| --- |
| REQ-LFR-SRS-5213\_Ed1DesignFor the transmission of the housekeeping to the DPU, the LFR FSW shall implement the Housekeeping Parameter Report subservice (subtype = 25) of the PUS Housekeeping Reporting service (type = 3) as defined in ECSS-E-70-41A – “Telemetry and telecommand packet utilization”- but with the following restrictions concerning the structure of the reports:* All the parameters of the different HK reports shall be sampled once (i.e. copied one time in the HK report) per collection interval (i.e. per generation period).
* There are no fixed-length arrays.

SSS-CP-FS-140 |
| REQ-LFR-SRS-5214\_Ed1TestEach HK report shall be identified by a unique identifier called a SID (Structure Identification). The SID of the HK report is the first field in the packet source data after the packet data field header.SSS-CP-FS-150 |

The LFR FSW only produces one type of HK report.

|  |
| --- |
| REQ-LFR-SRS-5215\_Ed1TestEach SY\_LFR\_HK\_SAMPLING\_PER, LFR should generate a TM\_LFR\_HK packet with SERVICE\_TYPE = 3 and SERVICE\_SUBTYPE = 25 and PA\_LFR\_HK\_REPORT\_SID = LFR\_HK\_SID.See REQ-LFR-SRS-5216\_Ed2 for value setting for period.SSS-CP-FS-160 |
| REQ-LFR-SRS-5216\_Ed2TestAt boot, LFR sets SY\_LFR\_HK\_SAMPLING\_PER = SY\_RPW\_HK\_REPORT\_PERIOD\_MIN. This value cannot be changed.SSS-CP-FS-170 |

Currently, SY\_RPW\_HK\_REPORT\_PERIOD\_MIN = 1 second.

The default value for the generation period of each HK report is specified in this document.

**Summary**

The Table 4 summarizes the different sub-services of the Housekeeping Reporting service (service type = 3) which shall be implemented by the LFR FSW.

Table 4: PUS Housekeeping Reporting service

|  |  |  |  |
| --- | --- | --- | --- |
| **Subservice name** | **Subtype** | **Category** | **Comment** |
| Housekeeping Parameter Report | 25 | Report | Periodic |

The other subservices of the Housekeeping Reporting service will not be implemented.

#### HK counter management

|  |
| --- |
| REQ-LFR-SRS-5241\_Ed1TestAll the counters (error counters, packet counters, etc.) managed by the LFR Flight Software shall restart at 0 when they have reached their maximum value.Here are all counters in TM\_LFR\_HK:Counter 14 bits [0, 16383]SEQUENCE\_CNT Counters 16 bits [0,65535]HK\_LFR\_UPDATE\_INFO\_TC\_CNTHK\_LFR\_UPDATE\_TIME\_TC\_CNTHK\_LFR\_EXE\_TC\_CNTHK\_LFR\_REJ\_TC\_CNTHK\_LFR\_LE\_CNT HK\_LFR\_ME\_CNTHK\_LFR\_DPU\_SPW\_PKT\_RCV\_CNTHK\_LFR\_DPU\_SPW\_PKT\_SENT\_CNTCounters 8 bits [0,255]HK\_LFR\_DPU\_SPW\_TICK\_OUT\_CNTHK\_LFR\_DPU\_SPW\_[PARITY, DISCONNECT, ESCAPE, CREDIT, WRITE\_SYNC]HK\_LFR\_DPU\_SPW\_EARLY\_EOPHK\_LFR\_DPU\_SPW\_INVALID\_ADDRHK\_LFR\_DPU\_SPW\_EEPHK\_LFR\_DPU\_SPW\_RX\_TOO\_BIGHK\_LFR\_TIMECODE\_[ERRONEOUS, MISSING, INVALID]HK\_LFR\_TIME\_[TIMECODE\_IT, NOT\_SYNCHRO, TIMECODE\_CTR ]HK\_LFR\_AHB\_CORRECTABLESSS-CP-FS-201 |

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### EDAC management

#### EDAC management

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| REQ-LFR-SRS-5223\_Ed1DesignIn case of a detection of an error (correctable or not correctable; on instruction or on data) by the EDAC, the LFR FSW shall report the error (including the failing address) by using its periodic HK.Note correctable bit errors are not seen by the EDAC (SSS-CP-FS-455 is partially covered).SSS-CP-FS-455 |
| REQ-LFR-SRS-5224\_Ed1DesignIn case of detection of a correctable error, the LFR FSW shall scrub the failing memory location (write corrected data back).SSS-CP-FS-460 |
| REQ-LFR-SRS-5225\_Ed1DesignIn case of detection of a not correctable error during instruction fetch (instruction access error), the LFR FSW shall performed the actions specified in AD12.SSS-CP-FS-470 |
| REQ-LFR-SRS-5226\_Ed2DesignIn case of detection of a not correctable error during data access (data access exception); depending on the criticality of the data, the LFR FSW shall perform the actions specified in AD12.SSS-CP-FS-480 |
| REQ-LFR-SRS-5227\_Ed1DesignThe LFR FSW shall periodically scrub the entire memory area protected by EDAC (read, check memory status, write corrected data back).SSS-CP-FS-490 |
| REQ-LFR-SRS-5228\_Ed1DesignThe atomicity of the scrubbing actions (read / write back cycle) shall be guaranteed.SSS-CP-FS-495 |
| REQ-LFR-SRS-5229\_Ed1DesignThe LFR FSW shall maintain a counter of the correctable errors and a counter of the not correctable errors detected by EDAC.These counters are part of the HW status reported in the periodic HK reports.SSS-CP-FS-500 |

The aim of the scrubbing loop is to anticipate the detection of errors, and particularly to anticipate the detection of double errors. The scrubbing period will be determined during the software design phase.

### Watchdog management

A watchdog is implemented at LFR flight software level (software wathchdog executed in RTEMS tasks) but reliying on a hardware timer managed by IP core gptimer at FPGA level. LFR watchdog is implemented as follows :

* A very low priority RTEMS task called “LOAD” sets and starts a countdown timer of 10 seconds (hardware timer managed by IP core gptimer).
* The countdown timer is reloaded to his initial value (10s) every 1 s by “LOAD” task.
* In case of critical failure, the timer should reach 0 : an interruption is raised and a routine performing an exit(0) of LFR FSW is launched.

**NB :** When SpaceWire connection is lost a RTEMS task called “LINK” which has the highest priority (non preemptable) is activated to monitor and manage the SpaceWire reconnection status. Because “LINK” task priority will prevent in this case the reload of the countdown timer and to avoid an unrelevant watchdog trigger, “LINK” task will handle countdown reload every 1s until link is restored to nominal state. Then “LOAD” task will recover his ability to reload countdown.

#### Watchdog management

|  |
| --- |
| REQ-LFR-SRS-5230\_Ed1TestAfter initialization, the LFR FSW shall automatically enable the watchdog functionality.SSS-CP-FS-520 |
| REQ-LFR-SRS-5231\_Ed1InspectionWhen the watchdog functionality is enabled, the LFR FSW shall periodically reload the watchdog counter before this one reaches zero and makes the system reset.SSS-CP-FS-530 |
| REQ-LFR-SRS-5232\_Ed1Inspection anf TestWhen the watchdog reaches 0, the LFR FSW shall activate a software context back-up procedure.* The LFR analyzer shall at least save the reason of the reset (i.e. the watchdog reached zero).

SSS-CP-FS-540 |

It has to be noticed that such a requirement is not implementable for a watchdog done at software level. When the watchog reaches 0, the LFR behavior is equivalent of a TC\_LFR\_RESET execution.

### Cache Configuration

|  |
| --- |
| REQ-LFR-SRS-5289\_Ed1TestThe LFR FSW shall explicitly configure the data and instruction caches at startup.After the boot sequence, data cache and instruction cache should be enabled.SSS-CP-FS-610 |

### Telemetry management

#### Telemetry management

With LFR analyzer:

-For verification packets, DESTINATION\_ID shall be a copy of the SOURCE\_ID from the TC.

-For TM\_LFR\_PARAMETER\_DUMP and TM\_LFR\_KCOEFFICIENTS\_DUMP, DESTINATION\_ID shall be a copy of the SOURCE\_ID from TC\_LFR\_DUMP\_PAR and TC\_LFR\_DUMP\_KCOEFFICIENTS (Cat=6).

-For others TM (TM\_LFR\_SCIENCE, TM\_LFR\_HK) packets, DESTINATION\_ID shall be GROUND.

|  |
| --- |
| REQ-LFR-SRS-5239\_Ed2TestWhen building a TM packet, the LFR Flight Software shall set the Destination ID field by complying with the following rules:* For telemetry generated as an answer to a command, the Destination ID shall be the copy of the command Source ID field with exception of all TM packets having the packet category = 2 (HK essential), = 3 (Table), = 4 (HK routine), = 8 (diagnostic) and = 9 (dump).
* For telemetry resulting from a process designed to produce data for another process in another SW item, it shall contain the Destination ID of the receiving process.
* For telemetry not covered by the above cases, the field shall be set to zero, meaning Ground.

SSS-CP-FS-580 |
| REQ-LFR-SRS-5240\_Ed2TestThe LFR Flight Software shall maintain, for each couple of APID and Destination ID, a TM sequence counter incremented by 1 when a packet is released (see “Preliminary restriction about counters”):-The sequence counters shall wrap around from 2^14-1 to zero.-The sequence counter shall start at zero at startup.SSS-CP-FS-590 |

## Performance requirements

#### Time management

Time is managed by hardware VHDL design. FSW reads when needed the time in control register of VHDL module. FSW can only reset the local time to 0 using input register of VHDL module and also write received coarse time (from TC\_LFR\_UPDATE\_TIME) in coarse\_time\_load register of VHDL module. The VHDL implementation is detailed in AD18.

|  |
| --- |
| REQ-LFR-SRS-5217\_Ed1DesignThe format of the local time handled by the LFR FSW shall be compliant with the AD14 time pattern is made of a coarse time part coded on 32 bits (number of seconds) and a fine time part coded on 16 bits (number of fraction of seconds).* The resolution of the coarse part time is 1 second (LSB = 1 second).
* The resolution of the fine part time is 2-16 second (LSB = 15.2587891 μs).

SSS-CP-FS-350 |
| REQ-LFR-SRS-5218\_Ed1TestAfter initialization :* the LFR FSW shall start its local time setting the most significant bit of its local time to 1 and all other bits to 0 using dedicated register of VHDL module time management([AD18]).

Concerning software reset i.e. TC\_LFR\_RESET (see SSS-CP-EQS-220), the command performs exit(0).SSS-CP-FS-360 |
| REQ-LFR-SRS-5219\_Ed1TestThe LFR FSW shall synchronize its local time with the Central Time Reference (CTR) distributed as a SpaceWire command packet coupled to a SpaceWire time code.* The CTR SpaceWire command packet containing the CTR is not necessarily sent by the DMS every one second. After boot if no CTR is received after SY\_LFR\_TIME\_SYNC\_TIMEOUT seconds, LFR is considered not synchronized, relies on its internal clock and keeps sync bit to 1 (MSB of coarse time). During operations, If no CTR is received after 60 seconds LFR continues to rely on its internal clock and set sync bit to 1.
* When it is generated, the CTR SpaceWire command packet is transmitted > SY\_RPW\_CTR\_MIN\_DELAY prior to the time code itself (AD14).
* The CTR SpaceWire time code is transmitted with SY\_RPW\_CTR\_FREQUENCY frequency.
* The CTR SpaceWire command packet is distributed thanks to the “Accept Time Update” command (service type = 9, subtype = 129).
* The SpaceWire time code contains the least significant bits of the CTR coarse time part.

SSS-CP-FS-370 |

LFR FSW is compliant with the nominal behavior, every one second, sent by DPU

* One CTR SpaceWire command packet transmitted SY\_RPW\_CTR\_MIN\_DELAY prior to the time code itself (TC\_LFR\_UPDATE\_TIME)
* The CTR SpaceWire time code is transmitted with SY\_RPW\_CTR\_FREQUENCY frequency
* The SpaceWire time code contains the 6 least significant bits of the CTR coarse time part, (field CP\_RPW\_TIME of TC\_LFR\_UPDATE\_TIME)

If after the boot, LFR FSW receives the command packet coupled to a SpaceWire time code from the DPU , LFR local time will be synchronized (MSB = 0). Otherwise, LFR FSW will be not synchronized and MSB = 1.

If LFR lost the time synchronization after SY\_RPW\_DELAY\_WITHOUT\_CTR (MSB = 1) , LFR FSW will be synchronized again if the couple (CTR + timecode) is received.

If The SpaceWire time code is not equal to the 6 least significant bits of the CTR coarse time part,the field HK\_LFR\_TIMECODE\_CTR is incremented of 1 into the TM\_LFR\_HK.

If LFR FSW is synchronized (MSB=0) and if a CTR command packet has not been received prior to the time code, the time-code will be taken into account but HK\_LFR\_TIMECODE\_CTR will be incremented of 1 into the TM\_LFR\_HK because LFR FSW has tested the coarse time of the last TC\_LFR\_UPDATE\_TIME accepted and the time-code just received.

|  |
| --- |
| REQ-LFR-SRS-5237\_Ed2TestThe LFR Flight Software shall not acknowledge the “Accept Time Update” packet.SSS-CP-FS-376 |

The time pattern is given in (Solar Orbiter EID-A).

Table 5: Time pattern format

|  |  |
| --- | --- |
| **COARSE TIME** | **FINE TIME** |
| 0 |  | 7 | 8 |  | 15 | 16 |  | 23 | 24 |  | 31 | 32 |  | 39 | 40 |  | 47 |
| Byte 0 | Byte 1 | Byte 2 | Byte 3 | Byte 4 | Byte 5 |
| 231 |  | 224 | 223 |  | 216 | 215 |  | 28 | 27 |  | 20 | 2-1 |  | 2-8 | 2-9 |  | 2-16 |

The LFR receives the SpaceWire command packet coupled to a SpaceWire time code from the DPU.

The “Accept Time Update” command is not a PUS service.

|  |
| --- |
| REQ-LFR-SRS-5220\_Ed2Test and DesignUpon the reception of the CTR SpaceWire time code sent by DPU, the LFR FSW shall:* If a CTR command packet has been received prior to the time code:
	+ Update the coarse time part of its local time with the coarse time value previously transmitted in a CTR command packet. The SpaceWire time code contains the 6 least significant bits of the CTR coarse time part
* if a CTR command packet has not been received prior to the time code:
	+ update following HK fields if time code is valid : HK\_LFR\_DPU\_SPW\_TICK\_OUT\_CNT and HK\_LFR\_DPU\_SPW\_LAST\_TIMC. Management and processing of the time code is done exclusively by Spacewire IP (VHDL). Behavior is completely described in [AD18] and [RD03].

Also, the Spacewire IP will set the fine time part of its local time to 0 upon the reception of the CTR SpaceWire time code sent by DPU.Spacewire IP related behavior is validated by design (REQ-LFR-SRS-5401) : see [RD01].Note SY\_RPW\_CTR\_FREQUENCY, and SY\_RPW\_CTR\_MIN\_DELAY is defined in REQ-LFR-SRS-5219.SSS-CP-FS-380 |
| REQ-LFR-SRS-5221\_Ed1DesignThe LFR FSW shall use its local time to timestamp all its internal events and all the data packets (HK data and science data).* The LFR FSW local time value is copied in the S/C Time field of the TM packet data field header.

SSS-CP-FS-400 |
| REQ-LFR-SRS-5238\_Ed1TestOn successful time synchronization (i.e. when a CTR Time Update command packet followed by a SpaceWire time code were received), the LFR Flight Software shall set the most significant bit of its local time to 0.In TM\_LFR\_HK:The field HK\_LFR\_DPU\_SPW\_TICK\_OUT\_CNT is incremented of one.The field HK\_LFR\_DPU\_LAST\_TIMC is filled with the valid value of the time-codeSSS-CP-FS-405 |
| REQ-LFR-SRS-5222\_Ed1TestIf no SpaceWire time code or CTR message is received by the LFR FSW for a period greater than SY\_RPW\_DELAY\_WITHOUT\_CTR, the LFR FSW shall indicate this by setting the MSB of the time field of each packet to 1.SSS-CP-FS-410 |

The on-board time (CTR) conveyed in TC(9,129) is elapsed time in seconds since a zero point reference time: the arbitrary zero point reference time is 0.00 on Jan 1, 2000.

The zero point reference time has been chosen by Astrium such that there is no risk of the ms bit of the CUC time being used during the Solar Orbiter mission (including the extended mission).

Therefore, there is no conflict between EIDA R-788 and R-837.

|  |
| --- |
| REQ-LFR-SRS-5300\_Ed2TestThe LFR FSW shall maintain a local time with a resolution of at least SY\_RPW\_TIME\_RESOLUTION and a relative accuracy of SY\_RPW\_TIME\_ACCURACY for the LFR analyzer.SSS-CP-FS-340 |
| REQ-LFR-SRS-5301\_Ed1DesignBetween the reception of the CTR message and the time code, the LFR FSW shall increment its local time autonomously with a resolution of at least SY\_TIME\_RESOLUTION for the DAS and the LFR analyzer.SSS-CP-FS-390 |

The CTR is distributed by the DMS with an accuracy of 350 µs.

#### Response time

|  |
| --- |
| REQ-LFR-SRS-5302\_Ed1TestThe LFR FSW shall generate the TC execution report (success or failure) not longer than SY\_RPW\_ACK\_RESPONSE\_TIME from the completion of the TC execution.SSS-CP-FS-131 |

#### Command packets (DPU SW to RPW Analyzer SW)

|  |
| --- |
| REQ-LFR-SRS-5303\_Ed1TestThe maximum rate of command packets generated by the DPU to the LFR is SY\_LFR\_TC\_MAX\_RATE commands per second.SSS-IF-DPS-EQ-190 |

#### RMAP write commands

|  |
| --- |
| REQ-LFR-SRS-5304\_Ed2Deleted in RPW-SYS-SSS-00013-LES since Issue:2/Rev.: 0 (Date: 13/11/2013).SSS-IF-DPS-EQ-130 |

#### Data packets (RPW Analyzer SW to DPU SW)

|  |
| --- |
|  Deleted in SSS 3.0 |
| REQ-LFR-SRS-5306\_Ed1DesignThe LFR FSW shall support a data transmission scheme where the maximum wait time between acquisitions of the data packets by the DPU is SY\_LFR\_TM\_MAX\_OUTAGE (=10ms).SSS-IF-DPS-EQ-220 |

The maximum data rate and the maximum wait time between data packets are the inputs to size properly the reception and transmission buffers of the LFR.

#### LFR Boot Parameters

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| REQ-LFR-SRS-5307\_Ed1DesignThe LFR boot parameters are the following:-LFR RAM start address: SY\_LFR\_RAM\_LOW\_ADDR = 0x40000000.-LFR RAM size: SY\_LFR\_RAM\_SIZE = 0x00100000.-LFR stack pointer address: SY\_LFR\_STACK\_POINTER = 0x400ffff0.-LFR last reset reason configuration flag: SY\_LFR\_RESET\_CAUSE\_CONFIG = FALSE-LFR last reset reason address: SY\_LFR\_RESET\_CAUSE\_ADDR = 0x00000000-LFR MCFG1 register value: SY\_LFR\_MCFG1 = 0x000002ff-LFR MCFG1 register value: SY\_LFR\_MCFG1 = 0x000002ff.-LFR MCFG2 register value: SY\_LFR\_MCFG2 = 0x00000e60.-LFR MCFG3 register value: SY\_LFR\_MCFG3 = 0x00000000.-LFR MCFG register configuration flag (TRUE = registers to be configured / FALSE = registers not to be configured): SY\_LFR\_MCFG\_CONFIG = TRUE.-LFR FPU configuration flag (TRUE = a FPU is present / FALSE = no FPU): SY\_LFR\_FPU\_CONFIG = TRUE.-LFR scaler reload register address: SY\_LFR\_SCALER\_RELOAD\_ADDR = 0x80000304.-LFR scaler reload register value: SY\_LFR\_SCALER\_RELOAD\_VALUE = 0x00000018.-LFR Timer1 reload register address: SY\_LFR\_TIMER1\_RELOAD\_ADD = 0x80000314.-LFR Timer1 control register address: SY\_LFR\_TIMER1\_CTRL\_ADDR = 0x80000318.-LFR AHB register configuration flag (TRUE = registers to be configured / FALSE = registers not to be configured): SY\_LFR\_AHB\_CONFIG = FALSE.-LFR AHB status register address: SY\_LFR\_AHB\_STATUS\_ADDR = 0.-LFR AHB failing register address: SY\_LFR\_AHB\_FAILING\_ADDR = 0.-LFR watchdog configuration flag (TRUE = registers to be configured / FALSE = registers not to be configured): SY\_LFR\_WATCHDOG\_CONFIG = FALSE.-LFR watchdog register address (significant if SY\_LFR\_WATCHDOG\_CONFIG = TRUE): SY\_LFR\_WATCHDOG\_ADDR = 0.-LFR RAM wash flag: SY\_LFR\_RAM\_WASH\_CONFIG = TRUE-LFR RAM wash delay: SY\_LFR\_RAM\_WASH\_DELAY = 2000 ms-LFR RAM wash register: SY\_LFR\_RAM\_WASH\_ADDR = 0x80000000-LFR RAM wash register: SY\_LFR\_RAM\_WASH\_VALUE = 0x80000000SSS-IF-DPS-EQ-221 |

## Interface requirements

### Interface between the LFR FSW and the DPU software

The RPW DPU is connected to the LFR thanks to one SpaceWire interfaces (redundant link). No SpaceWire router is present inside the DPU.

In the SAFE mode, the DPU communicates only with the RPW Power Distribution Unit, while in the OPERATIONAL mode, the DPU communicates with all the RPW equipments.

In the STANDBY and SCIENCE LFR modes, the SpaceWire interface between the DPU and the LFR shall be enabled.

The precise conditions for enabling/disabling the interface between the active DPU software and the LFR is described in the capability requirements.

#### DPU/Analyzer SpW interface

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| REQ-LFR-SRS-5400\_Ed2DeletedSSS-IF-DPS-EQ-050 |

The SpaceWire interface toward the DPU at the LFR level is configured to work in the **autoStart** mode. As soon as the LFR will be powered on, it remains in a state in which there are waiting for an incoming null token to go in the running mode. Moreover, the LFR analyzer chooses its active SpaceWire port by detecting on which link there is activity (i.e. null token traffic): port toward the nominal DPU or port toward the redundant DPU (see the dual port functionality described in the AD13).

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| REQ-LFR-SRS-5401\_Ed1DesignThe LFR FSW shall handle the SpaceWire time-code generated by the DPU.SSS-IF-DPS-EQ-060 |

### Communication protocol

#### DPU/Analyzer communication protocol: addressing method

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| REQ-LFR-SRS-5402\_Ed1DesignThe logical addressing method to identify the SpaceWire target destination in the SpaceWire packets shall be used by the LFR flight software.SSS-IF-DPS-EQ-070 |

The different logical addresses are specified in the RPW DPU software ICD.

#### DPU/Analyzer SpW interface

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| REQ-LFR-SRS-5411\_Ed2TestThe logical address of the DPU SpaceWire interface toward LFR shall be SY\_DPU\_LFR\_LA. That means that all the SpaceWire packets produced by LFR toward the DPU shall have the Destination Logical Address field set to SY\_DPU\_LFR\_LA.SSS-IF-DPS-EQ-071 |
| REQ-LFR-SRS-5412\_Ed2TestThe logical address of the LFR SpaceWire interface toward DPU shall be SY\_LFR\_DPU\_LA. That means that all the SpaceWire packets produced by the DPU toward LFR shall have the Destination Logical Address field set to SY\_LFR\_DPU\_LA.SSS-IF-DPS-EQ-072 |

Note the naming conventions for these parameters are respected: SY\_DPU\_LFR\_LA is a DPU parameter (known by LFR) and SY\_LFR\_DPU\_LA is a LFR parameter known by DPU.

#### Flight SW maintenance of TDS, TNR-HFR, LFR

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| **REQ-LFR-SRS-5403\_Ed2**SSS-IF-DPS-EQ-110 is currently only tagged DAS (since RPW-SYS-SSS-00013-LES\_Issue2\_rev1). |

#### RMAP write commands

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| **REQ-LFR-SRS-5404\_Ed2**SSS-IF-DPS-EQ-120 is currently only tagged DAS (since RPW-SYS-SSS-00013-LES\_Issue2\_rev1). |

#### RMAP read commands

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| **REQ-LFR-SRS-5405\_Ed3**SSS-IF-DPS-EQ-140 is currently only tagged DAS (since RPW-SYS-SSS-00013-LES\_Issue2\_rev1).  |
| **REQ-LFR-SRS-5406\_Ed2**Deleted |

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#### DPU / RPW Analyzer SW communication protocol

The communication protocol used between the DPU Software and the LFR will be of the same type as that used between the DPU and the DMS. This protocol will then be based on:

* The Telecommand and Telemetry Packet Utilization Standard for formatting the command and the data ([AD7]).
* The CCSDS packet transfer protocol for the SpaceWire packet encapsulation.

The RMAP protocol won’t be used except for the specific cases of the LFR FSW maintenance.

The benefits of this approach relying on the use of a standardized and generic protocol are:

* Minimization of the development and testing effort.
* The same SGSE can be used to control and monitor the DPU and the RPW subsystems.
* Regulation of the data flow is naturally done thanks to the inherent flow control mechanism of the SpaceWire protocol assuming that each subsystem has sufficient reception and transmission buffers. No master/slave approach is required.
* No need to specify complex “rendezvous” and complex message choreography between the DPU and the subsystems (as it will be the case with the RMAP protocol).
* Possibility to have a transparent command mode of the RPW subsystem. Especially useful during the AIT activities.

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| REQ-LFR-SRS-5407\_Ed1TestThe LFR and the DPU Application Software shall communicate by mean of command packets and data packets formatted according to [AD7]:* The Packet Type bit shall be set to ‘1’ by the DPU in the TC packets (not tested at LFR level)
* The Packet Type bit is set to ‘0’ by the LFR flight software when sending TM toward the DPU. The packet IDs generated by the LFR are following:

 76 / 1 = 0x0cc1 0x0c = 000**0** 1100 (packet type = ‘0’)76 / 4 = 0x0cc4 0x0c = 000**0** 1100 (packet type = ‘0’)76 / 9 = 0x0cc9 0x0c = 000**0** 1100 (packet type = ‘0’)76 / 12 = 0x0ccc 0x0c = 000**0** 1100 (packet type = ‘0’)79 / 12 = 0x0cfc 0x0c = 000**0** 1100 (packet type = ‘0’)SSS-IF-DPS-EQ-160 |
| REQ-LFR-SRS-5408\_Ed1DesignThe SpaceWire communication protocol between the DPU Application Software and LFR FSW shall be the CCSDS packet transfer protocol as defined in [AD9].SSS-IF-DPS-EQ-170 |

The generic structure of the SpaceWire packets exchanged between the DPU Software and the LFR is presented in appendix.

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| REQ-LFR-SRS-5413\_Ed1TestAccording to [AD9], the SpaceWire protocol header of the packets exchanged between DPU and the LFR flight software shall be made up of 4 bytes:* Target Logical Address.
* Protocol ID = 0x02 meaning CCSDS.
* Reserved byte = 0x00.
* User Application byte = 0x00.

SSS-IF-DPS-EQ-175 |

### Telecommands

#### Command packets (DPU SW to RPW analyzer SW)

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| REQ-LFR-SRS-5409\_Ed1TestThe LFR FSW shall receive commands from the DPU as telecommand source packets according to [AD7] with a maximum length of SY\_LFR\_TC\_MAX\_LEN (228 bytes). If a telecommand with length > SY\_LFR\_TC\_MAX\_LEN is received, expected behaviour from LFR FSW is :* The TC is discarded at Spacewire driver level so no acknowledge of this TC is emitted by LFR FSW.
* The Spacewire driver updates its error counter : SPW\_RX\_TOO\_BIG
* In TM\_LFR\_HK packet, LFR FSW should update dedicated field HK\_LFR\_DPU\_SPW\_RX\_TOO\_BIG with counter info described up above.
* In TM\_LFR\_HK packet, LFR FSW should also increment dedicated field HK\_LFR\_ME\_CNT (medium severity).

In case of LFR FSW shall receive commands from DPU a telecommand with a length < CCSDS\_TC\_PKT\_MIN\_SIZE , LFR FSW doesn’t acknowledge the TC during acceptance stage and no failure report will be generated. CCSDS\_TC\_PKT\_MIN\_SIZE = 16 Bytes, minimal size of all TC\_LFR\_xxx.SSS-IF-DPS-EQ-180 |

The structure of the telecommand source packets is given in appendix.

### Data

#### Data packets (RPW Analyzer SW to DPU SW)

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| REQ-LFR-SRS-5410\_Ed1InspectionThe data (science data and non-science) generated by LFR shall be transmitted to the DPU as telemetry source packets according to [AD7] with a maximum length of SY\_LFR\_TM\_MAX\_LEN.SSS-IF-DPS-EQ-200 |

The structure of the telemetry source packets is given in appendix.

### Interface between the LFR FSW and the LFR HW

The LFR FSW will be executed on a Leon3 soft processor instantiated in an Actel RTAX FPGA. The Leon3 will be connected to an AMBA SoC bus jointly with other modules:

* ADC drivers for the analog signals sampling
* ADC drivers for the temperature monitoring
* Anti-aliasing filtering module
* Down-sampling filters
* FFT accelerator
* Spectral Matrices accelerator
* Averaged Spectral Matrices accelerator
* DAC for the SCM calibration signal generation
* SpaceWire communication module, with RMAP abilities

The LFR FSW will have the ability to configure the abovementioned modules via the AMBA bus by writing data into registers via the AMBA bus. It will also get pre-processed data from the modules via the AMBA bus.

## Operational requirements

### LFR mode management

The following modes description is taken from the SSS, it is here just to clarify the reading of this document. The reference document for the modes description is the SSS.

The LFR software modes are directly linked to the RPW software modes which are presented on Figure 3. The RPW software modes are managed by the DPU software. In the RPW SAFE mode, the LFR is switched off.

In the RPW SERVICE mode:

* LFR can be switched on or off independently of the other RPW equipments.
* LFR can be booted by the DPU over the SpaceWire link.
* No self test procedures are implemented on LFR. SSS requirements about self tests only applies to TDS.
* LFR can be configured by the DPU (parameter settings, etc.).

No scientific measurements are performed in the SERVICE mode. When the RPW DPU Software is in the SERVICE mode, LFR, if it has been switched on, is put in the STANDBY mode.



Figure 3: Overview of the RPW software modes

When in SCIENCE mode, the DPU will steer LFR in different modes, depending on its own sub-modes as described in Figure 4.

As a response to the DPU modes, the LFR shall manage the following modes:

* STANDBY: a mode where no scientific measurements are performed
* SCIENCE: a mode split into 4 sub-modes:
	+ NORMAL
	+ BURST
	+ SBM1
	+ SBM2



Figure 4: DPU SCIENCE mode state chart

The matching between RPW DPU software modes and LFR modes in presented in Table 6.

Table 6: RPW scientific modes against LFR modes

|  |  |  |
| --- | --- | --- |
| **RPW Scientific Modes** | **RPW Scientific Sub-Modes** | **LFR Modes** |
| **SURVEY** | SURVEY\_NORMAL | NORMAL |
| SURVEY\_BURST | BURST |
| SURVEY\_NORMAL\_C | NORMAL |
| SURVEY\_BURST\_C | BURST |
| **DETECTION** | SBM\_DETECTION | SBM1 |
| SBM1\_DUMP | SBM1 |
| SBM2\_ACQUISITION | SBM2 |
| SBM\_DETECTION\_C | SBM1 |
| SBM1\_DUMP\_C | SBM1 |
| SBM2\_ACQUISITION\_C | SBM2 |

#### Equipment mode management

##### General

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| REQ-LFR-SRS-5500\_Ed1TestThe LFR FSW shall handle the following modes:* STANDBY mode: no measurements are performed.
* SCIENCE mode: measurements are performed. The SCIENCE mode is split in four sub-modes:
	+ NORMAL
	+ BURST
	+ SBM1
	+ SBM2

Note: Refer to SSS-GEN-FS-040 about the SAFE mode.SSS-CP-EQS-230 |

##### STANDBY mode

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| REQ-LFR-SRS-5501\_Ed1TestWhen LFR FSW enters the STANDBY mode, it shall stop the acquisitions if they are active.SSS-CP-EQS-240 |
| REQ-LFR-SRS-5502\_Ed1TestIn the STANDBY mode, the LFR FSW shall accept commands to configure the HW and the SW, in particular, the command allowing configuring the different science sub-mode parameter sets.Note (according to the system requirements) at the end of reset, the equipment is nominally in halted mode.SSS-CP-EQS-250 |

##### SCIENCE mode

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| REQ-LFR-SRS-5503\_Ed1TestIn the NORMAL mode, the LFR FSW shall send to the DPU one single data stream whose content corresponds to the NORMAL mode parameter set.LFR data packets producted are- Waveforms CWF\_F3 and CWF\_LONG\_F3- Snapshots SWF\_F0, SWF\_F1, SWF\_F2- Averaged spectral matrix ASM\_F0, ASM\_F1, ASM\_F2- Basic Parameters BP1\_F0, BP1\_F1, BP1\_F2, BP2\_F0, BP2\_F1, BP2\_F2depending on the configuration of 6 parameters2 parameters configure the snapshots* SY\_LFR\_N\_SWF\_L (defaut value=2048 )
* SY\_LFR\_N\_SWF\_P (default value = 300s)

Actually, only SY\_LFR\_N\_SWF\_P can be change [min, max] and max = 65535 (no more multiple of 8)1 parameter configure the waveforms* SY\_LFR\_N\_CWF\_LONG\_F3 (default value= 0) not CWF\_LONG\_F3 product

1 parameter configure the averaged spectral matrix* SY\_LFR\_ASM\_P (default value=3600s)

This parameter depends on the Basic Parameter , the min value must be egal to 4s (defauft value of SY\_LFR\_N\_BP\_P0). Checking parameters is* SY\_LFR\_ASM\_P >= 4s
* SY\_LFR\_ASM\_P must be a multiple of SY\_LFR\_N\_BP\_P0

2 parameters configure the Basic parameters* SY\_LFR\_N\_BP\_P0 (default value=4s)
* SY\_LFR\_N\_BP\_P1 (default value=20s)

Checking parameters is* Value must be >= default value
* SY\_LFR\_N\_BP\_P1 must be a multiple of SY\_LFR\_N\_BP\_P0

SY\_LFR\_N\_BP\_P1 could be equal to SY\_LFR\_N\_BP\_P0 (it’s a multiple).SSS-CP-EQS-260 |
| REQ-LFR-SRS-5504\_Ed1TestIn the BURST mode, the LFR FSW shall send to the DPU one single data stream whose content corresponds to the BURST mode parameter set.LFR data packets producted are- Waveforms CWF\_F2- Basic Parameters BP1\_F0, BP1\_F1, BP2\_F0, BP2\_F1depending on the the configuration of 2 parameters.2 parameters configure the basic parameters * SY\_LFR\_B\_BP\_P0 (default value= 1s)
* SY\_LFR\_B\_BP\_P1 (default value=5s)

Checking parameters is* Value must be >= default value
* SY\_LFR\_B\_BP\_P1 must be a multiple of SY\_LFR\_B\_BP\_P0

SY\_LFR\_B\_BP\_P1 could be equal to SY\_LFR\_B\_BP\_P0 (it’s a multiple).SSS-CP-EQS-270 |
| REQ-LFR-SRS-5505\_Ed1TestIn the SBM1 mode, the LFR FSW shall send to the DPU two concurrent data streams:* A low cadence data stream whose content corresponds to the NORMAL mode parameter set.
* A high cadence data stream whose content corresponds to the SBM1 mode parameter set.

The low cadence is already described in REQ\_LFR\_SRS\_5503\_Ed1.In high cadence, LFR data packets producted are- Waveforms CWF\_F1- Basic Parameters BP1\_F0, BP2\_F0depending on the the configuration of 2 parameters.2 parameters configure the basic parameters * SY\_LFR\_S1\_BP\_P0 (default value= 0.25s)
* SY\_LFR\_S1\_BP\_P1 (default value=1s)

Checking parameters is* Value must be >= default value
* SY\_LFR\_S1\_BP\_P1 must be a multiple of SY\_LFR\_S1\_BP\_P0

SY\_LFR\_S1\_BP\_P1 could be equal to SY\_LFR\_S1\_BP\_P0 (it’s a multiple).SSS-CP-EQS-280 |
| REQ-LFR-SRS-5506\_Ed1TestIn the SBM2 mode, the LFR FSW shall send to the DPU two concurrent data streams:* A low cadence data stream whose content corresponds to the NORMAL mode parameter set.
* A high cadence data stream whose content corresponds to the SBM2 mode parameter set.

The low cadence is already described in REQ\_LFR\_SRS\_5503\_Ed1.In high cadence, LFR data packets producted are- Waveforms CWF\_F2- Basic Parameters BP1\_F0, BP1\_F1, BP2\_F0, BP2\_F1depending on the the configuration of 2 parameters.2 parameters configure the basic parameters * SY\_LFR\_S2\_BP\_P0 (default value= 0.25s)
* SY\_LFR\_S2\_BP\_P1 (default value=1s)

Checking parameters is* Value must be >= default value
* SY\_LFR\_S2\_BP\_P1 must be a multiple of SY\_LFR\_S2\_BP\_P0

SY\_LFR\_S2\_BP\_P1 could be equal to SY\_LFR\_S2\_BP\_P0 (it’s a multiple).SSS-CP-EQS-290 |
| REQ-LFR-SRS-5590\_Ed1TestUpon reception of a TC\_LFR\_ENTER\_MODE(SBM1) / TC\_LFR\_ENTER\_MODE(SBM2), LFR FSW shall not re-initialize the NORMAL data flow for waveform products if this one was already active to ensure waveform centering with other instruments. Spectral products dataflow from the NORMAL dataflow could be re-initialize because there is no synchronization constraints with other instruments. Upon reception of a TC\_LFR\_ENTER\_MODE(NORMAL), LFR FSW should reject the transition with TM\_LFR\_TC\_EXE\_NOT\_EXECUTABLE if NORMAL mode is already active so NORMAL dataflow will not be impacted.SSS-CP-EQS-326 |
| REQ-LFR-SRS-5591\_Ed1TestLFR FSW shall stop to produce science packets as soon as it has sent the acknowledgment packet related to the mode transition to STANDBY.  SSS-CP-EQS-327 |
| REQ-LFR-SRS-5592\_Ed1TestLFR FSW shall ignore the synchronization bit of the CP\_LFR\_ENTER\_MODE\_TIME parameter (most significant bit) when they handle a TC\_LFR\_ENTER\_MODE command.  SSS-CP-EQS-328 |

##### Mode transition

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| REQ-LFR-SRS-5507\_Ed1TestA mode transition shall correspond to the activation by the LFR FSW of the set of configuration parameters corresponding to the mode.SSS-CP-EQS-300 |
| REQ-LFR-SRS-5508\_Ed1TestThe LFR FSW software shall have one TC\_LFR\_ENTER\_MODE command for activating the modes, with the two following parameters:* One parameter for selecting the mode: STANDBY, NORMAL, BURST, SBM1, SBM2.
* One parameter giving the time at which the transition has to take place, i.e. when the set of parameters corresponding to the mode shall be activated. This time parameter always corresponds to the occurrence of a SpaceWire time code. This time parameter is also used as a reference time for the synchronization of the acquisitions (adjustment of the equipment sampling times).

Note: Refer to SSS-GEN-FS-040 about the SAFE mode;SSS-CP-EQS-310 |
| REQ-LFR-SRS-5509\_Ed1TestThe LFR FSW shall ensure, using its internal time, the synchronization of the LFR mode transition on the due date.Mode change at a due date is implemented like this :If TC is accepted :1. We stop the current mode immediately
2. We restart real time tasks with required mode parameters
3. We configure hardware in order to make it start acquisition of data at specified due date
4. After those steps we consider LFR is in the requested mode (which can be checked in HK)

This procedure implies that a succesful mode transition at a due date only can be validated after analyse of SCIENCE\_CWF packets (PA\_LFR\_ACQUISITION\_TIME should be equal to due date, sometimes we observe some fine time prior the last time of the TM\_LFR\_EXE\_SUCCESS of TC.SSS-CP-EQS-320 |
| REQ-LFR-SRS-5565\_Ed1TestLFR FSW shall execute the mode transition on the next sharp second (current coarse time +1) if the time given in parameter of the TC\_LFR\_ENTER\_MODE packet is equal to 0.SSS-CP-EQS-321 deviated (see RFD) |
| REQ-LFR-SRS-5566\_Ed1TestLFR FSW shall reject the TC\_LFR\_ENTER\_MODE packet if the time given in parameter is lower than the current time.For LFR, the CP\_LFR\_ENTER\_MODE\_TIME is <= current time. In this case a TM\_LFR\_TC\_EXE\_NOT\_EXECUTABLE is generated.SSS-CP-EQS-322 |
| REQ-LFR-SRS-5567\_Ed1TestLFR FSW shall accept all the transition between modes excepting if the destination mode is equal to the source mode. In this case a TM\_LFR\_TC\_EXE\_NOT\_EXECUTABLE is generated.SSS-CP-EQS-325 |
| REQ-LFR-SRS-5571\_Ed1TestLFR FSW shall reject the TC\_LFR\_ENTER\_MODE packet if the CP\_LFR\_ENTER\_MODE\_TIME parameter is greater than the current time plus 3 seconds.In this case a TM\_LFR\_EXE\_NOT\_EXECUTABLE is generated.SSS-CP-EQS-323 |

The configuration of each mode is performed before the transition itself thanks to the command allowing configuring the parameter set of the mode.

#### Acquisition synchronization

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| REQ-LFR-SRS-5510\_Ed1DesignThe LFR FSW shall allow adjusting the LFR sampling times by using its internal time (which is synchronized with the spacecraft clock) and the reference time that is transmitted as a parameter of the TC\_LFR\_ENTER\_MODE command.SSS-CP-EQS-330 |
| REQ-LFR-SRS-5511\_Ed1TestThe LFR FSW shall ensure that the waveform acquisitions are synchronized exactly on the second, with a precision higher than 500 μs. E.g. . with a 16 samples/second cadence, the first sample shall be taken exactly on the second and the 17th sample exactly on the next second. This requirement should be implemented by using the SpaceWire time code to have internal LFR time synchronized with SC time.SSS-CP-EQS-340 |

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| REQ-LFR-SRS-5512\_Ed1TestConsidering waveform snapshots, the LFR FSW shall centre, with a precision higher than 1 ms, the snapshot time window on the reference time that is transmitted as a parameter of the TC\_LFR\_ENTER\_MODE command. Following snapshots will be centered on T0+n\*p where T0 is the reference time transmitted by TC\_LFR\_ENTER\_MODE command, n is an integer and p the period between 2 snapshots (specified by SY\_LFR\_N\_SWF\_P value).SSS-CP-EQS-350 |

#### Inter-equipment shared data

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| REQ-LFR-SRS-5553\_Ed1TestThe LFR flight software shall be able to receive and process the shared status/HK distributed by the DPU at regular time intervals (≤ 2000 ms) as TC\_LFR\_UPDATE\_INFO packets. It has to be noted that LFR flight software will process those status even for time intervals > 2000ms and for every LFR mode.SSS-CP-EQS-351 |
| ~~REQ-LFR-SRS-5554\_Ed1~~~~Test~~~~LFR FSW (LFR and TDS in LF backup mode) shall adapt their on-board processing in accordance with the working mode of the BIAS Unit (outputs configuration) appearing into the shared Status/HK packets.~~~~SSS-CP-EQS-352~~ Deleted in SSS V3.0 |
| REQ-LFR-SRS-5555\_Ed1TestThe LFR flight software shall extract the relevant parameters from the shared status/HK packets for inserting them into their scientific TM packets.* In particular, the LFR flight software shall systematically reflect the BIAS Unit outputs configuration into their scientific TM packets with those dedicated fields : PA\_BIA\_MODE\_MUX\_SET, PA\_BIA\_MODE\_HV\_ENABLED, PA\_BIA\_MODE\_BIAS1\_ENABLED, PA\_BIA\_MODE\_BIAS2\_ENABLED,PA\_BIA\_MODE\_BIAS3\_ENABLED, PA\_BIA\_ON\_OFF.

SSS-CP-EQS-353 |
| REQ-LFR-SRS-5564\_Ed1TestThe LFR FSW shall not acknowledge the TC\_LFR\_UPDATE\_INFO packets. However, dedicated HK fields will be incremented if the command has been accepted : HK\_LFR\_UPDATE\_INFO\_TC\_CNT. This TC will be rejected and HK\_LFR\_UPDATE\_INFO\_TC\_CNT will not be incremented if CP\_TDS\_MODE\_COPY or CP\_THR\_MODE\_COPY or CP\_LFR\_MODE\_COPY are inconsistent or wrong values.SSS-CP-EQS-354 |

#### Science data acquisition and processing

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| REQ-LFR-SRS-5513\_Ed1TestThe LFR FSW shall receive the data acquired or pre-processed by the hardware part of the LFR.SSS-CP-EQS-360 |
| REQ-LFR-SRS-5514\_Ed1TestThe LFR FSW shall perform the suitable treatments on the acquired data in order to generate the data products expected in the current working mode. This concerns all Basic Parameters products which are computed onboard from ASM products.SSS-CP-EQS-370 |
| REQ-LFR-SRS-5515\_Ed1TestThe LFR FSW shall transmit the science data to the DPU as packets compliant to the PUS service n°21.SSS-CP-EQS-380 |
| REQ-LFR-SRS-5516\_Ed1TestThe structure and content of the source data fields of the science data packets generated by the LFR FSW shall be compliant to the RPW IDB.SSS-CP-EQS-390 |
| REQ-LFR-SRS-5517\_Ed1TestThe LFR FSW shall use its internal time to time-stamp all the packets (HK or science data) it transmits to the DPU.SSS-CP-EQS-400 |
| REQ-LFR-SRS-5518\_Ed2TestEach data packet generated by the LFR FSW shall contain the (one and only one) absolute time information (SCET): the time of the first sample containeded in the packet (acquisition time). The time of the other samples are deduced from the time of the first sample.* The absolute time value shall be copied twice:1) in the time field of the TM packet data field header (PUS header)2) in the TM packet source data auxiliary header (data fields).
* If needed, some relative timestamps can be added in the data packet to tag data blocks

SSS-CP-EQS-410 |
| REQ-LFR-SRS-5573\_Ed1TestLFR FSW shall always set the segmentation grouping flag of the scientific TM packets to the value “Stand-alone packet”.For LFR, here is the exhaustive list of scientific TM packets that should be tagged “Stand-alone packet” :TM\_LFR\_SCIENCE\_NORMAL\_CWF\_F3 TM\_LFR\_SCIENCE\_NORMAL\_CWF\_LONG\_F3 TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F0 TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F1 TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F2 TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F0 TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F1 TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F2 TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F0 TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F1 TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F2 TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F0 TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F1 TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F2 TM\_LFR\_SCIENCE\_BURST\_CWF\_F2 TM\_LFR\_SCIENCE\_BURST\_BP1\_F0 TM\_LFR\_SCIENCE\_BURST\_BP1\_F1 TM\_LFR\_SCIENCE\_BURST\_BP2\_F0 TM\_LFR\_SCIENCE\_BURST\_BP2\_F1 TM\_LFR\_SCIENCE\_SBM1\_CWF\_F1 TM\_LFR\_SCIENCE\_SBM1\_BP1\_F0 TM\_LFR\_SCIENCE\_SBM1\_BP2\_F0 TM\_LFR\_SCIENCE\_SBM2\_CWF\_F2 TM\_LFR\_SCIENCE\_SBM2\_BP1\_F0 TM\_LFR\_SCIENCE\_SBM2\_BP1\_F1 TM\_LFR\_SCIENCE\_SBM2\_BP2\_F0 TM\_LFR\_SCIENCE\_SBM2\_BP2\_F1SSS-CP-EQS-415 |

### Data products and data packets

This section defines all the data that can be produced by the LFR FSW and transmitted to the DPU.

The list of the enabled products according to the mode, the number of samples per second, the number of points per snapshots, the measurement time, the spectrum frequency count, etc., are software parameters that can be changed upon command.

In the following sections, f0, f1, f2 and f3 are the sampling frequencies managed by LFR:

* f0 = 24576 Hz
* f1 = 4096 Hz
* f2 = 256 Hz
* f3 = 16 Hz

#### Continuous waveforms

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| REQ-LFR-SRS-5519\_Ed1TestThe LFR FSW shall be able to generate continuous waveforms containing the following components:* In NORMAL mode and SBM modes:
	+ Electric field components sampled at f3: V\_f3, E1\_f3, E2\_f3
	+ Magnetic field components sampled at f3: B1\_f3, B2\_f3, B3\_f3 (Only if SY\_LFR\_N\_CWF\_LONG\_F3 bit is set to 1 with TC\_LFR\_LOAD\_NORMAL\_PAR. By default, SY\_LFR\_N\_CWF\_LONG\_F3 bit is set to 0)
* In BURST mode and SBM2 mode:
	+ Electric field components sampled at f2: V\_f2, E1\_f2, E2\_f2
	+ Magnetic field components sampled at f2: B1\_f2, B2\_f2, B3\_f2
* In SBM1 mode:
	+ Electric field components sampled at f1: V\_f1, E1\_f1, E2\_f1
	+ Magnetic field components sampled at f1: B1\_f1, B2\_f1, B3\_f1

SSS-CP-EQS-420 |

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| REQ-LFR-SRS-5524\_Ed2TestThe LFR FSW shall transmit to the DPU the continuous waveforms in the following data packets:* In NORMAL mode and SBM modes: TM\_LFR\_SCIENCE\_NORMAL\_CWF\_F3 or TM\_LFR\_SCIENCE\_NORMAL\_CWF\_LONG\_F3 depending on the LFR configuration specified in TC\_LFR\_LOAD\_NORMAL\_PAR
* In BURST mode: TM\_LFR\_SCIENCE\_BURST\_CWF\_F2
* In SBM1 mode: TM\_LFR\_SCIENCE\_SBM1\_CWF\_F1
* In SBM2 mode: TM\_LFR\_SCIENCE\_SBM2\_CWF\_F2

Where F1, F2 or F3 identify the sampling frequency.SSS-CP-EQS-470 |

Note: The TM\_LFR\_SCIENCE\_NORMAL\_CWF\_F3 packets don’t contain the B components. They are only transmitted in the TM\_LFR\_SCIENCE\_NORMAL\_CWF\_LONG\_F3 packets. The nominal case is to transmit TM\_LFR\_SCIENCE\_NORMAL\_CWF\_F3 packets, but, in case of failure of MAG instrument, LFR can be configured to transmit TM\_LFR\_SCIENCE\_NORMAL\_CWF\_LONG\_F3 packets instead of TM\_LFR\_SCIENCE\_NORMAL\_CWF\_F3 packets.

#### Waveform snapshots

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| REQ-LFR-SRS-5520\_Ed2TestThe LFR FSW shall be able to generate waveform snapshots containing the followingcomponents:* In NORMAL mode and SBM modes, SY\_LFR\_N\_SWF\_L samples every SY\_LFR\_N\_SWF\_P seconds:
	+ Electric field components sampled at f0: V\_f0, E1\_f0, E2\_f0
	+ Magnetic field components sampled at f0: B1\_f0, B2\_f0, B3\_f0
	+ Electric field components sampled at f1: V\_f1, E1\_f1, E2\_f1
	+ Magnetic field components sampled at f1: B1\_f1, B2\_f1, B3\_f1
	+ Electric field components sampled at f2: V\_f2, E1\_f2, E2\_f2
	+ Magnetic field components sampled at f2: B1\_f2, B2\_f2, B3\_f2
* In NORMAL mode : LFR FSW will use 3 dedicated buffers (F0, F1 and F2) containing SY\_LFR\_N\_SWF\_L samples to perform generation of the snapshot products.
* In SBM modes : LFR FSW will extract snapshot values from CWF\_F2 buffer to perform generation of the snapshot products.

SSS-CP-EQS-430 |

SY\_LFR\_N\_SWF\_L = 2048 samples (nominal value = always 2048)

SY\_LFR\_N\_SWF\_P = 300 seconds (nominal value)

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| REQ-LFR-SRS-5575\_Ed1TestThe LFR FSW shall be able to change the value of SY\_LFR\_N\_SWF\_P parameters upon reception of the TC\_LFR\_LOAD\_NORMAL\_PAR packet. Concerning SY\_LFR\_N\_SWF\_L : changing the value is not allowed on EM and generate TM\_LFR\_TC\_EXE\_INCONSISTENT for now. A LPP internal discussion has been initiated with scientists and technical engineer to determine the scientific and hardware relevance of this feature. Only default value (SY\_LFR\_N\_SWF\_L = 2048) is authorized.It has to be reminded that TC\_LFR\_LOAD\_NORMAL\_PAR is only accepted when LFR current mode is : STANDBY OR BURST (see tab 5.2)SSS-CP-EQS-431 |

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#### LFR data products - averaged spectral matrixes

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| REQ-LFR-SRS-5521\_Ed1TestThe LFR flight software shall be able to generate averaged spectral matrixes:* In NORMAL mode and SBM modes, every 3600 seconds:
	+ Averaged spectral matrix from the EM data stream at f0: ASM\_f0
	+ Averaged spectral matrix from the EM data stream at f1: ASM\_f1
	+ Averaged spectral matrix from the EM data stream at f2: ASM\_f2

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#### LFR data products - basic parameters set 1

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| REQ-LFR-SRS-5522\_Ed2TestThe LFR flight software shall be able to generate the following set of basic parameters (set 1):* In NORMAL mode and SBM modes, every 4 seconds:
	+ Basic parameter 1 at f0: PE\_f0, PB\_f0, nvec\_f0, ellip\_f0, dop\_f0, Sz\_f0, Vphi\_f0
	+ Basic parameter 1 at f1: PE\_f1, PB\_f1, nvec\_f1, ellip\_f1, dop\_f1, Sz\_f1, Vphi\_f1
	+ Basic parameter 1 at f2: PE\_f2, PB\_f2, nvec\_f2, ellip\_f2, dop\_f2, Sz\_f2, Vphi\_f2
* In BURST mode and SBM2 mode, every 1 second:
	+ Basic parameter 1 at f0: PE\_f0, PB\_f0, nvec\_f0, ellip\_f0, dop\_f0, Sz\_f0, Vphi\_f0
	+ Basic parameter 1 at f1: PE\_f1, PB\_f1, nvec\_f1, ellip\_f1, dop\_f1, Sz\_f1, Vphi\_f1
* In SBM1 mode, every 0.25 seconds:
	+ Basic parameter 1 at f0: PE\_f0, PB\_f0, nvec\_f0, ellip\_f0, dop\_f0, Sz\_f0, Vphi\_f0

Where:* PE\_fn is the spectral power of E field from the electric data stream (2E) at fn ; the number of bins is specified in AD2.
* PB\_fn is the spectral power of B field from the magnetic data stream (3B) at fn ; the number of bins is specified in AD2.
* nvec\_fn is the wave normal vector from the magnetic data stream (3B) at fn ; the number of bins is specified in AD2.
* ellip\_fn is the wave ellipticity from the magnetic data stream (3B) at fn ; the number of bins is specified in AD2.
* dop\_fn is the degree of polarization from the magnetic data stream (3B) at fn ; the number of bins is specified in AD2.
* Sz\_fn is the normalized z-Poynting flux from the EM data stream (2E +3B) at fn ; the number of bins is specified in AD2.
* Vphi\_fn is the phase speed from the EM data stream (2E +3B) at fn ; the number of bins is specified in AD2.

The LFR flight software shall be compliant to the following algorithm for the computation of thebasic parameters engineering values PB\_i from the raw values PA\_LFR\_SC\_BP1\_PB\_F2iconveyed in the TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F2 packet:- N\_Bit\_Exponent = 6- N\_Bit\_Significand = 16 - N\_Bit\_Exponent- Range\_Significand = (1 << N\_Bit\_Significand) – 1- Range\_Exponent = (1 << N\_Bit\_Exponent) - 1- Exponent\_max = 37- Exponent\_min = Exponent\_max – Range\_Exponent (where Exponent\_min is coded as a32-bit signed integer)- PB\_Exponent\_i = PA\_LFR\_SC\_BP1\_PB\_F2i >> N\_Bit\_Significand where i is in [1..12]- PB\_Significand\_i = PA\_LFR\_SC\_BP1\_PB\_F2i & Range\_Significand where i is in [1..12]- Exponent\_i = PB\_Exponent\_i + Exponent\_min (where Exponent\_i is coded as a 32-bitsigned integer)- Significand\_i = (PB\_Significand\_i / Range\_Significand + 1) / 2 where Significand\_i is afloating point value- PB\_i = (Significand\_i x 2^Exponent\_i) / SY\_DPU\_SBM1\_PB\_i^2 where PB\_i is a floatingpoint value and SY\_DPU\_SBM1\_PB\_i is a conversion parameter expressed in count/nTwhere i is in [1..12]SSS-CP-EQS-450 and SSS-CP-EQS-760 |

#### LFR data products - basic parameters set 2

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| REQ-LFR-SRS-5523\_Ed2TestThe LFR FSW shall be able to generate the following set of basic parameters (set 2):* In NORMAL mode and SBM modes, every 20 seconds:
	+ Basic parameter 2 at f0: auto\_f0, cross\_f0
	+ Basic parameter 2 at f1: auto\_f1, cross\_f1
	+ Basic parameter 2 at f2: auto\_f2, cross\_f2
* In BURST mode and SBM2 mode, every 5 second:
	+ Basic parameter 2 at f0: auto\_f0, cross\_f0
	+ Basic parameter 2 at f1: auto\_f1, cross\_f1
* In SBM1 mode, every 1 second:
	+ Basic parameter 2 at f0: auto\_f0, cross\_f0

Where:* auto\_fn corresponds to 5 autovariances from the EM data stream (2E +3B) at fn ; the number of bins is specified in AD2.
* cross\_fn corresponds to 10 complex cross correlations from the EM data stream (2E +3B) at fn ; the number of bins is specified in AD2.

SSS-CP-EQS-460 |

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#### LFR data packets - averaged spectral matrixes

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| REQ-LFR-SRS-5526\_Ed1TestThe LFR FSW shall transmit to the DPU the averaged spectral matrixes in the following data packets:* In NORMAL mode and SBM modes:
* TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F0
* TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F1
* TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F2

Where F0, F1 or F2 identifies the sampling frequency.SSS-CP-EQS-490 |

There are no averaged spectral matrices for the sampling frequency f3. The averaged spectral matrices are only produced in the NORMAL mode.

#### LFR data packets - basic parameters set 1

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| REQ-LFR-SRS-5527\_Ed1TestThe LFR FSW shall transmit to the DPU the set of basic parameters 1 in the following data packets:* In NORMAL mode and SBM modes:
	+ TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F0
	+ TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F1
	+ TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F2
* In BURST mode:
	+ TM\_LFR\_SCIENCE\_BURST\_BP1\_F0
	+ TM\_LFR\_SCIENCE\_BURST\_BP1\_F1
* In SBM1 mode: TM\_LFR\_SCIENCE\_SBM1\_BP1\_F0
* In SBM2 mode:
	+ TM\_LFR\_SCIENCE\_SBM2\_BP1\_F0
	+ TM\_LFR\_SCIENCE\_SBM2\_BP1\_F1

Where F0, F1 or F2 identify the sampling frequency.SSS-CP-EQS-500 |

There are no basic parameters set 1 for the sampling frequency f3.

#### LFR data packets - basic parameters set 2

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| REQ-LFR-SRS-5528\_Ed1TestThe LFR FSW shall transmit to the DPU the set of basic parameters 2 in the following data packets:* In NORMAL mode and SBM modes:
	+ TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F0
	+ TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F1
	+ TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F2
* In BURST mode:
	+ TM\_LFR\_SCIENCE\_BURST\_BP2\_F0
	+ TM\_LFR\_SCIENCE\_BURST\_BP2\_F1
* In SBM1 mode: TM\_LFR\_SCIENCE\_SBM1\_BP2\_F0
* In SBM2 mode:
	+ TM\_LFR\_SCIENCE\_SBM2\_BP2\_F0
	+ TM\_LFR\_SCIENCE\_SBM2\_BP2\_F1

Where Fx = F0, F1 or F2 identifies the sampling frequency.SSS-CP-EQS-510 |

There are no basic parameters set 2 for the sampling frequency f3.

#### LFR data packets

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| REQ-LFR-SRS-5529\_Ed1DesignThe LFR flight software shall transmit the science data packets to the DPU as soon as the packets are ready, without having to wait for a request from the DPU (sporadic transmission).SSS-CP-EQS-520 |

An overview of the data packets produced by LFR against the mode is given in appendix.

#### LFR calibration function

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| REQ-LFR-SRS-5556\_Ed1TestUpon reception of a TC\_LFR\_ENABLE\_CALIBRATION, the LFR flight software shall enable the LFR calibration function (generation of the calibration signal for the SCM). The calibration signal is detailed in [RD02]SSS-CP-EQS-522 |
| REQ-LFR-SRS-5557\_Ed1TestUpon reception of a TC\_LFR\_DISABLE\_CALIBRATION, the LFR flight software shall disable the LFR calibration function (generation of the calibration signal for the SCM).SSS-CP-EQS-523 |
| REQ-LFR-SRS-5558\_Ed1TestThe LFR flight software shall report in its periodic HK packet (TM\_LFR\_HK) the enable / disable status of the calibration function in this dedicated field : HK\_LFR\_CALIB\_ENABLED.SSS-CP-EQS-524 |

#### LFR NORMAL / BURST mode transition

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| REQ-LFR-SRS-5568\_Ed1TestWhen it performs a NORMAL / BURST mode transition, the LFR FSW shall stop the acquisition processing which is in progress if any.SSS-CP-EQS-524 |

For example, during the NORMAL to BURST transition, the LFR flight software shall stop the acquisition of the current snapshot if there is a snapshot acquisition which is in progress (at 256 Hz, the acquisition of 2048-sample snapshot takes 8 seconds).

#### LFR data for S/C potential computation

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| REQ-LFR-SRS-5569\_Ed1TestEach second, the LFR FSW shall put in its periodic HK packet (TM\_LFR\_HK) the value of the electric field components V, E1 and E2 sampled at 1Hz and decimated from F3 values V\_f3, E1\_f3, E2\_f3. This should be done by implementing an IIR filter upon F3 electrical values. Because of the 1Hz sampling frequency, the cut frequency cFreq should be like : cFreq < 0.5Hz AND all frequencies > cFreq should be filtered.Parameters details and explanation of this filter should be found in [RD02].**NB : This requirement is more covering than its parent SSS requirement. This is because it has been estimated after tests and simulations that a simple mean or median (e.g. FIR filters) applied was not reliable enough to fulfill the requirement specially concerning aliasing effects and possible artefacts.**SSS-CP-EQS-526 |

The DPU software will use the values of the electric field components sampled at f3 for computing the S/C potential with a time resolution of one second. The S/C potential computed by RPW is provided to the other Solar Orbiter instruments via the service 20.

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| REQ-LFR-SRS-5580\_Ed1TestThe LFR flight software shall report in its periodic HK packet (TM\_LFR\_HK) the availability of the electric field components sampled at f3.FPGA starts acquisition immediately after power-on and hardware init sequence. After flight software boot sequence and as soon as the filters are nominally working (stable) : electrical values written by VHDL in dedicated registers are read by LFR Flight software and following actions are performed:* HK\_LFR\_SC\_POTENTIAL\_FLAG is set to 1
* HK\_LFR\_SC\_V\_F3, HK\_LFR\_SC\_E1\_F3, HK\_LFR\_SC\_E2\_F3 are filled

This implies that even in STANDBY mode, flag is set to 1 and fields are filled with valid values. SSS-CP-EQS-533 |

#### LFR Frequency bins internal mask

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| REQ-LFR-SRS-5581\_Ed1TestUpon reception of a TC\_LFR\_LOAD\_FBINS\_MASK, the LFR flight software shall be able to update the internal mask used for avoiding some frequency bins in the computation of the basic parameters: * 1 mask f0 , 128 bits = 16 bytes
* 1 mask f1 , 16 bytes
* 1 mask f2 , 16 bytes

SSS-CP-EQS-527 |

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| REQ-LFR-SRS-5582\_Ed1TestThe LFR flight software shall be able to dump in the TM\_LFR\_PARAMETER\_DUMP packet the internal mask of frequency bins.SSS-CP-EQS-528 |

#### LFR Inter-calibration factors

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| REQ-LFR-SRS-5583\_Ed1TestUpon reception of several TC\_LFR\_LOAD\_KCOEFFICIENTS packets, the LFR flight software shall be able to update the inter-calibration factors (k-coefficients) used for computing the poynting flux and phase velocity estimators: * 32 coefficients (coded on 4 bytes) for 36 frequencies.

SSS-CP-EQS-529 |

For uploading all the coefficients (4608 bytes), 36 TC packets are needed. The coefficients are correlated to the distance from the Sun. They have to be updated every 8 to 10 days. The coefficient updating will be updated using the S/C timeline.

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| REQ-LFR-SRS-5584\_Ed1TestUpon reception of a TC\_LFR\_DUMP\_KCOEFFICIENTS packet, the LFR flight software shall be able to dump in two TM\_LFR\_KCOEFFICIENTS\_DUMP packets the inter-calibration factors (k-coefficients).SSS-CP-EQS-531 |

### Start-up phase

#### Startup phase

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| REQ-LFR-SRS-5530\_Ed1TestThe LFR FSW shall be ready to accept commands within SY\_LFR\_DELAY\_ACC\_TC milliseconds after the boot process has been completed.SSS-CP-EQS-010 |
| REQ-LFR-SRS-5531\_Ed1TestAfter successful time synchronization, the LFR FSW shall enable the generation of its periodic housekeeping reports.SSS-CP-EQS-020 |
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### HK reporting

#### Equipment HK reporting

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| REQ-LFR-SRS-5533\_Ed1TestThe LFR FSW shall provide periodically to the DPU a TM\_LFR\_HK packet (HK report) reflecting the status of the LFR.Here are the fields filled by LFR FSW in TM\_LFR\_HK:8 fields of SOURCE\_DATA/PARAMETERS/HK\_LFR\_STATUS\_WORDHK\_LFR\_MODEHK\_LFR\_DPU\_SPW\_ENABLEDHK\_LFR\_DPU\_SPW\_LINK\_STATESY\_LFR\_PAS\_FILTER\_ENABLEDSY\_LFR\_WATCHDOG\_ENABLED-->ENABLED HK\_LFR\_CALIB\_ENABLEDHK\_LFR\_RESET\_CAUSE4 fields of SOURCE\_DATA/PARAMETERS/LFR\_SW\_VERSIONSY\_LFR\_SW\_VERSION\_N[1,2,3,4]3 fields of SOURCE\_DATA/PARAMETERS/LFR\_FGPA\_VERSIONSY\_LFR\_FGPA\_VERSION\_N[1,2,3]13 fields of SOURCE\_DATA/PARAMETERS/RESOURCE\_STATISTICSHK\_LFR\_CPU\_LOADHK\_LFR\_CPU\_LOAD\_MAX HK\_LFR\_CPU\_LOAD\_AVEHK\_LFR\_Q\_SD\_FIFO\_SIZE\_MAX (=50)HK\_LFR\_Q\_SD\_FIFO\_SIZEHK\_LFR\_Q\_RV\_FIFO\_SIZE\_MAX (=10)HK\_LFR\_Q\_RV\_FIFO\_SIZE HK\_LFR\_Q\_P0\_FIFO\_SIZE\_MAX (=10)HK\_LFR\_Q\_P0\_FIFO\_SIZEHK\_LFR\_Q\_P1\_FIFO\_SIZE\_MAX (=10)HK\_LFR\_Q\_P1\_FIFO\_SIZEHK\_LFR\_Q\_P2\_FIFO\_SIZE\_MAX (=5)HK\_LFR\_Q\_P2\_FIFO\_SIZE12 fields of SOURCE\_DATA/PARAMETERS/TC\_STATISTICSHK\_LFR\_UPDATE\_INFO\_TC\_CNTHK\_LFR\_UPDATE\_TIME\_TC\_CNTHK\_LFR\_EXE\_TC\_CNTHK\_LFR\_REJ\_TC\_CNTHK\_LFR\_LAST\_EXE\_TC\_CNT[ID, TYPE, SUBTYPE, TIME]HK\_LFR\_REJ\_EXE\_TC\_CNT[ID, TYPE, SUBTYPE, TIME]5/6 Fields of SOURCE\_DATA/PARAMETERS/ANOMALY\_STATISTICSHK\_LFR\_LE\_CNT HK\_LFR\_ME\_CNT HK\_LFR\_HE\_CNT --> 0HK\_LFR\_LAST\_ER\_[RID , CODE, TIME]4/8 fields of SOURCE\_DATA/PARAMETERS/HK\_VHDL\_BLK\_STATUSHK\_LFR\_VHDL\_AA HK\_LFR\_VHDL\_SM HK\_LFR\_VHDL\_IIR HK\_LFR\_VHDL\_CAL 4 fields of SOURCE\_DATA/PARAMETERS/DPU\_SPACEWIRE\_IF\_STATISTICSHK\_LFR\_DPU\_SPW\_PKT\_RCV\_CNTHK\_LFR\_DPU\_SPW\_PKT\_SENT\_CNTHK\_LFR\_DPU\_SPW\_TICK\_OUT\_CNTHK\_LFR\_DPU\_SPW\_LAST\_TIMC3 fields of SOURCE\_DATA/PARAMETERS/TEMPERATURESHK\_LFR\_[SCM, PCB, FGPA]3 fields of SOURCE\_DATA/PARAMETERS/SPACECRAFT\_POTENTIALHK\_LFR\_V\_F3HK\_LFR\_SC\_E1\_F3HK\_LFR\_SC\_E2\_F36 fields of SOURCE\_DATA/PARAMETERS/SY\_LFR\_COMMON\_PARAMETERSSY\_LFR\_[BW, SP0, SP1, R0, R1, R2]7 fields of SOURCE\_DATA/PARAMETERS/ERRORS\_COUNTERS/SPACEWIRE/LOW\_SEVERITYHK\_LFR\_DPU\_SPW\_[PARITY, DISCONNECT, ESCAPE, CREDIT, WRITE\_SYNC]4 fields of SOURCE\_DATA/PARAMETERS/ERRORS\_COUNTERS/SPACEWIRE/MEDIUM\_SEVERITYHK\_LFR\_DPU\_SPW\_EARLY\_EOPHK\_LFR\_DPU\_SPW\_INVALID\_ADDRHK\_LFR\_DPU\_SPW\_EEPHK\_LFR\_DPU\_SPW\_RX\_TOO\_BIG3 fields of SOURCE\_DATA/PARAMETERS/ERRORS\_COUNTERS/TIMECODE/LOW\_SEVERITYHK\_LFR\_TIMECODE\_[ERRONEOUS, MISSING, INVALID]3 fields of SOURCE\_DATA/PARAMETERS/ERRORS\_COUNTERS/TIMECODE/MEDIUM\_SEVERITYHK\_LFR\_TIME\_[TIMECODE\_IT, NOT\_SYNCHRO, TIMECODE\_CTR ]1 field of SOURCE\_DATA/PARAMETERS/ERRORS\_COUNTERS/AHB/LOW\_SEVERITYHK\_LFR\_AHB\_CORRECTABLE16 fields of SOURCE\_DATA/PARAMETERS/REACTION\_WHEELS\_FREQUENCYHK\_LFR\_SC\_RW1\_F[1,2,3,4]\_FLAGHK\_LFR\_SC\_RW2\_F[1,2,3,4]\_FLAGHK\_LFR\_SC\_RW3\_F[1,2,3,4]\_FLAGHK\_LFR\_SC\_RW4\_F[1,2,3,4]\_FLAGSSS-CP-EQS-040 |
| REQ-LFR-SRS-5534\_Ed1TestThe LFR HK report shall contain:* A SW status
	+ Software version
	+ Current mode
	+ Error counters, last error code, time of the last error, auxiliary information about the error
	+ Reason of the reset (power on, software reset requested by TC, software reset due to a processor exception, hardware reset requested by TC, hardware reset triggered by watchdog, unknown cause)
	+ Other status specific to LFR
* A HW status
	+ State of the SpaceWire interface (received packet counter, sent packet counter, link state, etc.)
	+ Watchdog status
	+ SEU counters (counter of the correctable errors and a counter of the not correctable errors detected by the EDAC)
	+ Temperatures
	+ Other HW status specific to LFR

All managed HK fields are described in REQ-LFR-SRS-5533\_Ed1.SSS-CP-EQS-050 |
| REQ-LFR-SRS-5535\_Ed1TestThe LFR FSW shall send its HK report as a packet compliant to the PUS service n°3.SSS-CP-EQS-060 |
| REQ-LFR-SRS-5536\_Ed1TestThe generation period of the LFR HK report packets is fixed to SY\_LFR\_HK\_SAMPLING\_PER. SY\_LFR\_HK\_SAMPLING\_PER is set to 1s in FSW and cannot be changed dynamically.SSS-CP-EQS-070 |
| REQ-LFR-SRS-5537\_Ed1DeletedThis section has been left blank intentionally (SSS-CP-EQS-080 deleted).SSS-CP-EQS-080 |
| REQ-LFR-SRS-5538\_Ed1DesignThe generation period of the HK equipment report packets cannot be changed by command.SSS-CP-EQS-090 |
| REQ-LFR-SRS-5539\_Ed1DesignThe generation of the HK equipment reports cannot be disabled.SSS-CP-EQS-100 |

The transmission period of the SpaceWire time-code provided by the DPU is 1 s and should match exactly the HK generation period.

### Event reporting

#### Equipment Event reporting

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| REQ-LFR-SRS-5540\_Ed1TestThe LFR FSW shall report the normal progress of operations and activities having an operational significance by updating the value of the suitable status parameters in its periodic HK report :HK\_LFR\_MODEHK\_LFR\_DPU\_SPW\_ENABLEDHK\_LFR\_DPU\_SPW\_LINK\_STATE HK\_LFR\_SC\_POTENTIAL\_FLAGSY\_LFR\_PAS\_FILTER\_ENABLEDHK\_LFR\_CALIB\_ENABLEDHK\_LFR\_SC\_V\_F3 HK\_LFR\_SC\_E1\_F3HK\_LFR\_SC\_E2\_F3SY\_LFR\_BWSY\_LFR\_SP0SY\_LFR\_SP1SY\_LFR\_R0SY\_LFR\_R1SY\_LFR\_R2HK\_LFR\_UPDATE\_INFO\_TC\_CNT HK\_LFR\_UPDATE\_TIME\_TC\_CNTHK\_LFR\_EXE\_TC\_CNTHK\_LFR\_REJ\_TC\_CNTHK\_LFR\_LAST\_EXE\_TCHK\_LFR\_LAST\_EXE\_TC\_TYPEHK\_LFR\_LAST\_EXE\_TC\_SUBTYPEHK\_LFR\_LAST\_EXE\_TC\_TIMEHK\_LFR\_LAST\_REJ\_TC\_IDHK\_LFR\_LAST\_REJ\_TC\_TYPEHK\_LFR\_LAST\_REJ\_TC\_SUBTYPEHK\_LFR\_LAST\_REJ\_TC\_TIMEHK\_LFR\_SC\_RW[1,2,3,4]\_F[1,2,3,4]\_FLAGSSS-CP-EQS-110 |
| REQ-LFR-SRS-5541\_Ed2TestThe LFR FSW shall also report anomalies and errors (including SpaceWire errors) by using its periodic HK report and by managing the following parameters:* Low level error counter: incremented each time a new low level error / anomaly is detected by LFR FSW.
* Medium level error counter: incremented each time a new medium level error / anomaly is detected by the LFR FSW.
* Last error report id: the error report id corresponds to the category of the error (AHB, SpaceWire, Buffer management, etc.); the last error report id parameter contains the id of the last error that has occurred.
* Last error code: in a given error category, each error or anomaly that can occur is identified by an error code; the last error code parameter contains the code of the last error that has occurred.
* Time of the last error.
* Individual error counters: each individual error identified by its category and its code is associated to a specific error counter.

Criticity classification is made as follows :

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| --- | --- | --- |
| **LE (LOW)** | **ME (MEDIUM)** | **HE (HIGH)** |
| HK\_LFR\_DPU\_SPW\_PARITY | HK\_LFR\_DPU\_SPW\_EARLY\_EOP |  |
| HK\_LFR\_DPU\_SPW\_DISCONNECT | HK\_LFR\_DPU\_SPW\_INVALID\_ADDR |  |
| HK\_LFR\_DPU\_SPW\_ESCAPE | HK\_LFR\_DPU\_SPW\_EEP |  |
| HK\_LFR\_DPU\_SPW\_CREDIT | HK\_LFR\_DPU\_SPW\_RX\_TOO\_BIG |
| HK\_LFR\_DPU\_SPW\_WRITE\_SYNC |  |
| HK\_LFR\_TIMECODE\_ERRONEOUS |  |
| HK\_LFR\_TIMECODE\_MISSING |  |
| HK\_LFR\_TIMECODE\_INVALID |  |
| HK\_LFR\_TIME\_TIMECODE\_IT |  |
| HK\_LFR\_TIME\_NOT\_SYNCHRO |  |
| HK\_LFR\_TIME\_TIMECODE\_CTR |

SSS-CP-EQS-120 |
| REQ-LFR-SRS-5542\_Ed2TestThe LFR FSW shall report the three levels of severity: low, medium and high.SSS-CP-EQS-130 |

Following DPU classification, LFR only handles low and medium criticity errors (cf. REQ-LFR-SRS-5541).

### Command feedback

#### Equipment command feedback

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| REQ-LFR-SRS-5543\_Ed3TestThe LFR FSW shall acknowledge all the commands it receives from the DPU excepted the both following commands for which no TM\_LFR\_TC\_EXE\_yyy packets shall be generated:* TC\_LFR\_UPDATE\_INFO
* TC\_LFR\_UPDATE\_TIME.

The parameters HK\_LFR\_EXE\_TC\_CNT to HK\_LFR\_LAST\_REJ\_TC\_TIME shall not be updated upon reception of TC\_LFR\_UPDATE\_INFO and TC\_LFR\_UPDATE\_TIME.SSS-CP-EQS-140 |
| REQ-LFR-SRS-5544\_Ed2Test and DesignThe LFR FSW shall produce, depending on the final status of the execution and the possible encountered errors, the following command acknowledgment packets (which are compliant to the PUS service n°1):* TM\_LFR\_TC\_EXE \_SUCCESS in case of execution success
* TM\_LFR\_TC\_EXE\_CORRUPTED in case of error detected during the acceptance stage verifications (Illegal APID, Illegal packet type, Illegal packet subtype, wrong CRC, wrong or incomplete length).
* TM\_LFR\_TC\_EXE\_INCONSISTENT in case of wrong or inconsistent field (in the header fields or in the data fields
* TM\_LFR\_TC\_EXE\_NOT\_EXECUTABLE in case of command that cannot be executed at this time
* TM\_LFR\_TC\_EXE\_ERROR if a malfunction or an error is detected during the execution.

SSS-CP-EQS-150 |
| REQ-LFR-SRS-5574\_Ed1TestUpon reception of a TC\_LFR\_UPDATE\_INFO packet, LFR FSW shall increment the HK\_LFR\_UPDATE\_INFO\_TC\_CNT counter only if the packet is correct and has been accepted.SSS-CP-EQS-141 |
| REQ-LFR-SRS-5572\_Ed1TestUpon reception of a TC\_LFR\_UPDATE\_TIME packet, LFR FSW shall increment the HK\_LFR\_UPDATE\_TIME\_TC\_CNT counter only if the packet is correct and has been accepted.SSS-CP-EQS-142 |

### SpaceWire link monitoring

#### SpaceWire link monitoring

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| REQ-LFR-SRS-5559\_Ed1InspectionThe LFR flight software shall monitor the state of the SpaceWire interface.SSS-CP-EQS-151 |
| REQ-LFR-SRS-5560\_Ed1InspectionIn case of detection of any SpaceWire failure (link errors, network level errors, ...) identified in AD12, the LFR flight software shall trace it in its periodic HK report.SSS-CP-EQS-152 |
| REQ-LFR-SRS-5561\_Ed1Test and InspectionAfter the loss of the SpaceWire connection, if the analyzer has failed to (re-)establish the connection with the DPU within a SY\_LFR\_DPU\_CONNECT\_TIMEOUT timeout period, then the LFR flight software shall:* Reset the SpaceWire interface. (by inspection)
* Reset the connection timeout period. (by inspection)
* Start again the connection process.(by test)

SSS-CP-EQS-153 |
| REQ-LFR-SRS-5562\_Ed1TestThe LFR flight software shall perform up to SY\_LFR \_DPU\_CONNECT\_ATTEMPT attempts of connection with the DPU.SSS-CP-EQS-154 |
| REQ-LFR-SRS-5563\_Ed1TestAfter SY\_LFR\_DPU\_CONNECT\_ATTEMPT unsuccessful attempts of connection with the DPU, the LFR flight software shall:* Enter into STANDBY.

SSS-CP-EQS-155 |

### Configuration management

#### General

#### Equipment configuration management

The configuration actions can consist in changing the software parameters or in changing the hardware parameters.

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| REQ-LFR-SRS-5545\_Ed1TestThe LFR FSW shall handle two kinds of parameters:* Parameters (software or hardware) associated to the configuration of the science sub modes managed by the equipment (NORMAL, BURST, SBM1, SBM2). These parameters can be, for example, the list of the enabled products, the number of samples per second, the number of points per snapshots, the measurement time, the spectrum frequency count, etc. The values of those parameters can be modified at LFR FSW level through TC\_LFR\_LOAD\_XXX\_PAR (where XXX is NORMAL, BURST, SBM1 or SBM2).
* Other parameters (software or hardware), independent of the Science sub-mode configuration (so-called common parameters). The values of those parameters can be modified at LFR FSW level through TC\_LFR\_LOAD\_COMMON\_PAR.

The values of those parameters currently used by LFR FSW can be retrieved through TC\_LFR\_DUMP\_PARAMETER.SSS-CP-EQS-160 |
| REQ-LFR-SRS-5546\_Ed2TestThe LFR FSW shall concurrently handle as many distinct configuration parameter sets as science sub-modes (NORMAL, BURST, SBM1, SBM2) it manages e.g. when LFR FSW is in a given mode, configuration parameters for all non-active dataflows can be changed. SSS-CP-EQS-170 |

#### Equipment configuration management

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| REQ-LFR-SRS-5548\_Ed1TestThe LFR FSW shall handle commands for configuring the different science sub-mode parameter sets.* NORMAL mode parameters: TC\_LFR\_LOAD\_NORMAL\_PAR
* BURST mode parameters: TC\_LFR\_LOAD\_BURST\_PAR
* SBM1 mode parameters: TC\_LFR\_LOAD\_SBM1\_PAR
* SBM2 mode parameters: TC\_LFR\_LOAD\_SBM2\_PAR

SSS-CP-EQS-190 |
| REQ-LFR-SRS-5549\_Ed1TestA science sub-mode parameter set that is in use cannot be changed.Normal sub-mode parameter can’t be changed if current mode is NORMAL, SBM1, SBM2.Burst sub-mode parameter can’t be changed if current mode is burst.SBM1sub-mode parameter can’t be changed if current mode is SBM1.SBM2sub-mode parameter can’t be changed if current mode is SBM2.A TM\_LFR\_EXE\_NOT\_EXECUTABLE is generated in this case.SSS-CP-EQS-200 |
| REQ-LFR-SRS-5550\_Ed1TestAdditionally, the LFR FSW, depending on the features of the equipment, shall have one command for configuring the parameters not directly linked to the science sub-mode configuration.* Common parameters: TC\_LFR\_LOAD\_COMMON\_PAR

This command configures 6 parameters coded on bit* SY\_LFR\_BW
* SY\_LFR\_SP0
* SY\_LFR\_SP1
* SY\_LFR\_R0
* SY\_LFR\_R1
* SY\_LFR\_R2

This command can be perform in any mode. SSS-CP-EQS-210 |

#### Equipment parameter dump

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| REQ-LFR-SRS-5551\_Ed1TestThe LFR FSW shall allow to dump in TM\_LFR PARAMETER\_DUMP packets, upon the reception of TC\_LFR\_DUMP\_PAR command, all their functional and operational configuration parameters (software and hardware).SSS-CP-EQS-215 |

### Software reset

#### Software reset

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| REQ-LFR-SRS-5552\_Ed1TestUpon reception of a TC\_LFR\_RESET command, the LFR FSW shall terminate by performing an exit(0) command.SSS-CP-EQS-220 |

In order to be compliant with the RMAP boot process, such a reset commanded by software has to be performed, thanks to a dedicated hardware module (controlled by software) inside the LFR allowing to trigger simultaneously the RESET signal and the DSUBRE signal of the processor (the DSUBRE signal allows to put the processor in the debug state).

### LFR filtering of S/C reaction wheel emission frequencies

**Important note :** Filtering of s/c reaction wheel emission frequencies is only applicable at Basic parameters computation level e.g. spectral matrices are filtered for basic parameters computation. The production process for Waveforms (CWF/SWF) and ASM products transmitted is not concerned by it so the result of the filtering can only be seen in BP products transmitted.

**Basic Parameters (BP)
filtering of SC reaction wheel emissions**

**has been applied**

Hann window

FFT

**Spectral Matrices**

**(ASM)**

Compressed output
(TM)

Stream at fm

5 components (E1, E2, B1, B2, B3)

(m= 0, 1, 2)

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| REQ-LFR-SRS-6000\_Ed1TestUpon reception of the TC\_LFR\_UPDATE\_INFO packet, the LFR flight software shall discard in the Basic Parameters (BP) science data processing the 16 S/C reaction wheel emission frequencies, according to:- the reaction wheel frequencies CP\_RPW\_SC\_RW[1-4]\_F[1-4]- the available/unavailable state of each frequency can be deduced of CP\_RPW\_SC\_RW[1-4]\_F[1-4] which is set to NaN if the reaction wheel emission frequency filtering is disabled. Strict IEEE-754 32 bits standard NaN representation should be considered e.g. value is coded by setting the exponent part to 0xFF AND anything except all 0 bits for fraction part.- the filtering bandwidths SY\_LFR\_SC\_RW\_DELTA\_F \* SY\_LFR\_RW[1-4]\_K[1-4]associated respectively to the reaction wheel frequencies CP\_RPW\_SC\_RW[1-4]\_F[1-4] to be filtered.The LFR flight software should determine following below parameters a polluted bandwidth and so a 128 bit mask for each channel F0, F1 and F2 representing which ASM bins should be filtered e.g. removed from Basic parameters set computation. Because the Hann window (cf. REQ-RPW-LFR2404 of RD02) spreads energy over each bin: for each given RW frequency to be filtered, several adjacent corresponding ASM bins can be polluted (for each FN channel). The mechanism used by LFR flight software should implement the algorithm described in REQ-LFR-SRS-6020.SSS-CP-EQS-750 |

No filtering is performed on the unavailable frequencies.

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| REQ-LFR-SRS-6020\_Ed1TestLet’s consider Fn as the LFR sampling frequency for a given channel : F0 = 24576HzF1 = 2048HzF2 = 256HzWe define a “center area” as the bandwidth around an ASM proper frequency (ASM bin) where 90% of the energy is located when this frequency is acquired by LFR. This center area is :asmFreq +/- 0.285\*Fn/256 (where asmFreq is an ASM bin frequency)So for ASM frequencies of :F0 : center area is asmFreq +/- 27.36HzF1 : center area is asmFreq +/- 4.56HzF2 : center area is asmFreq +/- 0.285HzWe also define a “polluted bandwidths” as :CP\_RPW\_SC\_RW[1-4]\_F[1-4] +/- (SY\_LFR\_SC\_RW\_DELTA\_F \* SY\_LFR\_RW[1-4]\_K[1-4])Considering those 2 bandwidths as intervals (“center area” is an open interval, “polluted bandwidth” is a closed interval)**, following rules should be applied :*** All ASM bins included in “polluted bandwidth” should be filtered (regardless of “center area”).
* For each of “polluted bandwidth” limits :
* If limit is included in “center area” of an ASM bin of index k : ASM bins of indexes k-1, k and k+1 should be filtered.
* If limit is not included in “center area” of an ASM bin (e.g. limit is between 2 consecutive “center areas”): only the 2 ASM bins surrounding the limit should be filtered.

Different cases are summed on below illustration:LFR Internal |

Note: the threshold of 90% of energy is reasonable, but it is arbitrary. The 0.285 coefficient is a consequent of this 90% limit.

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| REQ-LFR-SRS-6001\_Ed1TestThe LFR flight software shall report in its periodic HK packet (fields HK\_LFR\_SC\_RW[1-4]\_F[1-4]\_FLAG of TM\_LFR\_HK) the available/unavailable state for each of the 16 S/C reaction wheel frequencies conveyed in the TC\_LFR\_UPDATE\_INFO packet. Flag convention is 0 if frequency is unavailable (e.g. a NaN was conveyed in TC\_LFR\_UPDATE\_INFO) and 1 if an available frequency was conveyed.SSS-CP-EQS-751 |

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| REQ-LFR-SRS-6002\_Ed1TestUntil reception of the first TC\_LFR\_UPDATE\_INFO packet, the LFR flight software shall consideras unavailable the 16 S/C reaction wheel frequencies e.g. no filtering of S/C reaction wheel emissions should be performed and HK packets should report HK\_LFR\_SC\_RW[1-4]\_F[1-4]\_FLAG flags all set set to 0.SSS-CP-EQS-752 |

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| REQ-LFR-SRS-6003\_Ed1TestUpon reception of a TC\_LFR\_LOAD\_FILTER\_PAR packet, the LFR flight software should be able tochange:SY\_LFR\_SC\_RW\_DELTA\_F (default value = 0.045 Hz) which represents the uncertainty +/- SY\_LFR\_SC\_RW\_DELTA\_F around the the reaction wheel effective frequency. Acceptable values are SY\_LFR\_SC\_RW\_DELTA\_F >=0the 32-bit float values of kxy factor coefficients (>=0) used by the DPU to compute, from eachreaction wheel fundamental frequency, the frequencies (harmonics) to be filtered (dimensionless)o SY\_LFR\_RW1\_K1 (default value = 1)o SY\_LFR\_RW1\_K2 (default value = 8)o SY\_LFR\_RW1\_K3 (default value = 24)o SY\_LFR\_RW1\_K4 (default value = 48)o SY\_LFR\_RW2\_K1 (default value = 1)o SY\_LFR\_RW2\_K2 (default value = 8)o SY\_LFR\_RW2\_K3 (default value = 24)o SY\_LFR\_RW2\_K4 (default value = 48)o SY\_LFR\_RW3\_K1 (default value = 1)o SY\_LFR\_RW3\_K2 (default value = 8)o SY\_LFR\_RW3\_K3 (default value = 24)o SY\_LFR\_RW3\_K4 (default value = 48)o SY\_LFR\_RW4\_K1 (default value = 1)o SY\_LFR\_RW4\_K2 (default value = 8)o SY\_LFR\_RW4\_K3 (default value = 24)o SY\_LFR\_RW4\_K4 (default value = 48)SSS-CP-EQS-753 |

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| REQ-LFR-SRS-6004\_Ed1TestThe LFR flight software shall report in the TM\_LFR\_PARAMETER\_DUMP packet, the following 32-bit unsigned values of the masks used for the frequency filtering process:- PA\_LFR\_RW\_MASK\_F0\_WORD1- PA\_LFR\_RW\_MASK\_F0\_WORD2- PA\_LFR\_RW\_MASK\_F0\_WORD3- PA\_LFR\_RW\_MASK\_F0\_WORD4- PA\_LFR\_RW\_MASK\_F1\_WORD1- PA\_LFR\_RW\_MASK\_F1\_WORD2- PA\_LFR\_RW\_MASK\_F1\_WORD3- PA\_LFR\_RW\_MASK\_F1\_WORD4- PA\_LFR\_RW\_MASK\_F2\_WORD1- PA\_LFR\_RW\_MASK\_F2\_WORD2- PA\_LFR\_RW\_MASK\_F2\_WORD3- PA\_LFR\_RW\_MASK\_F2\_WORD4According to [AD2] (§1.2 Bit Numbering Convention) and to be consistent with FBINS processing (described in [RD4]), following conventions should be applied :* For each sampling frequency (F0, F1 or F2), most significant bit of WORD1 corresponds to the highest frequency that can be masked and least significant bit of WORD4 corresponds to the lowest frequency that can be masked.
* In PA\_LFR\_RW\_MASK\_Fn\_WORDi items : if a bit is set to 1, frequency is not masked. If set to 0, frequency is masked.

SSS-CP-EQS-754 |

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| REQ-LFR-SRS-6005\_Ed1TestThe LFR flight software shall be able to dump in the TM\_LFR\_PARAMETER\_DUMP packet theS/C reaction wheel filtering parameters conveyed in the TC\_LFR\_LOAD\_FILTER\_PAR packet :SY\_LFR\_SC\_RW\_DELTA\_F (default value = 0.045 Hz) which represents the uncertainty +/- SY\_LFR\_SC\_RW\_DELTA\_F around the the reaction wheel effective frequency.the 32-bit float values of kxy factor coefficients used by the DPU to compute, from eachreaction wheel fundamental frequency, the frequencies (harmonics) to be filtered (dimensionless). Those kxy factor are also used by LFR FSW to determine the polluted bandwidth (see REQ-LFR-SRS-6000 and REQ-LFR-SRS-6020) :o SY\_LFR\_RW1\_K1 (default value = 1)o SY\_LFR\_RW1\_K2 (default value = 8)o SY\_LFR\_RW1\_K3 (default value = 24)o SY\_LFR\_RW1\_K4 (default value = 48)o SY\_LFR\_RW2\_K1 (default value = 1)o SY\_LFR\_RW2\_K2 (default value = 8)o SY\_LFR\_RW2\_K3 (default value = 24)o SY\_LFR\_RW2\_K4 (default value = 48)o SY\_LFR\_RW3\_K1 (default value = 1)o SY\_LFR\_RW3\_K2 (default value = 8)o SY\_LFR\_RW3\_K3 (default value = 24)o SY\_LFR\_RW3\_K4 (default value = 48)o SY\_LFR\_RW4\_K1 (default value = 1)o SY\_LFR\_RW4\_K2 (default value = 8)o SY\_LFR\_RW4\_K3 (default value = 24)o SY\_LFR\_RW4\_K4 (default value = 48)SSS-CP-EQS-755 |

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| REQ-LFR-SRS-6006\_Ed1TestFBINS\_MASKS and RW\_MASKS effects should be combined with a logical AND in the BP processing:[Bins removed from BP processing] = FBINS\_MASKS && RW\_MASKSSSS-CP-EQS-527 AND SSS-CP-EQS-750 |

### LFR REAL TIME FILTERING OF SWA/PAS PERTURBATIONS

**Important note:** Instant spectral matrixes whose acquisition time is in invalid duration are rejected.

Because PAS filtering is applied at instant matrices processing level, filter effect will be visible in ASM transmitted through telemetry (nominally every hour).

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| REQ-LFR-SRS-6100\_Ed1TestIf SY\_LFR\_PAS\_FILTER\_ENABLED is set to enabled, the LFR flight software shall discard from the ASM computation(every 4s onboard) all the FFT (e.g. instant spectral matrices) processed that are inside or intersecting\* the invalid duration. This invalid duration is defined by :- The perturbation duration SY\_LFR\_PAS\_FILTER\_TBAD,- The modulus of the coarse time defining the perturbation instant SY\_LFR\_PAS\_FILTER\_MODULUS e.g. for a given timecode: [number of seconds since 1/1/2000] % SY\_LFR\_PAS\_FILTER\_MODULUS = index of the timecode inside a period containing a perturbation that LFR FSW should consider.- The offset (integer) added for computing the perturbation instant SY\_LFR\_PAS\_FILTER\_OFFSET. This offset is added to the first timecode of a modulo to define a new timecode occurrence.- The time-shift relatively to the timecode occurrence identifying the perturbation startSY\_LFR\_PAS\_FILTER\_SHIFT,Examples can be found in §4.5.10.11 and figure 27 of [AD1].\*This has for consequence for LFR FSW to take into account the maximum amount of non-perturbated data for F0, F1 and F2 but also to discard a whole instant spectral matrix even if only a part of it is in the invalid duration.SSS-CP-EQS-761 |

NB : Here as a reminder the number of instant spectral matrices(SM) computed per second by LFR :

At F0 : 96 SM/sec 🡺 an onboard ASM is made of 384 SM

At F1 : 16 SM/sec 🡺 an onboard ASM is made of 64 SM

At F2 : 1 SM/sec 🡺 an onboard ASM is made of 4 SM

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| REQ-LFR-SRS-6101\_Ed1TestIf SY\_LFR\_PAS\_FILTER\_ENABLED is set to disabled, the LFR flight software shall disable thefiltering of its spectral matrixes e.g. none of the instant spectral matrices (SM) should be discarded.SSS-CP-EQS-762 |

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| REQ-LFR-SRS-6102\_Ed1TestAt startup, the LFR flight software shall disable the filtering of its spectral matrixes by setting SY\_LFR\_PAS\_FILTER\_ENABLED to 0.SSS-CP-EQS-763 |

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| REQ-LFR-SRS-6103\_Ed1TestUpon reception of a TC\_LFR\_LOAD\_FILTER\_PAR packet, the LFR flight software shall allow tochange the values of the following parameters:SY\_LFR\_PAS\_FILTER\_ENABLED: the enabled/disabled state of the LFR real time filteringof SWA/PAS perturbations (default value = enabled)o If set to enabled, the filtering process shall be enabledo If set to disabled, the filtering process shall be disabledSY\_LFR\_PAS\_FILTER\_MODULUS: the modulus of the coarse time defining theperturbation instant (default value = 4)SY\_LFR\_PAS\_FILTER\_TBAD: the perturbation duration (default value = 1 second)SY\_LFR\_PAS\_FILTER\_OFFSET: the offset added for computing the perturbation instant(default value = 0)SY\_LFR\_PAS\_FILTER\_SHIFT: the time-shift relatively to the timecode occurrenceidentifying the perturbation start (default value = 0.5 second)Parameters uploaded through TC\_LFR\_LOAD\_FILTER\_PAR (if valid) should be applied immediately by LFR FSW for ASM computation e.g. not waiting for the end of a complete modulus.Acceptance process of these parameters should be done by LFR FSW following this sequence and rules :**Step 1:** Parameters are checked even ifSY\_LFR\_PAS\_FILTER\_ENABLED = 0 (disable)**Step 2:** parameters are checked individually to verify that they are in their limit definition. Those limits are :SY\_LFR\_PAS\_FILTER\_MODULUS = [4,8]SY\_LFR\_PAS\_FILTER\_TBAD = [0.0,4.0]SY\_LFR\_PAS\_FILTER\_OFFSET= [0,7]SY\_LFR\_PAS\_FILTER\_SHIFT= [0.0, 1.0]If one of the parameters is out of bound, LFR FSW emits a TM\_LFR\_TC\_EXE\_INCONSISTENT.**Step 3:** consistency between those parameters is checked according to this rule:SY\_LFR\_PAS\_FILTER\_OFFSET + SY\_LFR\_PAS\_FILTER\_SHIFT < SY\_LFR\_PAS\_FILTER\_MODULUSIf parameters are not compliant with this rule : a TM\_LFR\_TC\_EXE\_INCONSISTENT will be emitted by LFR FSW indicating that SY\_LFR\_PAS\_FILTER\_MODULUS is erroneous (PA\_RPW\_BYTE\_POSITION=12)SSS-CP-EQS-764 |

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| REQ-LFR-SRS-6104\_Ed1TestThe LFR flight software shall be able to dump in the TM\_LFR\_PARAMETER\_DUMP packet dedicated fields the SWA/PAS perturbation filtering parameters currently applied :SY\_LFR\_PAS\_FILTER\_ENABLEDSY\_LFR\_PAS\_FILTER\_MODULUSSY\_LFR\_PAS\_FILTER\_TBADSY\_LFR\_PAS\_FILTER\_OFFSETSY\_LFR\_PAS\_FILTER\_SHIFTSSS-CP-EQS-765 |

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| REQ-LFR-SRS-6105\_Ed1TestThe LFR flight software shall report in its periodic HK packet (TM\_LFR\_HK) the enable / disablestatus of the filtering of PAS/SWA perturbations in SY\_LFR\_PAS\_FILTER\_ENABLED field (0 = disabled, 1=enabled)SSS-CP-EQS-766 |

## Resources requirements

#### RPW equipment hardware

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| REQ-LFR-SRS-5600\_Ed1DesignTo make possible the coexistence of the CCSDS protocol and RMAP protocol, the LFR equipment hardware shall be able to route the SpaceWire packets to the software in case of CCSDS packets or to the FPGA firmware in case of RMAP packets.SSS-HR-EQ-040 |
| REQ-LFR-SRS-5601\_Ed1DesignAfter powering on or after a reset, the LEON3 processor of the analyzers shall enter in debug mode or halted mode without executing any instructions.Note debug and halted modes are the same. As long as the DPU has not booted LFR, nothing happens (no ROM on board of LFR).SSS-HR-EQ-050 |

## Design requirements and implementation constraints

#### Design requirements and constraints

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| REQ-LFR-SRS-5704\_Ed2DesignThe RPW flight software shall be developed according to the [AD6] standard.SSS-DR-001 |
| REQ-LFR-SRS-5705\_Ed2InspectionThe RPW DPU Application Software and the RPW Analyzer Flight Software shall reside in the DPU EEPROM (non-volatile memory).SSS-DR-003 |
| REQ-LFR-SRS-5700\_Ed1InspectionFor each RPW flight software, the following margins for the estimates of processor load and memory occupation shall be met:* 50% before/at PDR (i.e. the CPU load shall be less than 66%).
* 40% before CDR (i.e. the CPU load shall be less than 72%).
* 25% at FM AR (i.e. the CPU load shall be less than 80%).

SSS-DR-010 |
| REQ-LFR-SRS-5701\_Ed1DesignThe RPW flight Software shall have functionally distinct areas of memory assigned to:* Code
* Fixed constants
* Variable parameters

SSS-DR-020 |
| REQ-LFR-SRS-5706\_Ed1DesignThe RPW flight Software shall be structured in modules.SSS-DR-025 |
| REQ-LFR-SRS-5702\_Ed1DesignThe RPW flight Software shall be structured such that modifications can be made to a software module without affecting other module positions in the memory.SSS-DR-030 |

In this context, a module is a function or a set of functions if the code is written in C language and a class if the code is written in C++.

The C functions or classes contained in the source files are compiled to produce object files which are linked by the linker to produce with other object files an executable. The role of the linker is to assign to the different C functions or C++ methods (the modules) an address in the executable memory and to solve the links between the different modules. The growth on one module can then impact all the modules positions in memory if nothing has been foreseen to avoid this situation.

To avoid this situation and fulfill the requirement above, a solution can be to write a linker script which adds spare space after each module in order to allow future growths of the modules without impacting the other modules. The use of virtual tables and polymorphism capabilities of C++ can be another way to achieve this requirement. Another important point is that, to increase the maintainability, an object file should have a small size and then contain few C functions or C++ methods.

#### Size of the flight SW executable image

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| --- |
| REQ-LFR-SRS-5703\_Ed1InspectionThe maximum size of the LFR FSW executable image (trap table + .text section + .data section) is SY\_LFR\_EXE\_MAX\_SIZE.SSS-DR-040 |

Currently: SY\_LFR\_EXE\_MAX\_SIZE = 400 kBytes.

#### Implementation requirements and constraints

|  |
| --- |
| REQ-LFR-SRS-5707\_Ed1DesignConcerning the SpaceWire link implementation up to the packet and network levels, the RPW flight Software shall be compliant to [AD7], [AD8] and SOL.S.ASTR.RS.00038[Solar Orbiter SpaceWire Application Protocol Specification].SSS-IR-010 |
| REQ-LFR-SRS-5708\_Ed1DesignThe RPW flight Software shall be developed using a high-level language (C or C++).SSS-IR-020 |

## Security and privacy requirements

This section has been left blank intentionally.

## Portability requirements

This section has been left blank intentionally.

## Software quality requirements

This section has been left blank intentionally.

## Software reliability requirements

This section has been left blank intentionally.

## Software maintainability requirements

This section has been left blank intentionally.

## Software safety requirements

This section has been left blank intentionally.

## Software configuration and delivery requirements

####  Flight software delivery format

|  |
| --- |
| REQ-LFR-SRS-51400\_Ed2DesignThe LFR FSW executable image (trap table + .text section + .data section) shall be delivered to the PI team (LESIA) as a set of several files compliant to the SREC format.Separate files shall be provided for each .text section and each .data section.SSS-SM-100 |
| REQ-LFR-SRS-51401\_Ed1DesignThe naming convention for the SREC files shall be the following:* RpwLfrApp\_[0-9][0-9][0-9][0-9]\_(text|data)(\_[a-zA-Z0-9\_-]\*)?.srec
* [0-9][0-9][0-9][0-9] corresponds to a counter starting from 0001.

SSS-SM-110 |

## Software operations requirements

***Data rate configuration***

|  |
| --- |
| REQ-LFR-SRS-5800\_Ed1InspectionEach analyzer flight software shall have its own user manual (SUM) covering the following points: -  General description -  Initialization phase - Modes and transitions - Housekeeping parameters and reports - Configuration (role of each configuration parameter that can be changed by TC) - Memory map (including physical mapping of SW onto subsystem HW) - Description of the science products (TM packets, auxiliary parameters, ...) - Data rates - Data time-stamping policy - FailuresSSS-OR-050 |

## Data definition and database requirements

This section has been left blank intentionally.

## Human factors related requirements

This section has been left blank intentionally.

## Adaptation and installation requirements

This section has been left blank intentionally.

# Validation requirements

This section has been left blank intentionally.

# Traceability

Applicable and reference documents prevail in case of contradiction with the SRS present document.

-See the AD17 file.

# Logical model description

This section has been left blank intentionally.

APPENDIX A. Command and data packet generic structure

The figure below shows the generic structure of the SpaceWire packets exchanged between the DPU and the LFR FSW. This structure is compliant with the CCSDS packet transfer protocol as defined in [AD9].

|  |  |  |  |
| --- | --- | --- | --- |
| **First transmitted byte** |  |  |  |
| Target Logical Address | Protocol Identifier = 0x02 | Reserved = 0x00 | User Application |
| CCSDS Packet (first byte) | CCSDS Packet | CCSDS Packet | CCSDS Packet |
| CCSDS Packet | CCSDS Packet | CCSDS Packet | CCSDS Packet |
| CCSDS Packet | CCSDS Packet (last byte) | EOP |  |
|  | **Last transmitted byte** |  |  |

Figure 5: SpaceWire packet format according to the CCSDS packet transfer protocol

Note the SpaceWire protocol header of the packets exchanged between DPU and the LFR FSW is specified in SSS-IF-DPS-EQ-175.

The CCSDS packets cans be Telecommand Source Packets or Telemetry Source Packets.

## Telecommand Source Packets

The figure below shows the structure of the Telecommand Source Packets. The maximum size of these packets for LFR will be 12+SY\_LFR\_TC\_MAX\_LEN bytes.

|  |
| --- |
| **CCSDS Telecommand Source Packet** |
| **Packet header (48 bits)** | **Packet data field (variable)** |
| **Packet****ID** | **Packet****sequence control** | **Packet****length** | **Data****field****header** | **Application****Data** | **Packet****error****control** |
| **Version****number** | **Packet****type** | **Data****field****header****flag** | **APID** | **Sequence****flags** | **Sequence****count** |  |  |  |  |
| **3** | **1** | **1** | **11** | **2** | **14** |
| **2** | **2** | **2** | **4** | **variable** | **2** |
|  | **SY\_LFR\_TC\_MAX\_LEN bytes MAX** |  |
|  | **6+SY\_LFR\_TC\_MAX\_LEN bytes MAX** |
| **12+SY\_LFR\_TC\_MAX\_LEN bytes MAX** |

|  |
| --- |
| **APID** |
| **Process ID** | **Packet Category** |
| Enumerated | Enumerated |
| 7 bits | 4 bits |

|  |
| --- |
| **Data field header** |
| **CCSDS secondary****header flag** | **PUS version** | **Ack** | **Service Type** | **Service****subtype** | **Source ID** |
| Boolean | Enumerated | Enumerated | Enumerated | Enumerated | Enumerated |
| 1 bit | 3 bits | 4 bits | 8 bits | 8 bits | 8 bits |

Table 7: Rules to be applied to build Telecommand Source packets

|  |  |
| --- | --- |
| **Field** | **Rule or Value** |
| Version number | ‘000’ |
| Packet type | 1 |
| Data field header | Set to 1 if there is a data field header |
| Process ID | Defines the application which is the destination of the telecommand packet. Documented in AD10. |
| Packet category | ‘1100’ |
| Sequence flags | ‘11’ |
| Sequence count | Counter incremented per APID and Source ID |
| Packet length | (number of bytes in Packet Data Field) – 1 |
| CCSDS secondary header flag | 0 |
| PUS version | ‘001’ |
| Ack | ‘-00x’ acceptance of packet [0/1; no report/report required]‘x00-‘ completion of execution [0/1; no report/report required] |
| Service type | Service type to which the command packet relates |
| Service subtype | Together with the type, uniquely identifies the nature of the command |
| Source ID | Identifies the sender of the command (direct TC sent by ground, time-tagged commands, commands uplinked as part of TC files, etc.). Documented in AD10. |
| Application Data | Data elements of the command |
| Packet Error Control | CRC checksum: see algorithm in the Solar Orbiter Generic Frame and Packet Structure, appendix 6 |

## Telemetry Source Packets

The figure below shows the structure of the Telemetry Source Packets. The maximum size of the packets for the LFR is 4112 bytes.

|  |
| --- |
| **CCSDS Telemetry Source Packet** |
| **Packet header (48 bits)** | **Packet data field (variable)** |
| **Packet****ID** | **Packet****sequence control** | **Packet****length** | **Data****field****header** | **Source data** |
| **Version****number** | **Packet****type** | **Data****field****header****flag** | **APID** | **Segmentation/Grouping flags** | **Sequence****count** |  |  |  |
| **3** | **1** | **1** | **11** | **2** | **14** |
| **2** | **2** | **2** | **10** | **variable** |
|  | **4096 bytes MAX** |
|  | **4106 bytes MAX** |
| **4112 bytes MAX** |

|  |  |
| --- | --- |
| **Process ID** | **Packet Category** |
| Enumerated | Enumerated |
| 7 bits | 4 bits |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Spare** | **PUS version** | **Spare** | **Service type** | **Service****subtype** | **Destination ID** | **S/C time** |
| Fixed bit string | Enumerated | Fixed bitstring | Enumerated | Enumerated | Enumerated | EnumeratedCUC |
| 1 bit | 3 bits | 4 bits | 8 bits | 8 bits | 8 bits | 48 bits |

Table 8: Rules to be applied to build Telemetry Source packets

|  |  |
| --- | --- |
| **Field** | **Rule or value** |
| Version number | ‘000’ |
| Packet Type | 0 |
| Data Field Header | Set to 1 if there is a Data Field Header |
| Process ID | Defines the application which is the source of the telemetry packet. Documented in the Space to Ground ICD Vol. 2 (AD10) |
| Packet category | Identifies different types or categories of packets () |
| Segmentation Grouping Flags | ‘01’ First packet of a group of packets‘00’ Continuation packet‘10’ Last packet of a group of packets‘11’ Stand-alone packet |
| Sequence Count | Counter incremented by APID and Destination ID |
| Packet Length | (Number of bytes in Packet Data Field) - 1 |
| Spare | 0 |
| PUS version | ‘001’ |
| Spare | ‘0000’ |
| Service type | Service type to which the telemetry source packet relates |
| Service subtype | Together with the type, uniquely identifies the nature of the telemetry |
| Destination ID | Identifies the destination of the telemetry and where the TM packet has to be routed (on-board, ground).In case of TM generated as an answer to a TC: Destination ID = copy of the command Source ID, except for TM packet having the packet category = 2, 3, 4, 8 or 9, for which the Destination ID is set to 0. |
| S/C time | Defines the time when the generation of the packet was started. |
| Application data | Data element of the telemetry. |

APPENDIX B. Telecommand verification service



Figure 6: Telecommand verification service at the LFR level

(see details in “LFR TC PACKETS” and “LFR TM PACKETS” tables)

APPENDIX C. List of LFR TC/TM packets

Table 9: LFR TC packets

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **TC Name** | **Description** | **PID** | **Type** | **Subtype** |
| TC\_LFR\_RESET | Reset LFR | 76 | 181 | 1 |
| TC\_LFR\_LOAD\_COMMON\_PAR | Load the LFR common parameters | 76 | 181 | 11 |
| TC\_LFR\_LOAD\_NORMAL\_PAR | Load the LFR normal mode parameters | 76 | 181 | 13 |
| TC\_LFR\_LOAD\_BURST\_PAR | Load the LFR burst mode parameters | 76 | 181 | 19 |
| TC\_LFR\_LOAD\_SBM1\_PAR | Load the LFR SBM1 mode parameters | 76 | 181 | 25 |
| TC\_LFR\_LOAD\_SBM2\_PAR | Load the LFR SBM2 mode parameters | 76 | 181 | 27 |
| TC\_LFR\_DUMP\_PAR | Dump the LFR parameters | 76 | 181 | 31 |
| TC\_LFR\_ENTER\_MODE | Activate an LFR mode (standby, normal, burst, SBM1, SBM2) | 76 | 181 | 41 |
| TC\_LFR\_UPDATE\_INFO | Periodic packet containing HK from the RPW equipment | 76 | 181 | 51 |
| TC\_LFR\_ENABLE\_CALIBRATION | Enable LFR calibration function | 76 | 181 | 61 |
| TC\_LFR\_DISABLE\_CALIBRATION | Disable LFR calibration function | 76 | 181 | 63 |
| TC\_LFR\_UPDATE\_TIME | Contains the S/C time for on-board time synchronization | 76 | 9 | 129 |
| TC\_LFR\_LOAD\_KCOEFFICIENTS | Load LFR inter-calibration factors | 76 | 181 | 93 |
| TC\_LFR\_DUMP\_KCOEFFICIENTS | Dump LFR inter-calibration factors | 76 | 181 | 95 |
| TC\_LFR\_LOAD\_FBINS\_MASK | Load the LFR frequency bins internal masks | 76 | 181 | 91 |
| TC\_LFR\_LOAD\_FILTER\_PAR | Configure the SWA/PAS perturbation filtering parameters | 76 | 181 | 97 |

Table 10: LFR TM packets

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **TM Name** | **Description** | **PID** | **Type** | **Subtype** | **SID** |
| TM\_LFR\_TC\_EXE\_SUCCESS | TC execution success report | 76 | 1 | 7 | - |
| TM\_LFR\_TC\_EXE\_CORRUPTED | Execution Completed Failure Report in case of error detected during the acceptance stage verifications. | 76 | 1 | 8 | 42005 |
| TM\_LFR\_TC\_EXE\_INCONSISTENT | TC execution failure reportwrong or inconsistent header / data field | 76 | 1 | 8 | 5 |
| TM\_LFR\_TC\_EXE\_NOT\_EXECUTABLE | TC execution failure reportTC cannot be executed at this time | 76 | 1 | 8 | 42 |
| TM\_LFR\_TC\_EXE\_NOT\_IMPLEMENTED | TC execution failure reportTC not implemented yet | 76 | 1 | 8 | 42002 |
| TM\_LFR\_TC\_EXE\_ERROR | TC execution failure reportmalfunction detected | 76 | 1 | 8 | 42003 |
| TM\_LFR\_HK | HK report | 76 | 3 | 25 | 1 |
| TM\_LFR\_PARAMETER\_DUMP | LFR mode parameter dump | 76 | 181 | 32 | 10 |
| TM\_LFR\_KCOEFFICIENTS\_DUMP | LFR inter-calibration factors dump | 76 | 181 | 96 | 11 |
| **SCIENCE PACKETS** |
| TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F0 | Snapshot WF no comp. | 76 | 21 | 6 | 3 |
| TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F1 | Snapshot WF no comp. | 76 | 21 | 6 | 4 |
| TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F2 | Snapshot WF no comp. | 76 | 21 | 6 | 5 |
| TM\_LFR\_SCIENCE\_NORMAL\_CWF\_F3 | Continuous WF no comp. | 76 | 21 | 6 | 1 |
| TM\_LFR\_SCIENCE\_NORMAL\_CWF\_LONG\_F3 | Continuous long WF  | 76 | 21 | 6 | 34 |
| TM\_LFR\_SCIENCE\_BURST\_CWF\_F2 | Continuous WF no comp. | 76 | 21 | 6 | 2 |
| TM\_LFR\_SCIENCE\_SBM1\_CWF\_F1 | Continuous WF no comp. | 79 | 21 | 6 | 24 |
| 6TM\_LFR\_SCIENCE\_SBM2\_CWF\_F2 | Continuous WF no comp. | 79 | 21 | 6 | 25 |
| TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F0 | ASM no comp. | 76 | 21 | 6 | 11 |
| TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F1 | ASM no comp. | 76 | 21 | 6 | 12 |
| TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F2 | ASM no comp. | 76 | 21 | 3 | 13 |
| TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F0 | BP1 no comp. | 76 | 21 | 3 | 14 |
| TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F1 | BP1 no comp. | 76 | 21 | 3 | 15 |
| TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F2 | BP1 no comp. | 76 | 21 | 3 | 16 |
| TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F0 | BP2 no comp. | 76 | 21 | 3 | 19 |
| TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F1 | BP2 no comp. | 76 | 21 | 3 | 20 |
| TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F2 | BP2 no comp. | 76 | 21 | 3 | 21 |
| TM\_LFR\_SCIENCE\_BURST\_BP1\_F0 | BP1 no comp. | 76 | 21 | 3 | 17 |
| TM\_LFR\_SCIENCE\_BURST\_BP2\_F0 | BP2 no comp. | 76 | 21 | 3 | 22 |
| TM\_LFR\_SCIENCE\_BURST\_BP1\_F1 | BP1 no comp. | 76 | 21 | 3 | 18 |
| TM\_LFR\_SCIENCE\_BURST\_BP2\_F1 | BP2 no comp. | 76 | 21 | 3 | 23 |
| TM\_LFR\_SCIENCE\_SBM1\_BP1\_F0 | BP1 no comp. | 79 | 21 | 3 | 28 |
| TM\_LFR\_SCIENCE\_SBM1\_BP2\_F0 | BP2 no comp. | 79 | 21 | 3 | 31 |
| TM\_LFR\_SCIENCE\_SBM2\_BP1\_F0 | BP1 no comp. | 79 | 21 | 3 | 29 |
| TM\_LFR\_SCIENCE\_SBM2\_BP2\_F0 | BP2 no comp. | 79 | 21 | 3 | 32 |
| TM\_LFR\_SCIENCE\_SBM2\_BP1\_F1 | BP1 no comp. | 79 | 21 | 3 | 30 |
| TM\_LFR\_SCIENCE\_SBM2\_BP2\_F1 | BP2 no comp. | 79 | 21 | 3 | 33 |

APPENDIX D. LFR data packets against modes

|  |  |
| --- | --- |
| **NORMAL** | TM\_LFR\_SCIENCE\_NORMAL\_CWF\_F3TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F0TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F1TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F2TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F0TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F1TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F2TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F0TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F1TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F2TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F0TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F1TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F2 |
| **BURST** | TM\_LFR\_SCIENCE\_BURST\_CWF\_F2TM\_LFR\_SCIENCE\_BURST\_BP1\_F0TM\_LFR\_SCIENCE\_BURST\_BP2\_F0TM\_LFR\_SCIENCE\_BURST\_BP1\_F1TM\_LFR\_SCIENCE\_BURST\_BP2\_F1 |
| **SBM1** | TM\_LFR\_SCIENCE\_NORMAL\_CWF\_F3TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F0TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F1TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F2TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F0TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F1TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F2TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F0TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F1TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F2TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F0TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F1TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F2 |
| TM\_LFR\_SCIENCE\_SBM1\_CWF\_F1TM\_LFR\_SCIENCE\_SBM1\_BP1\_F0TM\_LFR\_SCIENCE\_SBM1\_BP2\_F0 |
| **SBM2** | TM\_LFR\_SCIENCE\_NORMAL\_CWF\_F3TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F0TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F1TM\_LFR\_SCIENCE\_NORMAL\_SWF\_F2TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F0TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F1TM\_LFR\_SCIENCE\_NORMAL\_ASM\_F2TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F0TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F1TM\_LFR\_SCIENCE\_NORMAL\_BP1\_F2TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F0TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F1TM\_LFR\_SCIENCE\_NORMAL\_BP2\_F2 |
| TM\_LFR\_SCIENCE\_SBM2\_CWF\_F2TM\_LFR\_SCIENCE\_SBM2\_BP1\_F0TM\_LFR\_SCIENCE\_SBM2\_BP2\_F0TM\_LFR\_SCIENCE\_SBM2\_BP1\_F1TM\_LFR\_SCIENCE\_SBM2\_BP2\_F1 |

APPENDIX E. Justifications by email

