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Planck LFI User Manual Document

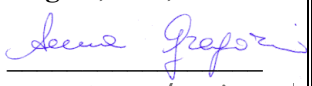
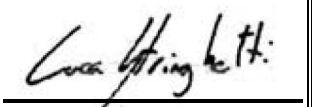
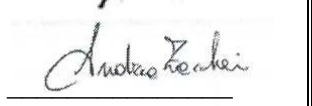
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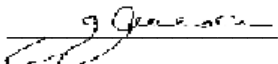
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Prepared by	A. GREGORIO LFI DPC Development Team	Date: August, 22 nd , 2008
		Signature: 
	M. MICCOLIS LFI Project System Team	Signature: 
	L. STRINGHETTI LFI AIV Manager	Signature: 
	A. ZACCHEI LFI DPC Manager	Signature: 
Agreed by	R.C. BUTLER LFI Program Manager	Date: August 22 nd , 2008
	A. ZACCHEI LFI DPC Manager	Signature: 



Approved by	N. MANDOLESI LFI Principal Investigator	Date: August 22nd, 2008 Signature: 



DISTRIBUTION LIST

Recipient	Company / Institute	E-mail address	Sent
T. PASSVOGEL	ESA/ESTEC/SCI-PT	Tpassvog@estec.esa.nl	
P. ESTARIA	ESA/ESTEC/SCI-PT	Pestaria@estec.esa.nl	
J. TAUBER	ESA/ESTEC/SA	Jtauber@astro.estec.esa.nl	
R. LAUREIJS	ESA/ESTEC/SA	Rlaureij@esa.int	
N. MANDOLESI	IASF/INAF – BOLOGNA	mandolesi@iasfbo.inaf.it	
R. C. BUTLER	IASF/INAF – BOLOGNA	butler@iasfbo.inaf.it	
M. BERSANELLI	UNIMI – MILANO	marco.bersanelli@mi.infn.it	
C. LAWRENCE	JPL – PASADENA	Lawrence.a.wade@jpl.nasa.gov	
F. PASIAN	INAF-OAT – TRIESTE	Pasian@ts.astro.it	
K. BENNETT	ESTEC/SSD – NOORDWIJK	Kbennett@astro.estec.esa.nl	
T. COURVOISIER	ISDC – VERSOIX	Thierry.Courvoisier@obs.unige.ch	
L. DANESE	SISSA – TRIESTE	Danese@sissa.it	
R. DAVIES	JBO – MACCLESFIELD	Rdd@jb.man.ac.uk	
R. DAVIS	JBO – MACCLESFIELD	Rjd@jb.man.ac.uk	
G. DE ZOTTI	INAF-OAPd – PADOVA	Dezotti@pd.astro.it	
K. ENQVIST	UN. of HELSINKI	Kari.enqvist@helsinki.fi	
T. GAIER	JPL – PASADENA	Todd.gaier@jpl.nasa.gov	
K. GORSKI	ESO – GARCHING	Kgorski@eso.org	
E. KOLLBERG	CUT – GOTHENBURG	kollberg@ep.chalmers.se	
P. LILJE	UIO – OSLO	per.lilje@astro.uio.no	
P. LUBIN	UCSB – SANTA BARBARA CALIFORNIA U.S	Lubin@cfi.ucsb.edu	
E. MARTINEZ - GONZALEZ	UN. de CANTABRIA – SANTANDER	Martinez@ifca.unican.es	
H.-U. NORGAARD- NIELSEN	DSRI – COPENHAGEN	hunn@dsri.dk	
R. REBOLO	IAC – LA LAGUNA TENERIFE	Rrl@ll.iac.es	
G. SMOOT	UN. of CALIFORNIA & LBNL	Smoot@cosmos.lbl.gov	
L. SPINOGLIO	IFSI – ROMA	Luigi@ifsi.rm.cnr.it	
G. TOFANI	CAISMI – FIRENZE	Tofani@arcetri.astro.it	
J. TUOVINEN	MIL – HELSINKI	jussi.tuovinen@vtt.fi	
N. VITTORIO	RM2 “TOR VERGATA” –	Vittorio@roma2.infn.it	

University of Trieste

LFI DPC Development Team



	ROMA		
L. WADE	JPL – PASADENA	Lawrence.a.wade@jpl.nasa.gov	
S. WHITE	MPA – GARCHING	Swhite@MPA-Garching.MPG.DE	
J.-L. PUGET	HFI – IAS	puget@ias.u-psud.fr	
G. EFSTATHIOU	HFI – CAM	gpe@ast.cam.ac.uk	
J.-M. LAMARRE	HFI – IAS	lamarre@ias.u-psud.fr	
J.-F. SYGNET	HFI – IAS	sygnet@ias.u-psud.fr	
F. BOUCHET	HFI – IAP	bouchet@iap.fr	
A.ZACCHEI	INAF-OAT – TRIESTE	Zacchei@oats.inaf.it	
SGS-DR Boards			



CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
0.1	30/09/04	All	First working issue	===
1.0	31/03/05	All	First issue	===
2.0	30/01/06	All	Complete description of the LFI procedures during Nominal Operations	===
2.1	20/12/06	§ 13.1 § 13.3 § 13.2 All All	Commissioning Operations: a first list Contingency Operations: a first list Corrections of a few errors in the Nominal Operations Update of performances and budgets Filling, where possible, of missing parts	===
2.2	30/06/07	§ 13.2 § 11 – 12 AN22-35	Corrections of a few errors in the Nominal Operations procedures, comments to procedures added Few updates, comments and reference to SCOS name of TM and TC added New	
3.0	22/08/2008	§ 9.2.3.3 § 10.3 § 11.1.1 § 11.1.9 § 11.2 § 11.4 § 11.5 § 11.6 § 12.1 § 13.1.1 § 13.1.2 § 13.2 § 13.3 § 13.4 AN06 AN19 AN36	Additional details on TM data flow AF Detailed description of memories allocation SSC definition in reply to NC 3634 TM(6,6) addition information added Definition of Synthetic parameters (see also AN36) Example of TM(1,8) added Example of TM(3,26) added Packets position ID added Duplication of table cancelled Commissioning procedures added CPV procedures added Nominal Operation procedures updated, new procedures added Contingency procedures updated Special remarks updated Annex on TM(3,25) updated Annex on TM(8,6) updated New annex Synthetic parameters	



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1 SCOPE

This document is a high level document.

This document gives a description of the baseline design of the LFI, including function and performance of each LFI sub system. Particular emphasis is given to the Radiometer Array Assembly (RAA) which carries the most critical elements of the instrument.

The scientific objectives for the LFI, a derivation of the main instrument requirements, and an assessment of systematic errors are described in the LFI Scientific Requirements document.

Spacecraft performances, capabilities and requirements imposed on the instruments are described in the IID part A, while instrument requirements and main performances are described in the IID part B. The interfaces between the LFI and HFI instruments are described in the LFI-HFI Interface Document.

In case of conflict between the contents of this Document and the IID-B or the LFI-HFI interface document, the contents of the latter documents shall take precedence.

This document has been issued as part of the activity performed under the ASI contract for Planck LFI Phase E2.

1.1 LIMITS OF APPLICABILITY



2 APPLICABLE/REFERENCE DOCUMENTS

2.1 ANNEX DOCUMENTS

- AN1 Description of the SCOS 2000 Fields for Telemetry Packets and Naming Convention Applied to PLANCK LFI
- AN2 TC Acceptance Report Success – TM(1,1)
- AN3 TC Acceptance Report Failure – TM(1,2)
- AN4 TC Execution Report Completed – TM(1,7)
- AN5 TC Execution Report Failure – TM(1,8)
- AN6 HK Parameter Report – TM(3,25)
- AN7 Diagnostic Parameter Report – TM(3,26)
- AN8 Event Report – TM(5,1)
- AN9 Exception Report – TM(5,2)
- AN10 Error/Alarm Report – TM(5,4)
- AN11 Memory Dump, Absolute Address – TM(6,6)
- AN12 Memory Check Report, Absolute Address – TM(6,10)
- AN13 Time Verification Report – TM(9,9)
- AN14 Enabled Tm Packet Report – TM(14,4)
- AN15 Link Connection Report – TM(17,2)
- AN16 Nominal Science Data Report – TM(21,1)
- AN17 Diagnostic Science Report – TM(21,2)
- AN18 Diagnostic Science Report – TM(21,3)
- AN19 Function Status Report – TM(8,6)
- AN20 Provided Services
- AN21 Planck Alignment Plan
- AN22 Load Memory Using Absolute Addresses – TC(6,2)
- AN23 Dump Memory Using Absolute Addresses – TC(6,5)
- AN24 Check Memory Using Absolute Addresses – TC(6,9)
- AN25 Start Function Different for various commands – TC(8,1)
- AN26 Stop Function Different for various commands – TC(8,2)
- AN27 Perform Activity of Function – TC(8,4)



- AN28 Report Function Status – TC(8,5)
- AN29 Enable Time Synchronisation – TC(9,4)
- AN30 Time Code Synchronise – TC(9,5)
- AN31 Enable Time Verification – TC(9,7)
- AN32 Enable Tx of TM Packets – TC(14,1)
- AN33 Disable Tx of TM Packets – TC(14,2)
- AN34 Report Enabled TM Packets – TC(14,3)
- AN35 Test Service – TC(17,1)
- AN36 Synthetic Parameters

2.2 APPLICABLE DOCUMENTS

- AD1 HERSCHEL/PLANCK Instrument Interface Document Part A PT-IID-A-04624 Issue 3/3
- AD2 HERSCHEL/PLANCK Instrument Interface Document Part B Instrument LFI
PT-IID-B/LFI-04142 Issue 3.4
- AD3 Planck – LFI Instrument Specification PL-LFI-PST-SP-001 Issue 2
- AD4 Herschel/Planck Operations Interface Requirements Document SCI-PT-RS-07360 Issue 2.2
- AD5 Planck LFI – Communications Interface Control Document PL-LFI-PST-ID-013 Issue 3.1
- AD6 SCOS-2000 Database Import ICD S2K-MCS-ICD-0001-TOS-GCI Issue 5.1
- AD7 ESA FMECA for ESA Spacecraft and Associated Equipment ESA PSS-01-303 AD6
- AD8 LFI-HFI Interface Document PL-LFI-PST-ID-001

2.3 REFERENCE DOCUMENTS

- RD1 Planck LFI – Radiometer Array Assembly ICD PL-LFI-PST-ID-004 Issue 3
- RD2 PLANCK-LFI Scientific Requirements Document PL-LFI-PST-SP-011
- RD3 Removed
- RD4 Planck LFI - Instrument ICD PL-LFI-PST-ID-003 Issue 3
- RD5 Planck LFI – 30 GHz Radiometer Chain Assembly ICD PL-LFI-PST-ID-005 Issue 3.1
- RD6 Planck LFI – 44 GHz Radiometer Chain Assembly ICD PL-LFI-PST-ID-006 Issue 3.1
- RD7 Planck LFI – 70 GHz Radiometer Chain Assembly ICD PL-LFI-PST-ID-007 Issue 3.1
- RD8 Planck LFI – Data Acquisition Electronics ICD PL-LFI-PST-ID-009 Issue 2.2
- RD9 System Harness and RAA Harness ICD PL-LFI-PST-ID-012



RD10	Herschel_Planck_Packet_Structure_ICD	SCI-PT-ICD-7527 Issue 5.0
RD11	LFI_On-Board_SW_URD	PL-LFI-PST-UR-001 Issue 2
RD12	LFI_FMECA	PL-LFI-PST-AN-001
RD13	44GHz_FEM_FMECA_-_Issue_0	PL-LFI-JBO-AN-002
RD14	30GHz_FEM_FMECA_-_Issue_0	PL-LFI-JBO-AN-001
RD15	General Design and Interface Requirements (GDIR)	H-P-1-ASPI-SP-0027 Issue 3.2
RD16	LFI-REBA and PACS-SPU Start-up SW and Low Level SW Drivers URD	DS/UR-FIR/027v.8 Issue 1
RD17_1	Data Acquisition Electronics (DAE) Data Acquisition Specification Document	PL-LFI-LAB-SP-015 Issue 4
RD17_2	Data Acquisition Electronics (DAE) – Power Box -Specification Document	PL-LFI-LAB-SP-016 Issue 4
RD18	Planck-LFI REBA Requirements Specification	PL-LFI-IAC-SP-001 Issue 3
RD19	Planck LFI 70 GHz RCA Requirements Specifications	PL-LFI-PST-SP-008
RD20	Planck LFI On-Board Data Processing, Compression and Telemetry Rate	Issue 1.0
RD21	Planck LFI Instrument and Development Plan	PL-LFI-PST-002
RD22	Planck LFI Project Breakdown Structure: Product Tree (PT) and Work Breakdown Structure	PL-LFI-PST-PW-001 Issue 4.0
RD23	FIRST/Planck Project, Planck Telescope Design Specifications	SCI-PT-RS-07024 Issue 1
RD24	Technical Description of GRASP8	TICRA S-894-02
RD25	4K Reference Load Interface Control Document	PL-LFI-PST-ID-010 Issue 2.1
RD26	Planck LFI – REBA Interface Control Document	FPL-IC-1214-02-CRS Issue 4
RD27	Testing Plan of the LFI instrument during the Planck Commissioning and CPV phase	PL-LFI-PST-PL-013

2.4 ACRONYMS LIST

ABCL	As-Built Configuration List
ACMS	Attitude Control and Measurement Subsystem
AIV	Assembly, Integration and Verification
AME	Attitude Measurement Error
AOCS	Attitude and Orbit Control System
APE	Absolute Pointing Error
ARE	Absolute Rate Error
AVM	Avionics Verification Model



BAU	Buffer Amplifier Unit (SPIRE)
BC	Bus Controller
BEM	Back End Module (LFI)
BEU	Back End Unit (LFI)
CCB	Configuration Control Board
CCE	Central Check-out Equipment
CDMS	Command and Data Management Subsystem
CDMU	Central Data Management Unit
CIDL	Configuration Item Data List
CQM	Cryogenic Qualification Model
CoG	Centre of Gravity
Co-I	Co-Investigator
CQM	Cryogenic Qualification Model
CVV	Cryostat Vacuum Vessel
DAE	Data Acquisition Electronics (LFI)
DC	Direct Current
DCCU	Dilution Cooler Control Unit
DDVP	Design, Development and Verification Plan
DPC	Data Processing Centre
ECR	Engineering Change Request
EGSE	Electrical Ground Support Equipment
EM	Engineering Model
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
ESA	European Space Agency
ESD	Electro Static Discharge
ESOC	European Space Operations Centre
ESTEC	European Space Research and Technology Centre
FCS	Flight Control System
FDIR	Failure Detection Isolation and Recovery
FEM	Front End Module (LFI)
FEU	Front End Unit (LFI)
FH	Feed Horn (LFI)
FINDAS	FIRST Integrated Network and Data Archive System
FIRST	Far InfraRed and Submillimetre Telescope
FMECA	Failure-Modes, Effects and Criticality Analysis
FOB	FIRST Optical Bench
FOV	Field Of View
FPLM	FIRST Payload Module
FPU	Focal Plane Unit
FS	Flight Spare
FSC	FIRST Science Centre
FSEC	FIRST Science Evaluation Committee
FSVM	FIRST Service Module
GSE	Ground Support Equipment



HFI	High Frequency Instrument (Planck)
HIFI	Heterodyne Instrument for FIRST
HK	House Keeping
IBDR	Instrument Baseline Design Review
ICC	Instrument Control Centre
ICD	Interface Control Document
ICDR	Instrument Critical Design Review
IFAR	Instrument Flight Acceptance Review
IHDR	Instrument Hardware Design Review
IID	Instrument Interface Document
ILT	Instrument Level Test
IST	Integrated System Test
ISVR	Instrument Science Verification Review
ITT	Invitation To Tender
JFET	Junction Field Effect Transistor
LEOP	Launch and Early Orbit Phase
LO	Local Oscillator (HIFI)
LOS	Line Of Sight
LOU	Local Oscillator Unit (HIFI)
LVDE	Low Vibration Drive Electronics
MGSE	Mechanical Ground Support Equipment
MLI	Multilayer Insulation
MOC	Mission Operations Centre
Mol	Moment of Inertia
MOS	Margin Of Safety
MPS	Mission Planning Subsystem
NCR	Non Conformance Report
OIRD	Operations Interface Requirements Document
OMT	Ortho Module Transducer (LFI)
OP	Observation Period
PACS	Photoconductor Array Camera and Spectrometer
PCS	Power Control Subsystem
PDE	Pointing Drift Error
PFM	Proto Flight Model
PI	Principal Investigator
PLM	Payload Module
PM	Project Manager
PPLM	Planck Payload Module
PSEC	Planck Science Evaluation Committee
PSF	Point Spread Function
PSVM	Planck Service Module
PT	Product Tree
QLA	Quick Look Analysis (software)
RAA	Radiometer Array Assembly (LFI)
RAM	Random Access Memory



RCA	Radiometer Chain Assembly (LFI)
RCS	Reaction Control Subsystem
REBA	Radiometer Electronics Box Assembly (LFI)
RF	Radio Frequency
RFW	Request for Waiver
RH	Reference Hole
RPE	Relative Pointing Error
RTA	Real Time Assessment (software)
S/C	Spacecraft
SCC	Sorption Cooler Compressor assembly (LFI)
SCCE	Sorption Cooler Cold End (LFI)
SCE	Sorption Cooler Electronics (LFI)
SCOS	Spacecraft Control and Operations System
SCP	Sorption Cooler Piping (LFI)
SCS	Sorption Cooler Subsystem (LFI)
SFT	Short Functional Test
SIN	Straylight Induced Noise
SIRD	Science Operations Implementation Requirements Document
SIST	Short Integrated System Test
SRPE	Spatial Relative Pointing Error
SSR	Solid State Recorder
SST	Stainless Steel
STM	Structural/Thermal Model
STMM	Simplified Thermal Model
SVM	Service Module
TBC	To be confirmed
TBD	To be determined
TBW	To be written
TCS	Thermal Control System
TE	Test Equipment (LFI)
TM	Telemetry
TMM	Thermal Mathematical Model
TPF	Task Parameter File
TT&C	Telemetry, Tracking and Command
TTC	Telemetry, Tracking and Command
VSWR	Voltage Standing Wave Ratio
WBS	Work Breakdown Structure
WFE	Wave Front Error
WG	Waveguide (LFI)



3 INSTRUMENT DESCRIPTION

3.1 THE PLANCK LOW FREQUENCY INSTRUMENT LFI

The Planck Low Frequency Instrument is built to achieve the sensitivity to measure CMB anisotropies in the frequency range 30 – 70 GHz to the fundamental accuracy limits imposed by cosmic variance and by astrophysical foregrounds. It uses state-of-the-art, cryogenic, coherent receivers based on ultra-low-noise indium phosphide (InP) high-electron-mobility transistors (HEMTs), taking full advantage of the remarkable advances in this technology over the last decade. The LFI represents the third generation millimeter-wavelength instrument designed for space observations of CMB anisotropies, following the COBE Differential Microwave Radiometer and the Microwave Anisotropy Probe (MAP).

The LFI radiometer design adopts InP HEMT low noise amplifiers (LNAs) for minimal power dissipation and best performance. To further minimise power consumption in the focal plane, the radiometers are split into two subassemblies connected by waveguides, one located at the telescope focal area, the other on the 300 K portion of the Planck satellite. These design features allow the entire front-end LNAs dissipation to be <0.55 W, which enables the active cooling of the focal assembly. This is achieved with a vibration-less hydrogen sorption cooler, which also provides 18 K pre-cooling to the HFI helium J-T cooler. Because the sorption cooler is necessary to both LFI and HFI, a redundant cooler is included in the flight hardware.

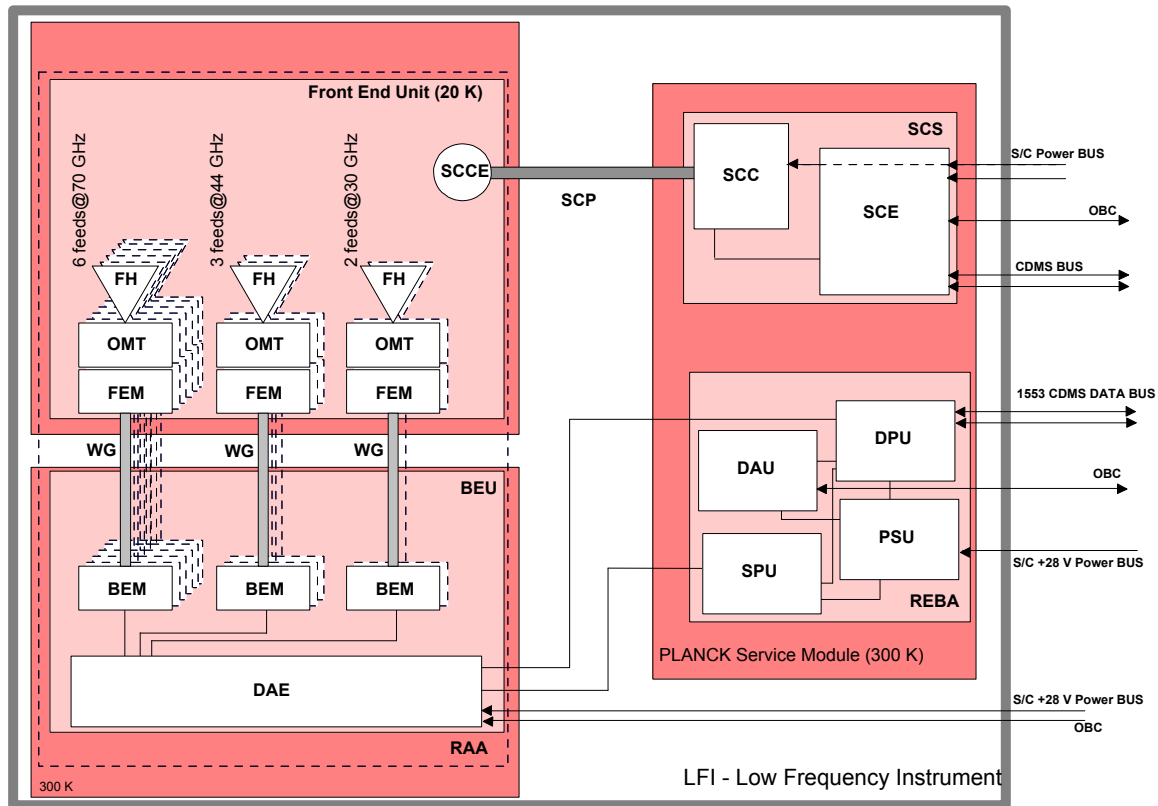


Figure 3-1 Block Diagram of LFI

As shown schematically in Figure 3-1, the LFI consists of the following subsystems:

- Radiometer Array Assembly (RAA)
- Sorption Cooler Subsystem (SCS)
- Radiometer Electronics Box Assembly (REBA)

The RAA includes the Front End Unit (FEU) and the Back End Unit (BEU), connected via waveguides. The FEU is located at the focus of the telescope, as one component of the joint LFI/HFI focal assembly (see Section 3.4). The BEU is mounted on the top of the Planck SVM.

The Radiometer Electronics Box Assembly (REBA) and the warm parts of the Sorption Cooler System (SCS) is located on one of the lateral panels of the service module (SVM). The FEU and the Sorption Cooler Compressor (SCC) are connected by concentric stainless steel tubes. The smaller tube carries hydrogen at ~60 atmospheres from the cooler compressors to the FEU, while the larger tube returns the hydrogen at ~0.3 atmospheres. These units are described in detail in following sections.

All LFI units are linked together by the LFI harness, which also connects to the spacecraft interface.



3.2 DESIGN DESCRIPTION

3.2.1 RADIOMETER CHAINS OVERALL DESIGN

3.2.1.1 LFI RADIOMETER CONCEPT

The LFI receivers with front-ends cooled to 20 K are direct detection radiometers where the signal is first amplified sufficiently (approximately 65 dB) and then detected with a diode. DC-voltage corresponding to the incoming noise power is therefore obtained without any Intermediate Frequencies (IF), mixers, or Local Oscillators (LO).

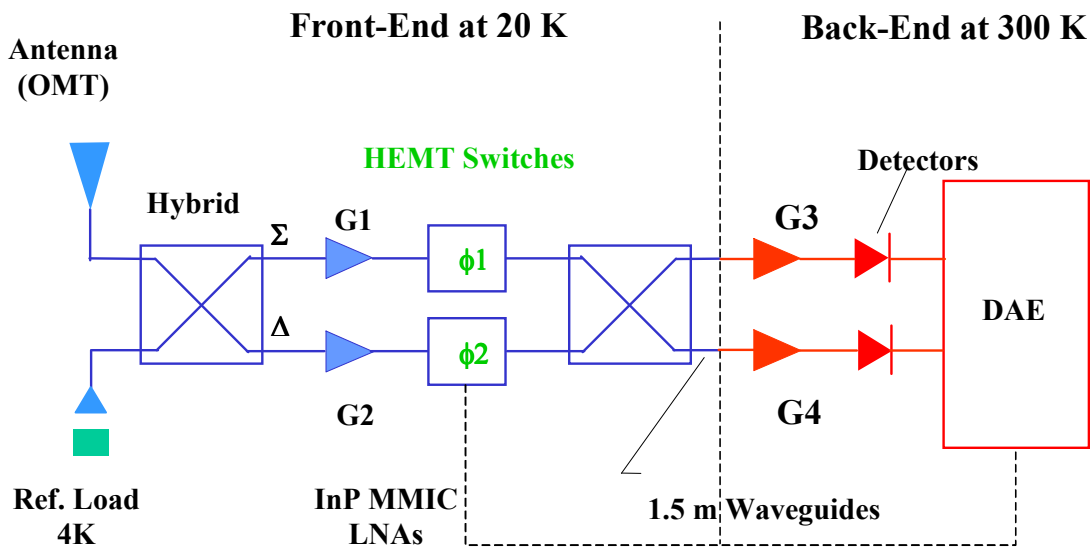


Figure 3-2 diagram of the baseline LFI pseudo-correlation receiver

The time scale of the stability of the receiver is driven by the 1 rpm rotation speed of the spacecraft, which requires a very low 1/f-noise or gain variation of the low noise amplifiers and other components.

The LFI uses a pseudo-correlation receiver concept (Figure 3-2). This radiometer concept is chosen to maximise the stability of the instrument by reducing the effect of non-white noise generated in the radiometer itself. In this scheme, the difference between the inputs to each of the chains (the signal from the telescope and that from a reference black body respectively) is continuously being observed. To remove the effect of instability in the back-end amplifiers and detector diodes, it is necessary to switch the signal detected at the diodes at high rate.

The signals from the sky and from a reference load are combined by a hybrid coupler, amplified in two independent amplifier chains, and separated out by another hybrid. The sky and the reference load power can then be measured and differenced. Since the reference signal has been subject to the same gain variations in the two amplifier chains as the sky signal, the true sky power can be recovered.



The differencing receiver greatly improves the stability if the two input signals are almost equal, at a cost of a factor of $\sqrt{2}$ in sensitivity compared to a perfectly stable total-power radiometer with the same noise temperature and bandwidth. The LFI team has proved both by analysis and by laboratory tests that radiometer concept is capable of greatly reducing the knee frequency. In Figure 3-3 we report the data stream obtained by M.Seiffert et al at JPL for the W band LFI prototype radiometer. This is based on the single-pole, double throw switching scheme (see Section 3.2.1.4). Shown are the undifferenced data from the two inputs (corresponding to odd and even samples) with substantial non-white noise, and the differenced data for which the stability improves by a factor 10000.

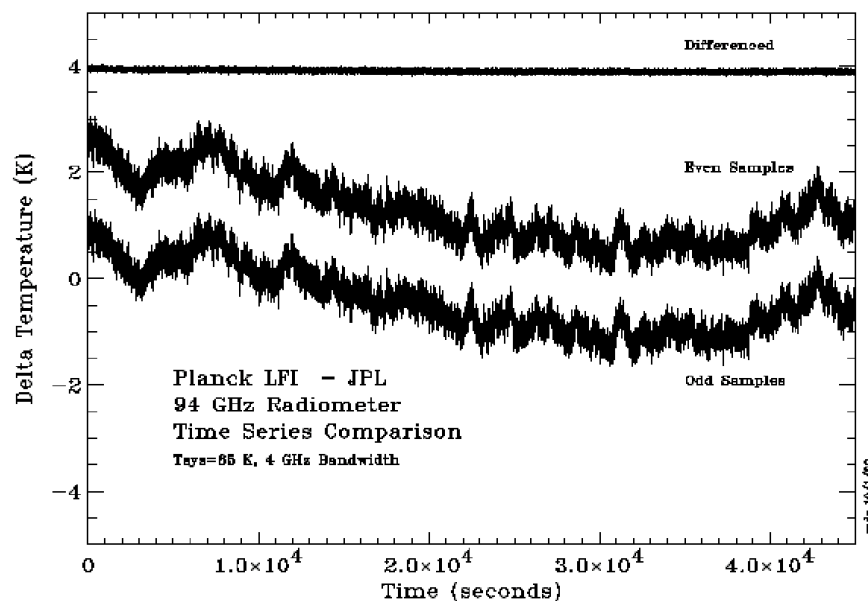


Figure 3-3 Display of data binned in to 1 second intervals. Even samples are with the switch in one position, odd the other. The odd-even differenced data are also shown, exhibiting substantially lower noise.

3.2.1.2 RADIOMETER CHAINS DESCRIPTION

We define as Radiometer Chain Assembly (RCA, see Figure 3-4) each functional unit from the feed horn to the BEM. The RAA therefore includes a set of 11 RCAs and the Data Acquisition Electronics, all mounted on a suitable mechanical structure. Although there are differences in the details of the radiometer chains at different frequencies their overall configuration is similar, and a general description of its design is provided in this section.

Planck LFI has 11 Radiometer Chain Assembly (RCA). Each RCA is constituted by feed horn and FEM in the FEU (at 20 K), BEM (at 300 K) in the BEU and four waveguides that connect each FEM-BEM couple. The frequency distribution of the RCA is the following:

- 2 RCAs at 30 GHz
- 3 RCAs at 44GHz
- 6 RCAs at 70 GHz

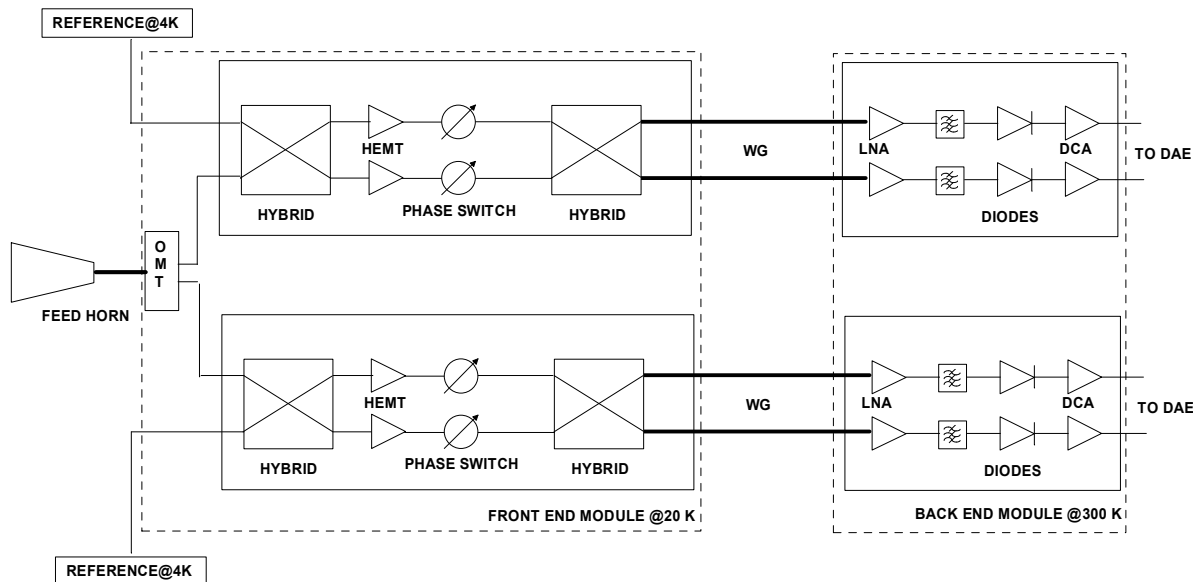


Figure 3-4 Radiometer Chain Assembly

The radiation focused by the Planck telescope is coupled to each radiometer chain by a corrugated feedhorn. The radiation pattern of the horn must be highly symmetric, with very low sidelobes and a beam width that matches the telescope edge taper requirement. In addition, the electromagnetic field inside the horn must propagate with low attenuation and low return loss. The OMTs separate the orthogonal polarizations with minimal losses and cross-talk.

The OMTs are followed by the Front End Modules (FEMs), which include the first hybrid couplers block, and the amplifiers block with phase switches and output hybrids. This front-end is designed to minimise instabilities in the radiometer while maintaining low thermal noise.

Each Front-end Module (FEM) contains two hybrid couplers for the two channels selected by the OMT. Each hybrid has two inputs, one of which sees the sky, the other looks at the reference load through a small dedicated horn. The external reference load provides a stable blackbody reference signal at approximately 4K. The low temperature is obtained by connecting the reference loads to the HFI 4K stage. The radiometric interface is provided by microwave absorber coupled to a small rectangular waveguide. The total additional heat power radiated to the HFI 4K stage does not exceed approximately 1 mW.

The low-noise amplifiers use InP HEMTs in cascaded gain stages. Following amplification the signals are passed through a phase switch. The phase switch adds 0 / 180 degrees of phase lag to the signals, thus selecting the input source as either the sky or the reference load at the FEM output.

The phase lagged pair of signals is then passed into a second hybrid coupler, separating the signals. The hybrid coupler combines the signals from the two amplification paths with a fixed phase offset between them. It has a 20% bandwidth, low loss, and amplitude balance needed at the output to ensure adequate signal isolation.

The front-end and back-end portions of each radiometer chain are connected through wave-guides.



The main feature of the waveguides is thermal isolation between the 20 K front-end and the 300 K back-end.

The radiometer chain continues in the Back End Module (BEM), which accepts four waveguides from the corresponding FEM. Each receiver back end module comprises four parallel chains of amplification, filtering, detection, and integration. Post-detection amplifiers are integrated into the BEMs to avoid data transmission problems between the radiometer and the digital acquisition system.

Each backend module is packaged into a box of a few centimetres on a side, including the biasing circuitry and the input and output connectors. To first order, the power output of each lag, depending on the phase switch status, is given by

$$P = \begin{cases} Gak\beta[T_{sky} + T_{sys}] \\ Gak\beta[T_{load} + T_{sys}] \end{cases} \quad (Eq. 3.2-1)$$

Where G is the effective gain of the system, a is the proportionality constant of the square law detector diode, k is the Boltzmann constant and β is the bandwidth of the chain.

After detection, the output signals (Sky and Reference) from each diode of each radiometer is processed to be easily transmitted to ground (see Paragraph 15.1.3). Taking the difference of the diode outputs helps removing systematic effects due to small asymmetries coupled with the two states of the phase switch. In fact, to first order, if T_{x-1} and T_{x-2} are the temperatures of the target x measured when the phase switch is in state 1 and 2 respectively, we have from the two diodes:

$$\begin{aligned} \Delta T_B &= (T_{Sky-1} - T_{Load-2}) \\ \Delta T_A &= (T_{Load-1} - T_{Sky-2}) \end{aligned} \quad (Eq. 3.2-2)$$

If an effect δT_1 and δT_2 is introduced by the switch state, i.e., $T_{x-1} = T_x + \delta T_1$ and $T_{x-2} = T_x + \delta T_2$, then by taking the difference of the two diodes outputs we have:

$$\begin{aligned} \Delta T_B - \Delta T_A &= (T_{Sky-1} - T_{Load-2}) - (T_{Load-1} - T_{Sky-2}) = \\ &= (T_{Sky} + \delta T_1 - T_{Load} - \delta T_2) - (T_{Load} + \delta T_1 - T_{Sky} - \delta T_2) \\ &= 2(T_{Sky} - T_{Load}) \end{aligned} \quad (Eq. 3.2-3)$$

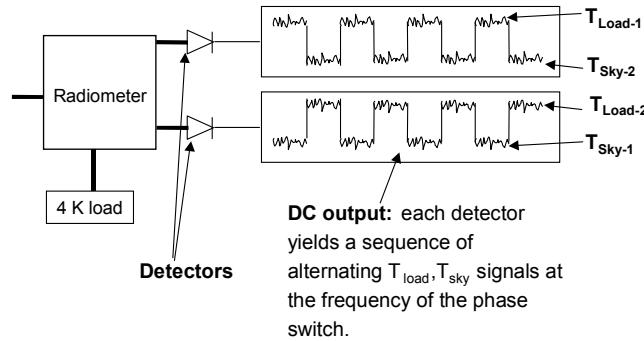


Figure 3-5 Schematic of the LFI radiometer signal output



3.2.1.3 FEED HORNS

Dual profiled corrugated horns have been selected at all LFI frequencies as the best design in terms of shape of the main lobe, level of the side lobes, control of the phase centre, and compactness. Dual profiled LFI horns are composed by a *Sine Squared* profiled section, and an *exponential* profile near the aperture plane. The design has consolidated the following corrugation profile, $R(z)$:

Sine squared region:

$$R(z) = Ri + (Rs - Ri) \left[\left(1 - A\right) \frac{z}{Ls} + A \sin^2 \left(\frac{\pi}{2} \frac{z}{Ls} \right) \right], \quad 0 \leq z \leq Ls \quad (\text{Eq. 3.2-4})$$

Exponential region:

$$R(z) = Rs + e^{\alpha(z-Ls)} - 1, \quad Ls \leq z \leq Le + Ls, \quad \alpha = \frac{1}{Le} \ln(1 + Ra - Rs) \quad (\text{Eq. 3.2-5})$$

Where:

- Ri : throat radius;
- Rs : sine squared region end radius, or exponential region initial radius;
- Ra : aperture radius;
- Ls : sine squared region length;
- Le : exponential region length;

The parameter A $0 \leq A \leq 1$ modulates the profile between linear and pure sine squared type.

The parameters $\frac{Le}{Le + Ls}$, A , Rs can be used to control, as far as possible, the position and frequency stability of the phase centre, and the compactness of the structure as well.

In order to optimise the optical matching of the feeds phase centres to the telescope focal surface, while preventing obscuration between horns, LFI has 6 different feed horn designs. For each frequency, the number of feeds and the number of different designs are reported in Table 3.2-1.

Table 3.2-1 – Number of LFI feed horns and number of different feed horn designs.

Frequency (GHz)	Number of Horns	Number of designs
30	2	1
44	3	2
70	6	3

The mechanical constraints derive from the Thermo/Mechanical model of the FPU and have been set on the bases of the design of the LFI Focal Plane (See an example in Figure 3-6).

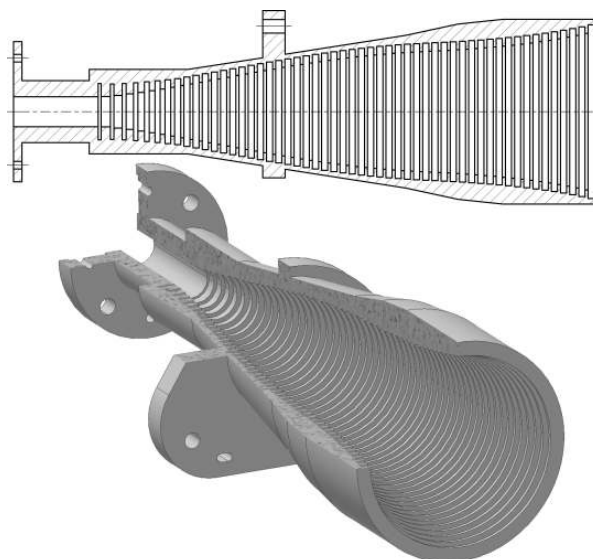


Figure 3-6 The 44 GHz Feed Horn Drawing

The electromagnetic specifications is partially related to the simulation performances of the feed-telescope system. These simulations are mainly devoted to show the trade off between angular resolution and stray light.

The Table below reports the performances and characteristics of the LFI feed horns. Although the required return loss is 25 dB (including flange effects and fabrication tolerances), for the design process the return loss has been set at -30 dB. The Return Loss and the cross polar values reported in the table are the worst values over the entire 20% of bandwidth based on measurements.

Table 3.2-2 Performances and characteristics of the LFI feed horns as derived from measurements at 300 K

Horn ID	Bandwidth [GHz]	Edge Taper [dB@22°]	X-pol Centre frequency [dB]	Return-Loss [dB]	Side Lobes Centre frequency [dB]
18	14	17.6	-34	-38	-40
19	14	17.0	-32	-34	-36
20	14	17.4	-34	-35	-36
21	14	17.4	-36	-34	-36
22	14	17.5	-32	-34	-36
23	14	17.4	-41	-34	-39
24	8.8	31.5	-34	-30	-42
25	8.8	31.5	-36	-31	-36
26	8.8	32.0	-35	-31	-36
27	6	30.3	-42	-28	-34
28	6	30.0	-42	-28	-34



3.2.1.4 ORTHOMODE TRANSDUCERS (OMTS)

The Ortho-Mode Transducer (OMTs) separates the two orthogonal polarisation components propagating inside the horn. The performances for the LFI OMTs at all frequencies are reported in the following table:

Table 3.2-3 Performance Characteristics of the LFI OMTs based on measurements. The values are the worst values over the entire 20% of bandwidth expect the Insertion Loss that is the average value.

OMT ID	Bandwidth [GHz]	X-Pol [dB]		Insertion-Loss [dB]		Return-Loss [dB]	
		Main arm	Side Arm	Main arm	Side arm	Main arm	Side arm
18	14	<29	<30	0.15	0.2	-15.0	-18.0
19	14	<26	<28	0.15	0.2	-15.0	-18.0
20	14	<32	<35	0.15	0.2	-15.0	-18.0
21	14	<32	<37	0.15	0.2	-15.0	-18.0
22	14	<26	<28	0.15	0.2	-15.0	-18.0
23	14	<26	<28	0.15	0.2	-15.0	-18.0
24	8.8	<38	<40	0.15	0.2	-13.0	-15.0
25	8.8	<31	<32	0.15	0.2	-13.0	-15.0
26	8.8	<27	<25	0.15	0.2	-13.0	-15.0
27	6	<38	<44	0.15	0.10	-16.0	-24.0
28	6	<36	<38	0.15	0.15	-16.0	-24.0

3.2.1.4.1 Design

One polarisation propagates directly from the circular waveguide to the rectangular on-axis waveguide. A circular to rectangular stepped transition provides the interface with a WR28 standard waveguide, and the short for the other orthogonal polarisation. The second polarisation component propagates in the side arm.

The OMT is composed by the central square waveguide with two slots (the through and the side one, which separate and pick up the two polarisations), the waveguide transition between the two slots and the WR28 standard waveguide, the 90 degrees bend for the side port, the 90 degrees stepped twist for the through port waveguide transition between the square and the input circular waveguide of the horn. A design of the 30 GHz OMT is shown in Figure 3-7.

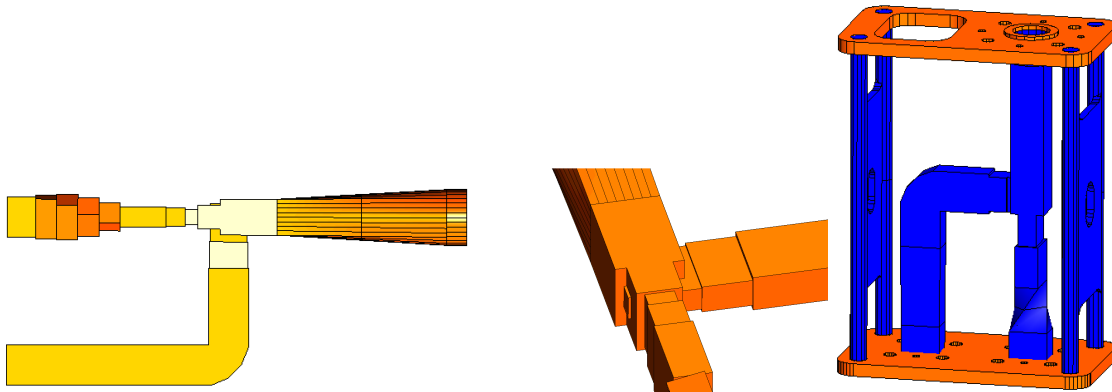


Figure 3-7 Left figure: Sketch of the 30 GHz OMT. A detail of the OMT nucleus is shown at the center. On the right figure the mechanical model of the OMT is showed.



A parametric investigation has been carried out to verify the stability of the OMT performances with respect to the mechanical tolerances: the performances of the OMT have been computed by changing the most significant dimensional parameters within the range of accuracy foreseen by the manufacturing technique. The performances are all compatible.

The 70 GHz OMT is essentially a scaled version of the 30 GHz OMT.

3.2.1.5 FRONT END MODULES (FEMS)

Front End Modules are located in the FPU, just in cascade of the Feed Horn and the Ortho Mode Transducers. 70 GHz FEMs are mounted onto the inner wall of the mainframe (the wall facing HFI instrument) from the HFI side. 44 and 30 GHz FEMs are inserted into the mainframe from the WG side and fixed to the bottom plate. Screws to bottom plate are inserted from WG side.

The LFI FEMs are the first active stage of amplification of the radiometer chain. Each FEM contains four amplification paths. Each path is composed by several cascaded LNAs followed by a phase switch. Two passive hybrids, at the input and output of the FEM, are used to mix couples of signals of the same radiometer (see Figure 3-4). This makes the instabilities of each chain to be applied to both the sky and load signals.

The FEMs Wiring Diagrams for One 4 Stage LNA are shown in the Figure 6-23, Figure 6-24 and Figure 6-25.

3.2.1.6 WAVEGUIDES

The LFI Front End Unit (FEU) (cooled at 20 K by the sorption cooler) is connected to the 300 K Back End Unit (BEU) by 44 rectangular waveguides approximately 2.0 meter long. Each waveguide exhibits low VSWR, low thermal conductivity, low insertion loss, and low mass. In addition, the waveguide path shall permit the LFI/HFI integration and the electrical bonding between FPU and BEU. Because of the Focal Plane Unit arrangement, the waveguides are in general twisted and bended in different planes and with different angles, depending on the particular waveguide. The Figure 3-8 reports a conceptual sketch of the LFI configuration. The waveguide path is shown.

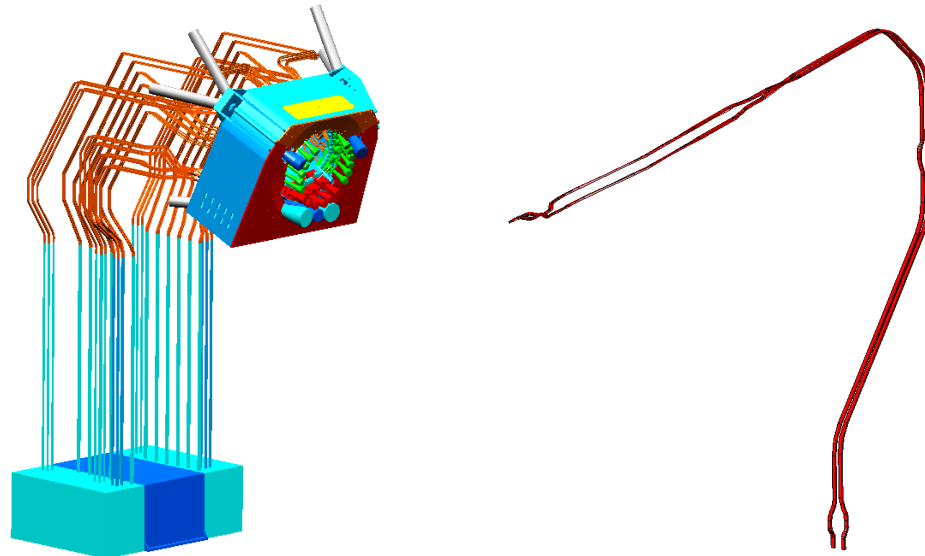


Figure 3-8 Left: Sketch of the LFI in which the waveguides are reported. Right: example of the path of two waveguides. The drawing is referred to the Copper section of the waveguide only and show the complexity of this section.

Table 3.2-4 Number of LFI waveguides and performances. The Insertion Loss (IL), Return Loss(RL) and Electrical Resistance (R) values are the requirements. In between parenthesis the goal is reported also. Note that the RL value includes possible degradation due to presence of flanges.

Frequency	Type	Number	IL [dB]	RL [dB]	R [mΩ]	
					@20 K	@300 K
30	WR28	8	2.0 (1.0)	≤ -20	11.8	27.3
44	WR22	12	3.0 (1.5)	≤ -20	14.7	34.1
70	WR12	24	4.0 (3.5)	≤ -20	26.2	60.5

All the required characteristics cannot be realised with single material waveguide configuration; therefore a composite waveguide configuration is needed. The schematic picture of the waveguide configuration is reported. The location, along the waveguide path, of the three thermal shields is reported. The waveguides are thermally and mechanically attached to these shields.

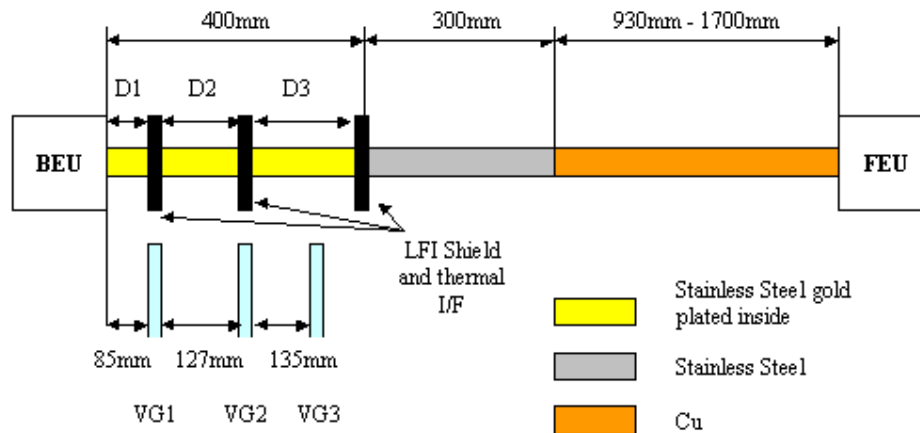


Figure 3-9 Schematic Configuration of the waveguides

SS thickness = 0.254 mm

Au thickness = 2 μm

Cu thickness = 0.4 mm

The WGs can be considered divided in three sections corresponding to different materials used for the waveguide manufacturing:

- a 400 mm of Stainless Steel straight waveguide section is attached to the BEU and ends after the 3rd V-groove. This section shall be 1–2 micron gold plated; the waveguide wall thickness is 254 micron;
- a 300 mm of non-plated Stainless Steel section provides a thermal break between the 50K groove and 20K stage;
- A bended and twisted 400 microns thin electroformed copper waveguide starts at the end of the SS-section and is attached to the FEU. The two main sections (SS and Cu) are connected between them by custom flanges. The length of the copper waveguide section varies from 930 mm to 1750 mm, with 2 to 4 Cu-joints. The so-called Cu joints are electroformed copper layer deposited in order to connect 2 pieces of Cu WG.

From the thermal point of view the waveguides have to connect 2 systems (BEM and FEM) that are at different temperatures. At BEM level the waveguides are at a temperature of 300K while at FEM level the temperature is 20K. Along the Stainless Steel section the waveguides have to reduce the thermal flow from 300K to 20K. The Stainless Steel waveguide is connected to all the V-grooves in order to dissipate the heat produced at BEU level.

The copper waveguides section is connected to a mechanical support structure in five points in order to increase the stiffness of the waveguide.

Each copper waveguide has different path and, whereas the straight Stainless Steel sections are identical for all the channels except for the cross dimensions that define the cut-off frequency. An example of the waveguide path for two waveguides in the copper section is shown in the right picture of Figure 3-8.



3.2.1.6.1 WG Electromagnetic Design

From the radiometric point of view not all the geometries could be permitted in order to avoid any possible mismatching between bends and twists. Thus, the goal of the simulation activity which has been performed was to establish criteria for the design phase and successively to evaluate the performances of the waveguides with high accuracy.

An analytical model of each discontinuity has been implemented. Such a model is based on the fact that an optimum length of the bend (or twist), at a fixed angle, could be found. Because of the optimistic predictions of the analytical model, accurate return loss simulations have been performed with appropriate software packages.

The analytical model permit to design high performance waveguide in a quick way, because no particular problems raised also in the combined discontinuities (see Paragraph 7.1.1.6 on Performance).

3.2.1.6.2 WG Mechanical Design

One of the main problems of the WG mechanical design is the choice of the appropriate path of the waveguide to minimize the losses and at the same time satisfy the mechanical constraints. Then, in the design of the waveguides, the following technological criteria have been applied:

1. Use of only one twist. This is due to the criticality in the production and tolerances of the mandrel for the twist.
2. Minimise number of different bends (this is done in order to have a fast production, simplify the waveguide mandrel integration before electroforming and have a better control on the mandrel production).
3. Pass though pre-defined points, given by the different systems (HFI, struts, etc...)
4. Stay inside into the physical envelope fixed by PPLM I/F.
5. Connect BEU and FPU (where I/F are frozen).
6. Minimise the length where possible.
7. Minimise RF losses using straight pieces wherever possible.

Mechanical analyses on a preliminary Waveguide Finite Element Model show that a support structure of the waveguides is needed. The following picture shows a sketch of such a support structure.

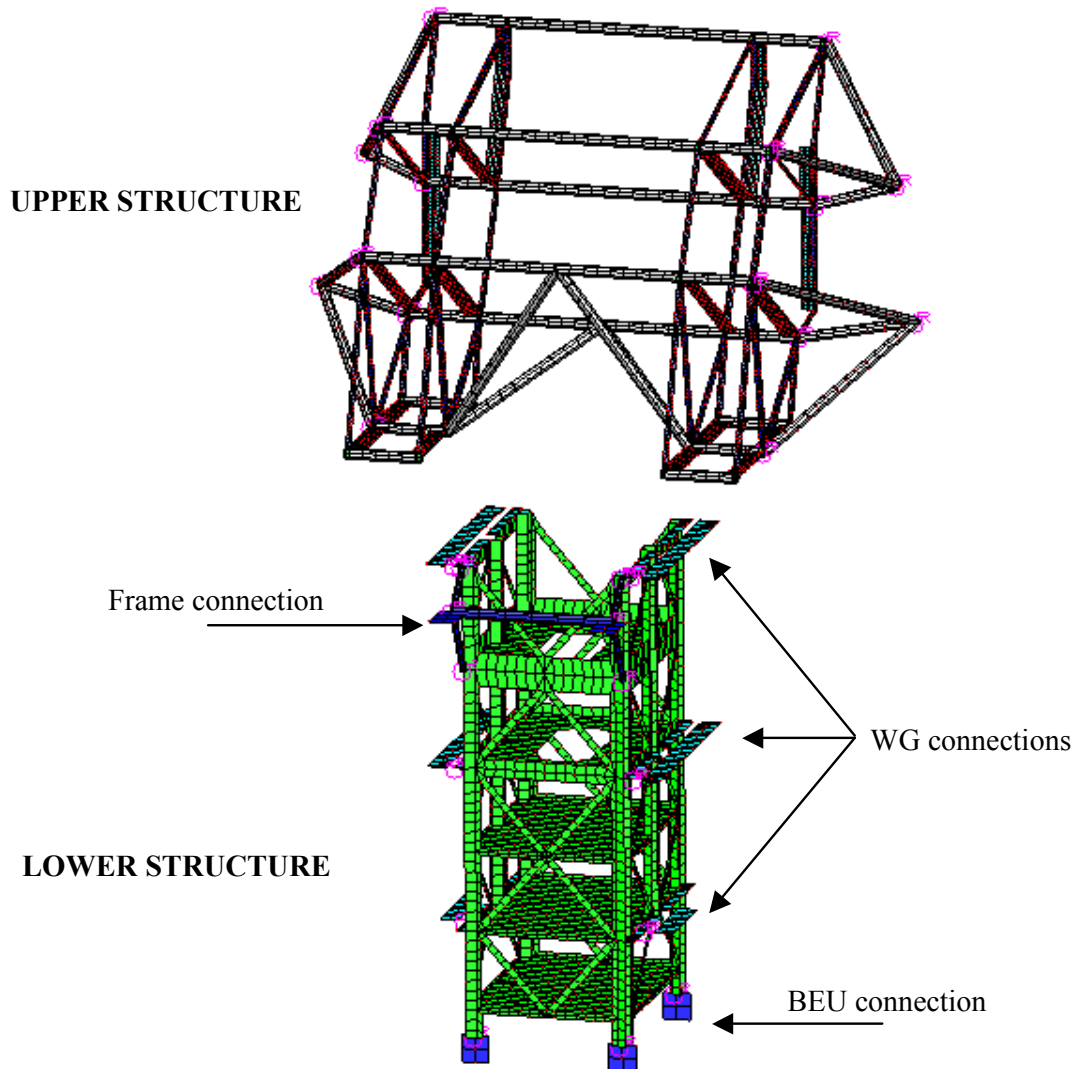


Figure 3-10 Pictures showing the waveguide support structure.

3.2.1.6.3 WG Flanges

Each Front End Module (FEM), composed by two radiometers, is attached to four waveguides. Since the spacing among waveguides of each FEM is not enough to accommodate standard flanges, custom flanges have been developed for connecting the waveguides to FEMs and BEMs. Other flanges are used to connect the copper section to the stainless steel section. In figure an example of the 30 and 44 flanges design is shown.

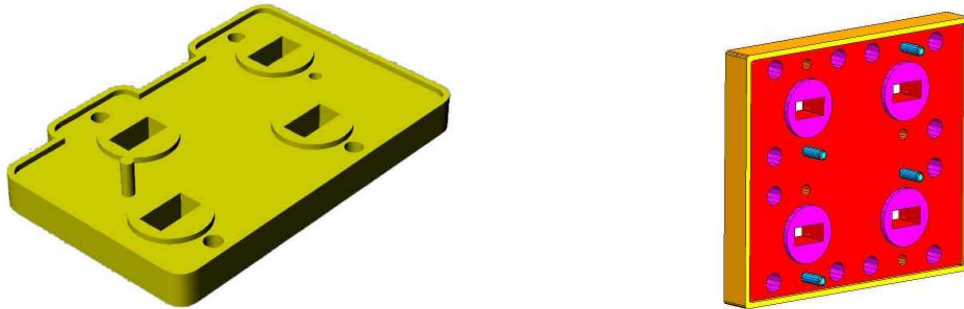


Figure 3-11 Examples of Flight Models Flanges. Left: waveguide – FEM flanges for the 30 GHz channel. Right: Waveguide – BEM flanges for the 44 GHz channel.

3.2.1.7 BEMS

The BEMs are composed by four identical channels each made of Low Noise Amplifiers (LNA), RF Band Pass Filter, RF to DC diode detector and DC amplifiers.

3.2.1.7.1 30 GHz BEM

Each LNA consists of two cascaded MMIC amplifiers (HMC263 from Hittite).

The Band Pass Filter is based on microstrip coupled line structure. Its design is a three order Chebyshev response band pass filter. Microstrip lines are made on Metclad substrate with thickness 0.254 mm and 2.17 dielectric relative constant.

The detector is composed by a hybrid reactive/passive matching network, and a Schottky diode. A commercial Agilent beam-lead and zero-bias diode was selected (model HSCH-9161). A view of the detector is shown in Figure 3.1-14.

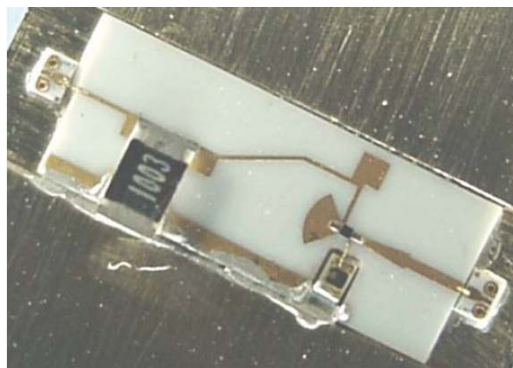


Figure 3-12 30 GHz Schottky diode detector

The detector diode is followed by a low noise OP27 operational amplifier that provides most of the DC amplification. A second stage is implemented using a OP200 operational amplifier to provide a balanced bipolar output.



3.2.1.7.2 44 GHz BEM

Each LNA consists of self designed MMIC amplifiers manufactured with the process ED02AH from OMMIC which employs a 0.2 μm gate length Pseudomorphic-High Mobility Transistor (PHEMT) on GaAs.

The topology chosen for the band-pass filter is a third order Chebyshev band pass filter made on a PTFE substrate (height=0.254mm, $\epsilon_r=2.17$), based on microstrip coupled line structure.

The detector is composed by a hybrid reactive/passive matching network and a Schottky diode. A commercial Agilent beam-lead and zero-bias diode was selected (model HSCH-9161). A view of the detector is shown in Figure 3-13.



Figure 3-13 44 GHz Schottky diode detector

The detector diode is followed by a low noise OP27 operational amplifier that provides most of the DC amplification. A second stage is implemented using a OP200 operational amplifier to provide a balanced bipolar output.

3.2.1.7.3 70 GHz BEM

The BEM is constructed of machined aluminium with separate filter, amplifier/detector assemblies and an overall housing for other circuits and components.

The FEM output signals are connected by waveguide from the Focal Plane Unit (FPU) assembly to the Back End Modules (BEM's) housed adjacent to, the Data Acquisition Electronics (DAE) assembly. To maintain compatibility with the FEM's, each BEM will accommodate, four receiver channels, from the four, waveguide outputs of each FEM. The BEM internal signal routes are not cross coupled and can be regarded as four identical parallel circuits.

Each BEM is constructed as two mirror halves. The two amplifier/detector assemblies each contain two amplifier/detector circuits. Each is supplied from one of a pair of printed circuit boards which also house two dc output amplifiers.

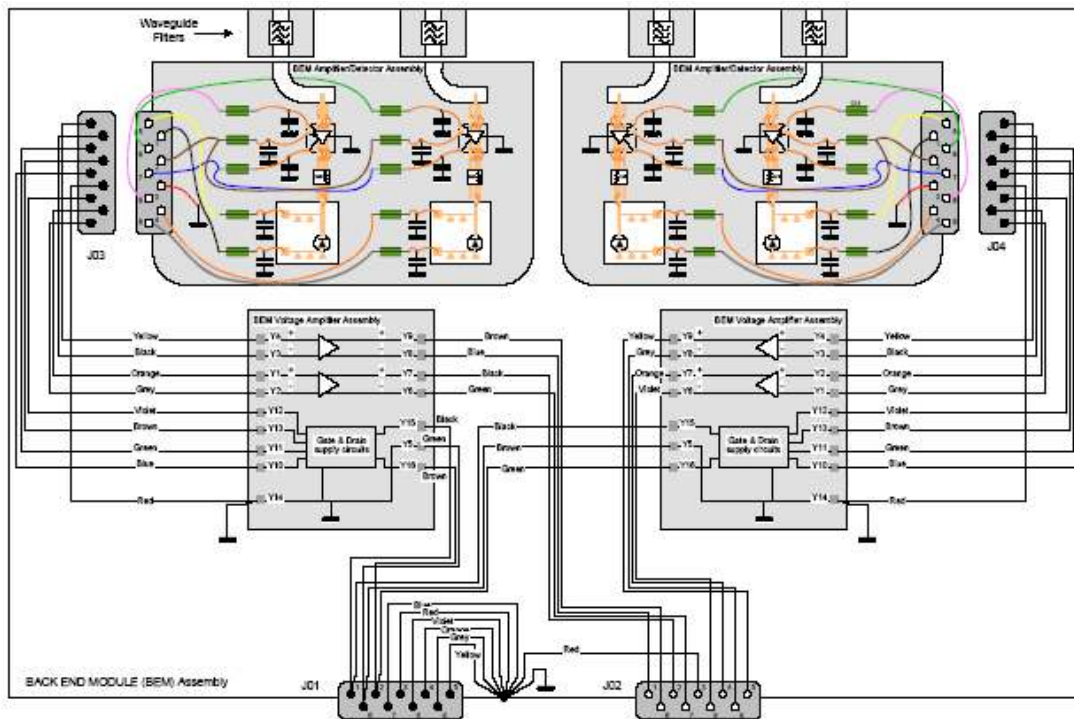


Figure 3-14 70 GHz BEM Overall Circuit Diagram

3.2.1.8 4K LOAD

The purpose of the 4 K reference load is to provide the radiometer with a stable reference signal. Reducing the input offset (the radiometric temperature difference between the sky and the reference load) reduces the minimum achievable radiometer 1/f noise knee frequency for a given amplifier fluctuation spectrum. A reference load temperature that matches the sky temperature (approximately 2.7 K) would be ideal.

In the 4KRL design, the reference temperature is provided by the HFI outer radiation shield, at a temperature around 4K.

A subset of the 4KRL goal performance are reported in Table 3.2-5.

Table 3.2-5 4KLRL performance

Property	HFI-mounted
Physical Temperature	< 5 K
Mass	0.6 kg
System reflectivity	< -20 dB
System leakage	< -40 dB
Required cooling power	< 1 mW
Horn –load separation	> 1.5 mm



3.2.1.8.1 Baseline Design

3.2.1.8.1.1 Materials

The material for the microwave absorbing target is ECCOSORB, CR series. CR-type is made from castable epoxy resin (Stycast), loaded with small (1-3 μm diameter) iron spheres. CR-type material can be machined after curing. Among the available materials of the CR, the material selected for the 4KRL targets is CR-110 and CR-117. Relevant properties of materials (from Emerson & Cummings data-sheets) are reported in Table 3.2-6.

Table 3.2-6 Eccosorb CR/MF series properties

Property	4 K	300 K	Reference
Density	1.6 g/cc	1.6 g/cc	Emerson & Cummings
Heat capacity	$10^4 \mu\text{J/g-K}$		Peterson & Richards '84
Attenuation (18 GHz)			
CR-110		6.6 dB/cm	Emerson & Cummings
CR-117		119 dB/cm	Emerson & Cummings

Eccosorb CR-110 was used for the COBE FIRAS calibrator and for many CMB spectrum balloon experiments. Some properties of this material are listed in Table 3.2-7.

Table 3.2-7 Eccosorb CR-110 properties

Property	4 K	300 K	Reference
Density	1.6 g/cc	1.6 g/cc	Emerson & Cummings
Heat capacity	$10^4 \mu\text{J/g-K}$		Peterson & Richards '84
Thermal Conductivity	0.8 mW / cm-K		Peterson & Richards '84
Boundary resistance	5 mm equiv.		Peterson & Richards '84
CTE		$3 \times 10^{-5} / ^\circ\text{C}$	Emerson & Cummings
30 GHz absorption	$.8 \text{ cm}^{-1}$	1.2 cm^{-1}	Hemmati et al. '85
30 GHz reflectivity	.13		Hemmati et al. '85
100 GHz absorption	1.2 cm^{-1}	2 cm^{-1}	Hemmati et al. '85
100 GHz reflectivity	.1		Hemmati et al. '85

CR-110 has the lowest iron density of the castable Eccosorb products. Using a higher iron density increases the absorption, but also increases the reflectivity from the front surface. Transmission and reflection values may vary up to 30 % depending upon Eccosorb sample preparation (Hemmati et al. '85). This variation means that appropriate margins included in the load design not severely limit performance.

3.2.1.8.1.2 Design description

Reference WGs and RH are either included in the FEM (70 GHz) or external to FEM (30 and 44 GHz).



The 4K reference load unit is formed by single targets, one for each radiometer (two for each FEM). Targets have different design for each of the LFI frequency: their dimension increase with reducing frequency. Due to the LFI Focal Plane design, where higher frequency radiometers (70 GHz) are placed around the HFI cryostat and the lower frequency radiometers (30 and 44 GHz) in a second row, the target mounting structure is separated in two parts. The upper one is located around the conical part of the HFI outer shield. The lower part is fixed in the cylindrical part (see Figure 3-15).

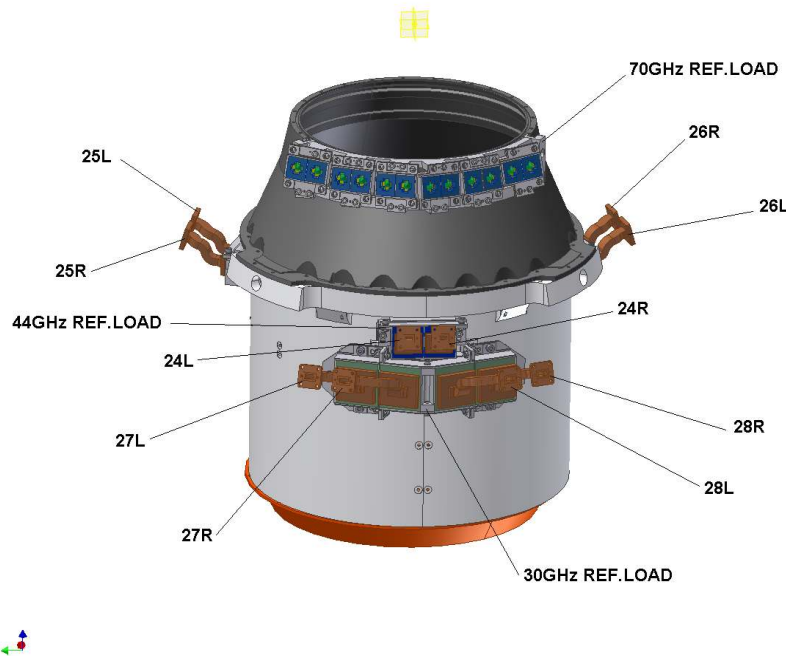


Figure 3-15 4K reference load targets mounted on the HFI 4K shield

Targets are formed of a *back* section, made of ECCOSORB CR117, which shows higher RF absorption but also high reflectivity. To reduce the target global reflectivity, a *front* section, assembled with an ECCOSORB specific cement to the *back* one, faces the radiometer Reference Horn. This last is casted from ECCOSORB CR110, whose RF reflectivity is lower than that of CR117. Target design is optimised to further reduce both reflectivity and leakage. Each target is metal backed and it is mounted in a metal enclosure. The actual design for targets is sketched in Figure 3-16.

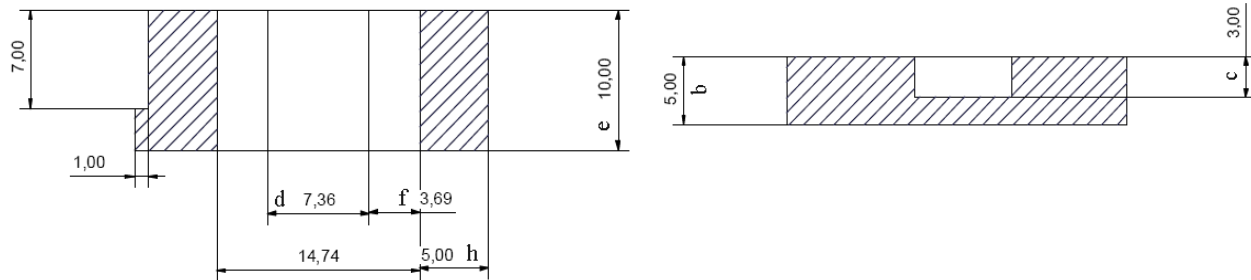


Figure 3-17 Sketch of the 44 GHz 4KRL Target

3.2.1.8.1.3 Reference horn

The horns used to couple to the 4 K reference load targets need to be relatively small because the targets themselves are small. An optimisation process produced a different horn design for each LFI band. Horn dimensions are reported in

Table 3.2-9, the definition of the parameters a to n is given in Figure 3-18.

The design, coupled with RT described above, are close to performance requirements.

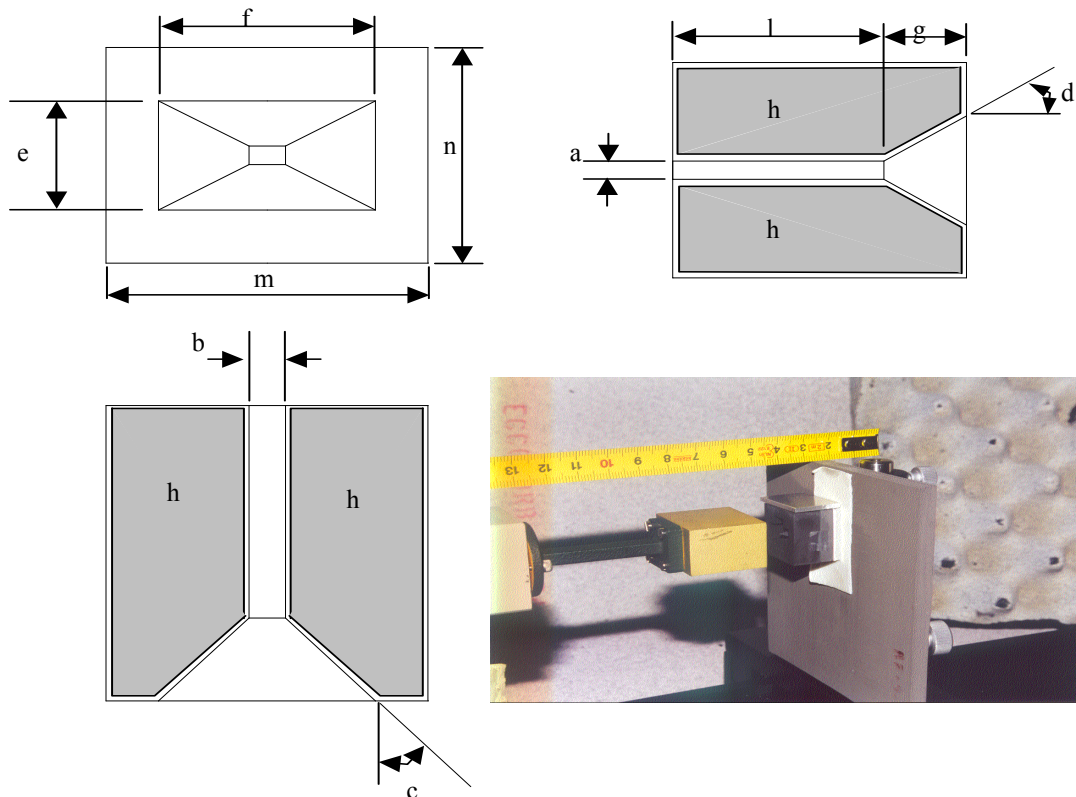


Figure 3-18 Sketch of reference horn (Left). 44 GHz Reference Horn and target during PD tests.



Table 3.2-9 – Dimensions for the 4K horns

Freq (GHz)	a mm	b mm	c deg	d deg	e mm	f mm	g mm	m Plane (mm)	n Plane (mm)
70	1.550	3.100	47.570	28.682	4.629	9.257	2.814	19.05	19.05
44	2.845	5.690	34.084	10.681	5.365	14.730	6.68	30	19.04
30	3.560	7.110	47.580	28.680	10.800	21.600	6.62	30	19.04

The main modification to this horn design is the introduction of grooves around the horn aperture as shown in Figure 3-19. They are small cavities, $\frac{1}{4}$ lambda deep, designed to reduce the leakage at the RH-RT gap. Test performed at IASF-BO (30 and 44 GHz) demonstrated the reduction of the leakage with respect to the old horn design.

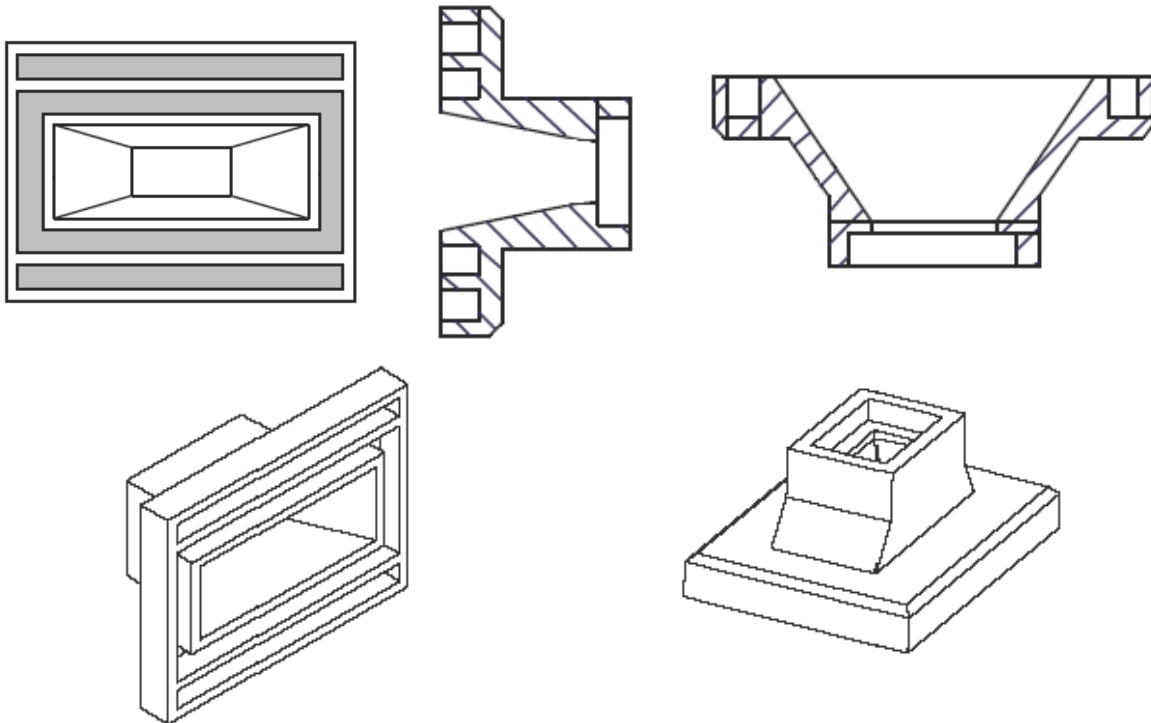


Figure 3-19: Sketch of the 44 GHz horn with grooves (grey area) around the aperture

The 4K load is made of two separate parts: an upper part for the high frequency channels and a lower part for the low frequency channels.

Upper part:

Reference targets are mounted on a supporting structure, thermally and mechanically connected to the HFI outer shield.

Each target faces a reference horn, two for each FEM. This ensemble is fixed to a support structure on the HFI 4K shield (see Figure 3-20). Thermal link between the mounting structure and the HFI is



obtained via fixation point only. Thermal washers are interposed to damp temperature fluctuations on targets induced by the HFI outer shield temperature oscillations.

Lower part:

In Figure 3-20 the most critical sector is shown. It is made with the same target geometry of the upper part, and it is fixed on the HFI shield. The reference horns face the loads and are connected to the FEMs through WGs.

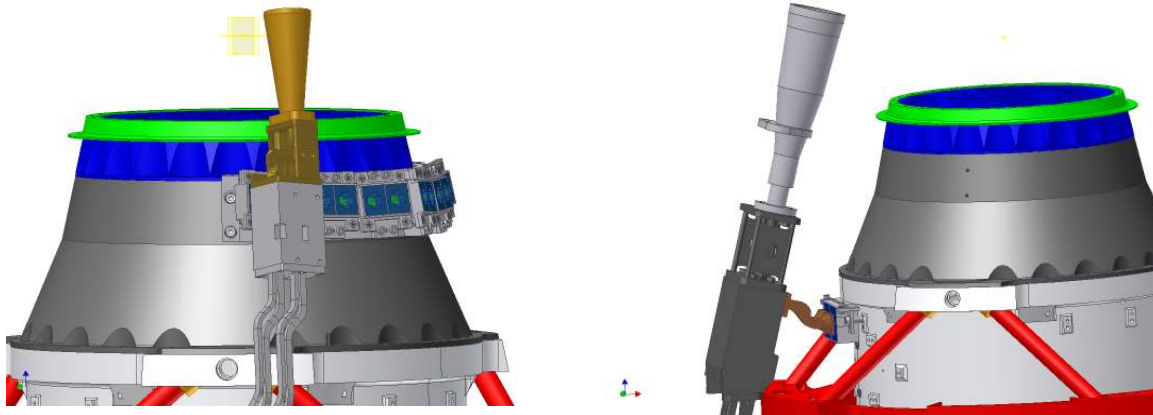


Figure 3-20 4K load upper support structure concept

3.2.2 RADIOMETER ARRAY ASSEMBLY (RAA)

This chapter provides a description of the Radiometer Array Assembly (RAA). The RAA consists of two main units (the front end unit, FPU and the Back End Unit, BEU), connected by a set of waveguides.

The Focal Plane Unit (FPU) is the heart of the LFI instrument and it contains the feed array and associated orthomode transducers (OMTs) and FEMs, all cooled to 20 K by the sorption cooler. The FPU comprises a set of 11 modules, which are mounted on a mechanical support which meets the thermo-mechanical requirements of the instrument and adds thermal inertia.

The BEU comprises the radiometer Back End Modules (BEM) and the Data Acquisition Electronics (DAE), which are connected by an internal harness.

The HFI Unit is located inside the LFI FPU and supported by the LFI structure. The LFI structure gives the mechanical and thermal interface to the HFI unit with the proper stiffness and thermal decoupling. The LFI structure also guarantees the proper alignment of the HFI detector with the telescope focal plane.

3.2.2.1 LFI FOCAL PLANE

3.2.2.1.1 FPU description

The FPU is the Focal Plane Unit placed in the telescope focal plane; the FPU is composed by the following subassemblies:



- The LFI Front Ends of the RAA
- The HFI Unit supported by the LFI structure
- The LFI structure composed by the supporting frame and PPLM interfacing bipodes.
- The Wave-Guides
- The Cryo harness

The FPU comprises 11 modules, each containing one feed horn, one orthomode transducer (OMT), two hybrid couplers and four cryogenic amplifiers. The two hybrids, the amplifiers and the phase switches are contained in the Front End Module (FEM).

The HFI Unit is located inside the LFI and supported by the LFI structure.

The alignment of the LFI/HFI instrument is guaranteed by:

- mechanical tolerances of the structure
- dimensioning of the mechanical parts considering the thermal contraction of the structure during cooling down
- mechanical verification of the LFI/HFI instrument through reference targets (e.g. photogrammetry)

HFI gives to LFI a reference load at 4K.

The LFI structure main functions are:

- provide mechanical support to the feed array of the LFI instrument
- provide the thermal inertia to the feed array
- provide mechanical support to the HFI instrument
- provide mechanical support to the cryo harness and FEU internal harness
- provide mechanical interface toward the PPLM interface
- provide thermal de-coupling toward the PPLM interface

The foreseen materials, with their thermal and mechanical properties, are reported in the next paragraphs together with the relevant structural analysis and results.

3.2.2.1.1.1 Mainframe structure

The core of the LFI structure is represented by the mainframe (as shown in Figure 3-18). The mainframe is made of Aluminum alloy. It provides mechanical support for the following parts: FEU, HFI, SC cold end, cryo harness, connectors.

It is constituted by two parts: the main body and the top cover: the top cover itself is constituted by two parts. During integration of the RAA the top cover is removed to provide easy access for internal harness and bolts. Before HFI integration the top cover is put into place and fixed to the main body of the mainframe.

The Front End components are connected both to the main body and to the top cover. In Figure 3-18 we show various pictures of the LFI mainframe.



The mainframe is designed to assure enough stiffness to the system in order to satisfy first eigenfrequency requirement (see below) and to sustain lift off loads. The mainframe also assures temperature uniformity and thermal inertia.

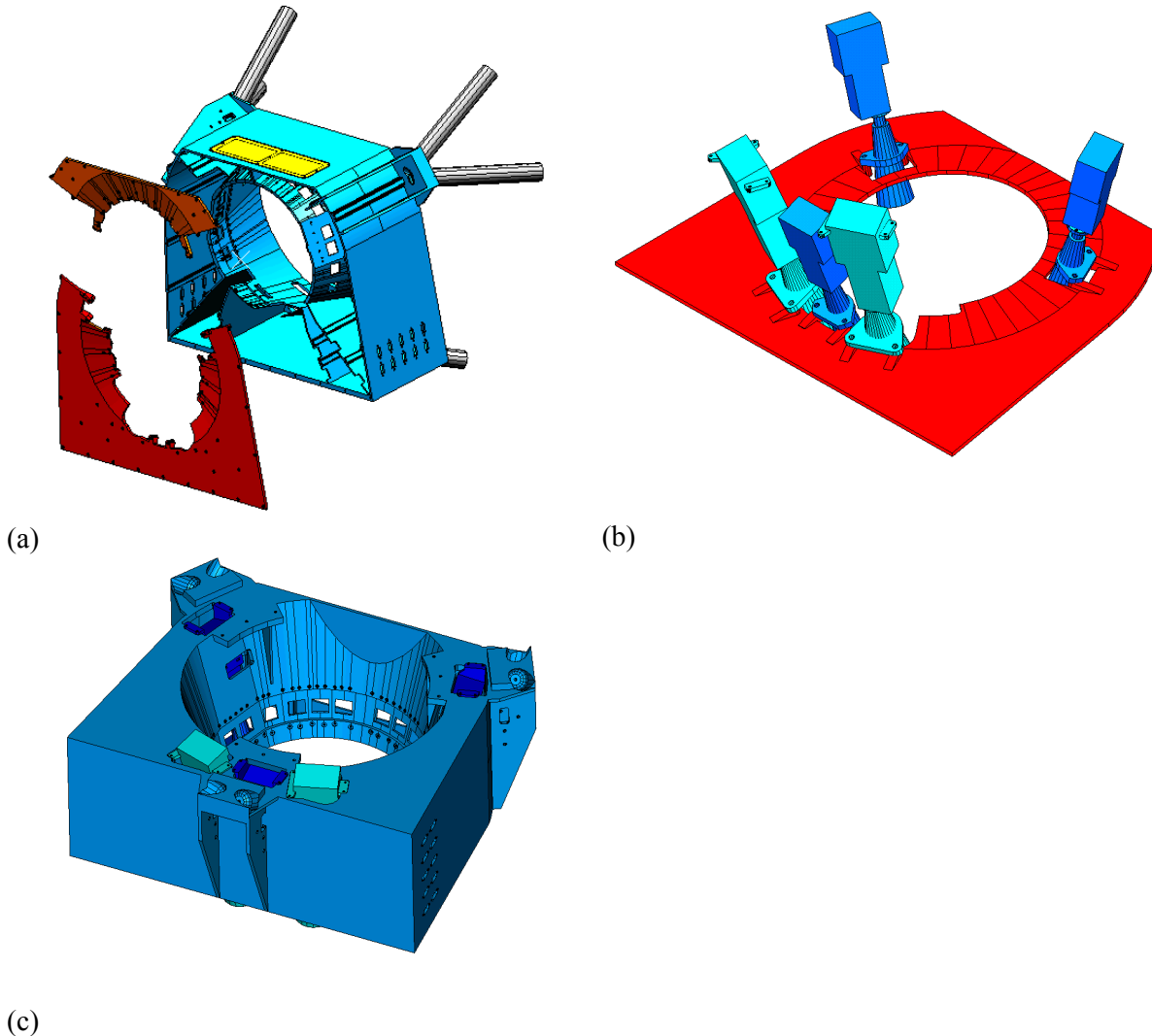


Figure 3-21 Views of the LFI mainframe: (a) mainframe exploded view with bipods; (b) top cover fixation; (c) FEM fixation

3.2.2.1.2 Feed horn disposition in the focal plane

The LFI feed array is arranged in a circle around the HFI front end unit. The geometry of the focal plane is driven by the following factors:

- The distance between the optical axis and the LFI feedhorns is minimised. Priority in this respect has been given to the highest frequencies (70 GHz), for which the effective angular resolution is most critical for the scientific objective;
- The Front Ends are oriented in such a way that the linear polarisation directions are evenly sampled by subsets of detectors at each frequency channel.



- c) The mounting of the Front Ends has to meet mechanical constraints due to the interface with the HFI and with the telescope structure;
- d) The location of the FEMs has to meet mechanical constraints imposed by the radiometer array assembly integration;
- e) The arrangement of the FEMs in the focal plane exploits as much as possible the optical symmetry of the telescope.

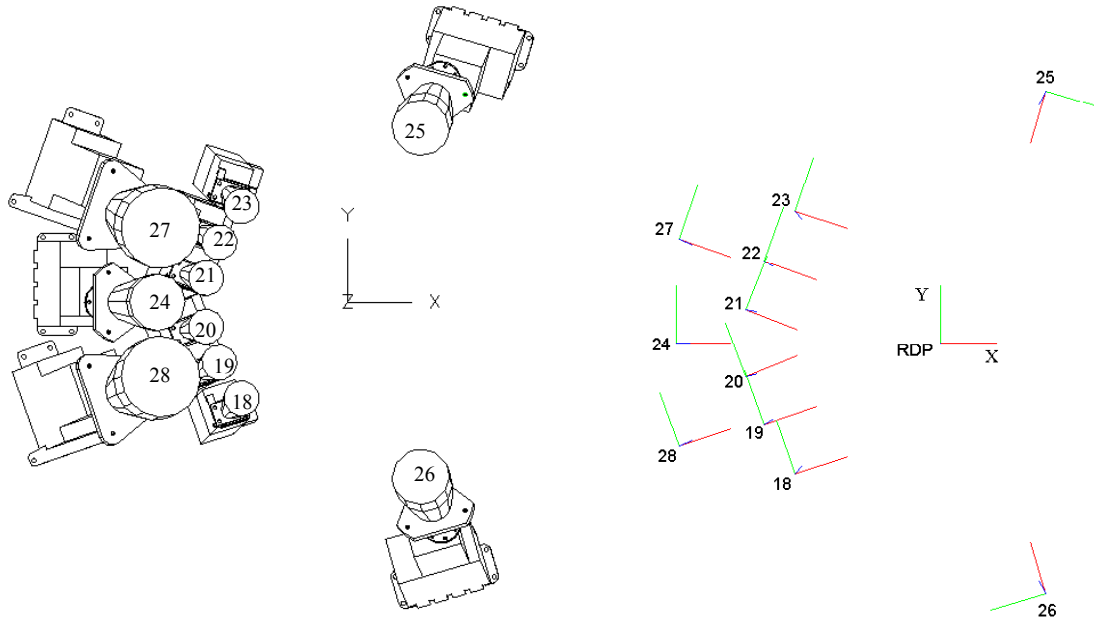


Figure 3-22 Left: top view of the LFI Focal Plane Unit configuration with the adopted numbering. Number 18 to 23: 70 GHz; number 24 to 26: 44 GHz; number 27 and 28: 30 GHz. Right: coordinate systems for the feed horns in the FPU referred to the Reference Detector Plane Coordinate System; the X-, Y-, and Z- axes are in red, green, and blue respectively.

The left panel of Figure 3-8 shows the LFI array of feed-horns in the focal plane. An optimised configuration of orientations has been achieved, with most of the pairs of feedhorns aligned in the direction of the scan (top-to-bottom in Figure 3-8) having their E-planes (H-planes) at 45 degrees from each other, as shown in the right panel of Figure 3-8 and reported in the following table. The alignment of pairs of feeds is not a strong requirement, but it simplifies the analysis.

Table 3.2-10 Alignment of LFI feedhorns

Frequency	Feed Number	Relative angle	Alignment
30 GHz	27 + 28	-45°	Aligned in scan direction
44 GHz	25 + 26	135°	Aligned in scan direction
44 GHz	24	-	Not Matched
70 GHz	18 + 23	-45°	Aligned in scan direction
70 GHz	19 + 22	-45°	Aligned in scan direction
70 GHz	20 + 21	-45°	Aligned in scan direction

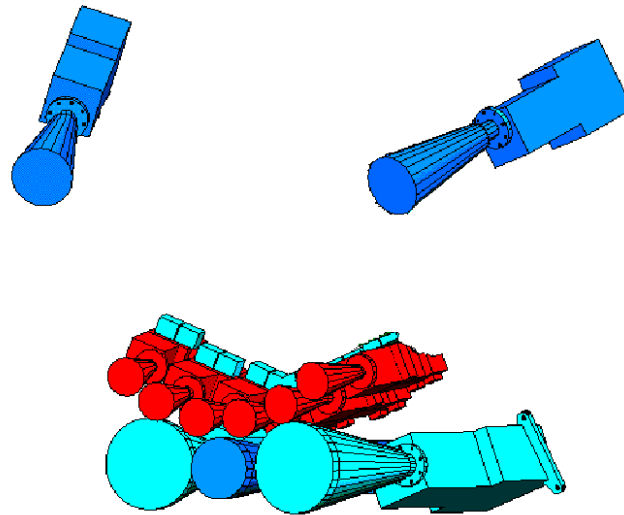


Figure 3-23 3D view of the LFI front-end modules aligned in the focal plane. In the inside the reference loads for the 70 GHz channel are also shown.

3.2.2.1.3 Optical interfaces

The location of the phase centre of each feed horn is placed at the focal surface defined by the Planck telescope (RD-4, Planck Telescope Design Document – PT-DS-07024) and is listed below.

Table 3.2-11 Phase centre location of LFI feed horns in the Focal Plane Unit (in the Reference Detector Plane).

FH #	Location ($X_{RDP}, Y_{RDP}, Z_{RDP}$) [mm, mm, mm]			Orientation (θ, ϕ, ψ) [$^{\circ}, ^{\circ}, ^{\circ}$]		
18	-76.38	-69.37	14.54	11.93	46.04	18.26
19	-92.41	-43.29	18.66	11.63	28.71	19.84
20	-101.86	-17.69	20.86	11.38	11.22	21.29
21	-101.86	17.69	20.86	11.38	-11.22	-21.29
22	-92.41	43.29	18.66	11.63	-28.71	-19.84
23	-76.38	69.37	14.54	11.93	-46.04	-18.26
24	-138.41	0.00	21.29	14.85	0.00	0.00
25	55.32	133.27	-17.90	16.44	-113.42	-106.18
26	55.32	-133.27	-17.90	16.44	113.42	106.18
27	-136.95	54.94	18.60	15.56	-23.01	-19.22
28	-136.95	-54.94	18.60	15.56	23.01	19.22

Extensive testing has been performed to evaluate the tolerance of obscuration of the LFI feeds (or HFI feeds) into other LFI feeds. The results show that no significant effects are present if the feed's



field of view is free within an angle of 45 degrees from the edge of the feed aperture. This confirms simulations performed by the Alcatel PPLM Architecture Study. The LFI focal plane meets this requirement.

3.2.2.2 BEU

The BEU comprises 11 radiometer Back End modules (BEM) and the Data Acquisition Electronics (DAE), which are connected by an external harness. The BEU is connected to the FEU by 44 waveguides, wires for DC biasing of the amplifiers, for switch control signals and temperature telemetry acquisition signals. Each Back End analog output is connected, by cables to an internal front end electronics on which amplification, filtering and digital conversion is performed.

3.2.2.2.1 DAE

The DAE (Data Acquisition Electronics) comprises the control electronics, the communication interface and the power conditioning and distribution electronics.

The DAE mainly consists of two separated parts. One is a set of five independent electronics boxes (Data Acquisition) while the other (DAE Power box) is a single box mainly in charge to supply the electrical power both to DAE and the RCAs.

The DAE is interfaced to all other units of the LFI sub-system (i.e. FEMs, BEMs and REBA -both Science Processing Unit – SPU, & Data Processing Unit - DPU) and to its power supply unit (DAE Power box).

Its main functions are listed below:

- Acquisition of scientific signals (representing the sky and reference load temperatures) from BEMs. The DAE manages 44 channels (4 for each of the 11 BEMs) as shown schematically Figure 3-24 for one channel;
- Filtering, and amplification of these signals;
- Conversion from analogue to digital form;
- Time marking and converted data temporary storage;
- Synchronisation between science data acquisition chains and the phase switches housed in the FEMs;
- Biases generation for FEMs amplifiers and DC power filtering for the BEMs;
- On Board Time management;
- HK data/Commands exchange with REBA;
- Analogue HK acquisition and A/D conversion;
- Control the DC/DC Converters housed in the DAE Power Box and distribute/route the secondary power lines to DAE's boxes.

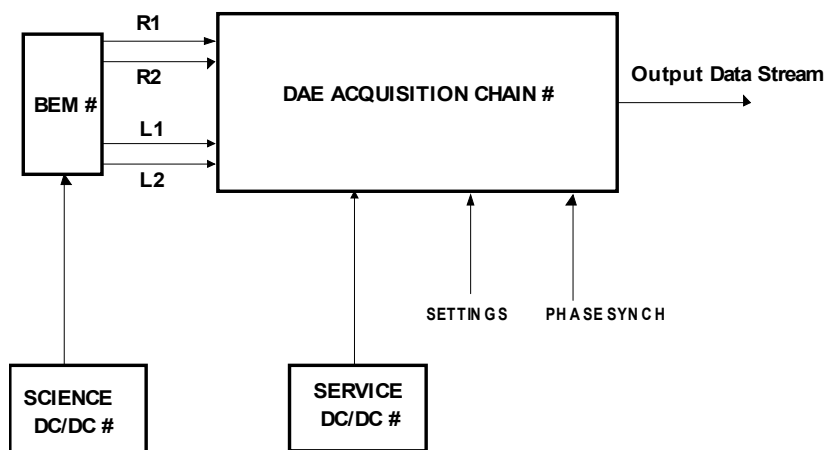


Figure 3-24 One channel BEM-DAE I/F

A view of the DAE is given in Figure 3-25 that shows, from left to right, the Left FEM Bias, the Left BEM Support Tray (the one with “grid panel” on the top), the DAE-BEU (the box in the middle), the Right BEM support Tray and the Right FEM Bias Tray.

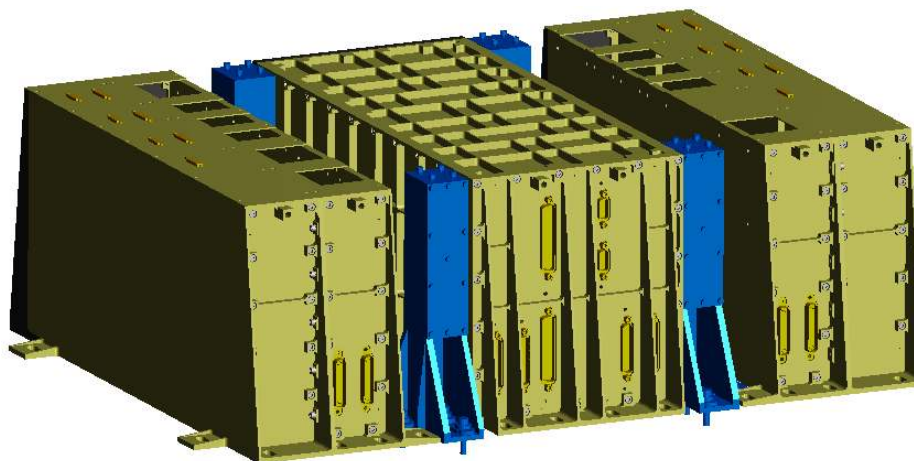


Figure 3-25 Solid View of the DAE, including also Wave guides lower support structure feet

3.2.3 REBA

The REBA is the electronic box in charge of processing the digitized scientific data and to manage the overall instrument.

It is also in charge of the communication with the spacecraft.

Figure 3-26 shows two different views of the REBA box.

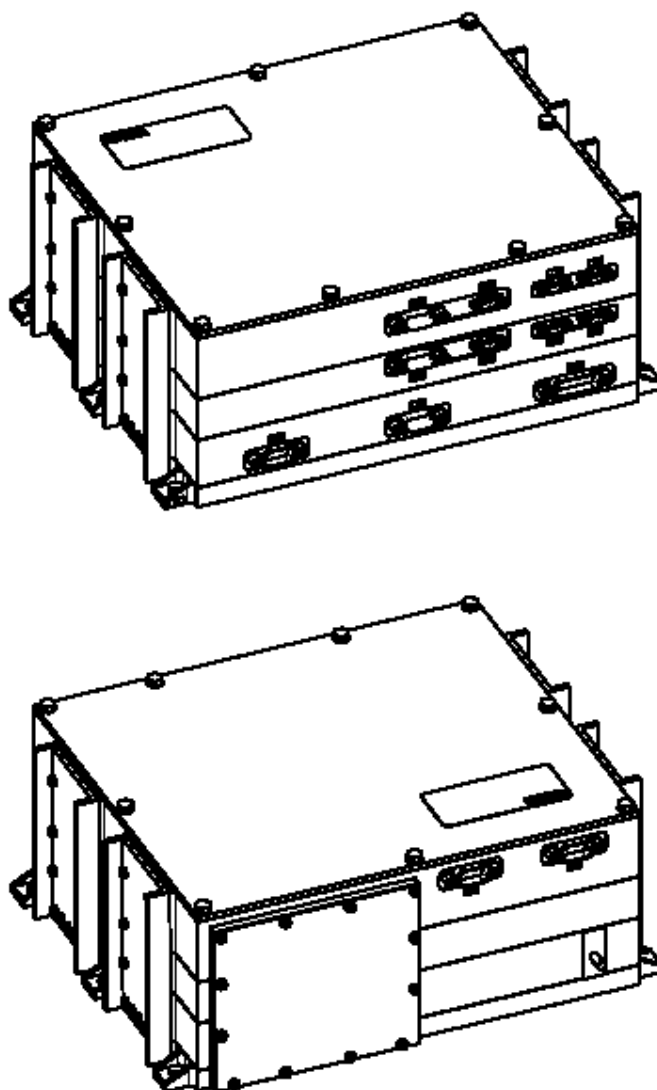


Figure 3-26 REBA aspect. View on the two different sides

3.2.3.1 REBA HARDWARE

There are two REBA boxes, one nominal and one redundant. The redundancy concept is cold, which means that both boxes are never ON at the same time; the operation of each unit shall be managed by the spacecraft switching-on the corresponding unit. The REBA_ASW is the same in each REBA box, so no software function is needed to distinguish one to the other REBA box.

Figure 3-27 reports the interface functional diagram for the complete LFI including the redundant REBA.

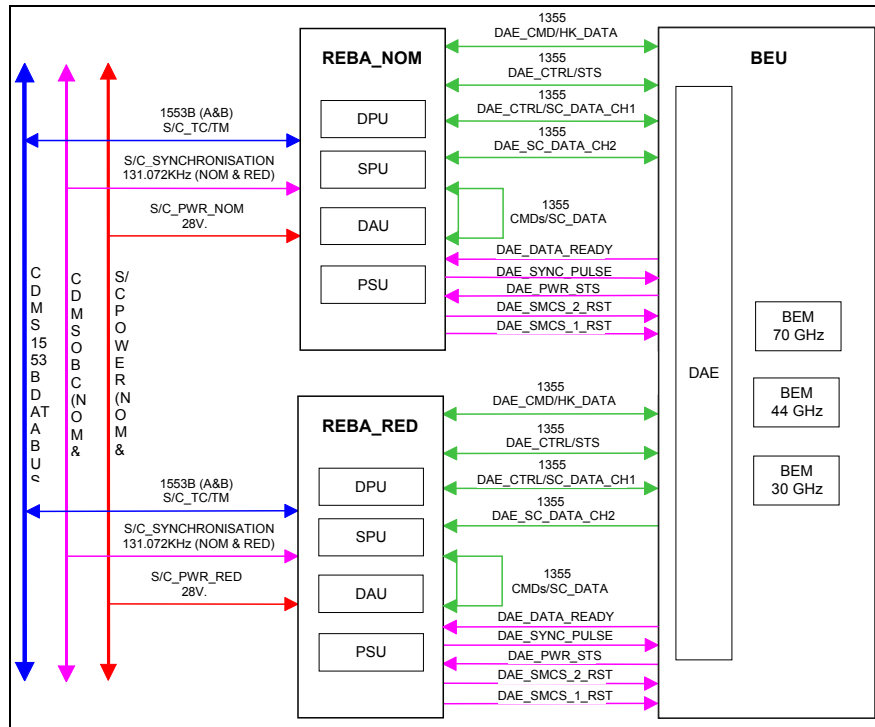


Figure 3-27 Interface Functional Diagram of the REBA, nominal and redundant

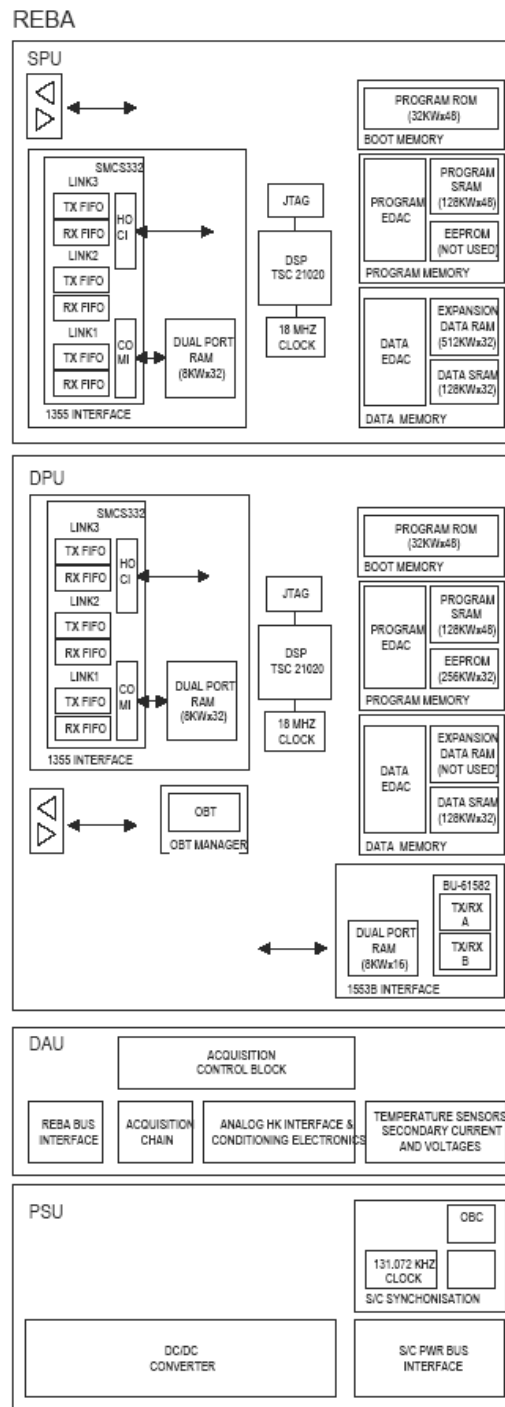


Figure 3-28 Functional block diagram of REBA

Each REBA consists of the following subunits:



- the Power Supply Unit (PSU) which feeds the REBA unit. It consists of a DC/DC converter that converts the primary power received from the spacecraft PDU to the secondary regulated voltages required only by the REBA and provides galvanic isolation towards the spacecraft side of the interface. The PSU DC/DC converter also receives the On-Board Clock (OBC) from the CDMS that is used to increment the internal On Board Time register. There is no software interface with the REBA_ASW.
- the Data Acquisition Unit (DAU) performs the analogue to digital conversion of the analogue housekeeping data of the REBA itself (temperatures and voltages). The REBA_ASW collects from the DAU the HK data.
- the Signal Processing Unit (SPU) is a computing subunit (see details in next paragraphs) and implements part of the REBA_ASW, the SPU_ASW. It receives the science data from the DAE through a IEEE 1355 link implemented in a SMCS chip. A second IEEE 1355 link is used to control by link the remote DAE SMCS chip. The third IEEE 1355 link communicates with the DPU. The SPU is in charge of the reduction and compression of the science data.
- the Digital Processing Unit (DPU) is a computing subunit (see details in next paragraphs) and implements part of the REBA_ASW, the DPU_ASW. It contains another SMCS chip with 3 IEEE 1355 links that communicate with the SPU, and the DAE. A MIL-STD 1553B link is used to communicate with the CDMS. The DPU is in charge of the control and monitoring of the instrument as well as the communication with the spacecraft (CDMS).

The functional block diagram of Figure 3.1-22 shows the different parts of one section of REBA.

3.2.3.1.1 SPU Hardware

The SPU hardware of LFI consists of one CPU, which main characteristics are:

- TSC21020E processor based architecture running up to 18 MHz.
- PROM Memory for Bootstrap Program Storage. (32 KW x 48 bits) (192 KB)
- SRAM Memory for Program Storage up to 512 KW x 48 bits (3 MB), protected by EDAC.
- SRAM Memory for Data Storage up to 512 KW x 32 bits (2 MB), protected by EDAC.
- Expansion Bus of 32 bit mapped at the Data Memory Bus address space. An SRAM Memory Data Expansion Module with 512KW x 32 bits (2 MB), protected by EDAC, are connected to the CPU.
- Three IEEE-1355 DS High Speed Serial Communication links, implemented by the SMCS332 chip and including an 8Kx32 bits (32 KB) Dual Port Ram buffer.
- Programmable Watchdog Timer

Two of the IEEE-1355 links are used by the SPU_ASW to communicate with the DAE (scientific data) and to control by link the DAE SMCS chip; the third one communicates with the DPU (commands and TM).

A “Data Ready” electrical signal is connected between DAE and the SPU, this signal produces an interruption in the SPU when the DAE is ready to transfer data.

The SPU_ASW is stored in the EEPROM located in the DPU board (see later description). It shall be transferred to the SPU by the DPU_ASW.

3.2.3.1.2 DPU Hardware

The DPU hardware of LFI consists of one CPU, whose main characteristics are:



- TSC21020E processor based architecture running up to 18 MHz.
- PROM Memory for Bootstrap Program Storage. (32 KW x 48 bits) (192KB)
- SRAM Memory for Program Storage up to 512 KW x 48 bits (3 MB), protected by EDAC
- SRAM Memory for Data Storage up to 512 KW x 32 bits (2 MB), protected by EDAC
- Three IEEE-1355 DS High Speed Serial Communication links, implemented by the SMCS332 chip and including an 8Kx32 bits (32 KB) Dual Port Ram buffer.
- One MIL-STD-1553B Data Bus Interface (redundant A+B) including a 8Kx16 bits (16KB) Dual Port Ram Buffer.
- Programmable Watchdog Timer
- One S/C OBT interface (131.072 KHz clock signal).
- One Back End Unit Timing interface (1 Hz signal).
- An EEPROM (1.5 MB), protected by EDAC, for on-board storage of the SPU_ASW and DPU_ASW.

One IEEE 1355 link is used by the DPU_ASW to communicate with the DAE to control by link the SMCS chip of DAE. The second one is used to communicate with the DAE to transfer commands and HK and the third one is used by DPU_ASW to communicate with the SPU (commands and TM)

Two Reset electrical lines are provided by the DPU to reset each of the two SMCS chips of DAE. The DPU_ASW is stored in the EEPROM.

3.3 OPERATING PRINCIPLES

The operations of the LFI are designed to be automatic and require little if any intervention from the ground. A small amount of commands is required for operating the instrument and eventually for diagnostic and reconfiguration purposes.

Each sky survey is conducted by the LFI with the instrument in the Normal Operations Mode mode. No deployable elements, or mechanically moving parts are included in the instrument. The scanning of the sky is achieved by progressive repointing of the satellite spin axis, with the Sun direction always within a cone 10 degrees from the spin axis.

Within the Normal Science Mode the instrument can be configured in order to fit with different science or diagnostic needs without changing the power consumption and thus the temperature in the FPU. Changes in power consumption in the FPU are minimised and should occur only in the case that failures in the radiometers that could create interference problems require an RCA to be switched off. Power adjustments on the first stage of the HEMT amplifiers which are contemplated, require extremely small power level variations.

The modes of operation of LFI are given in Figure 3-29.

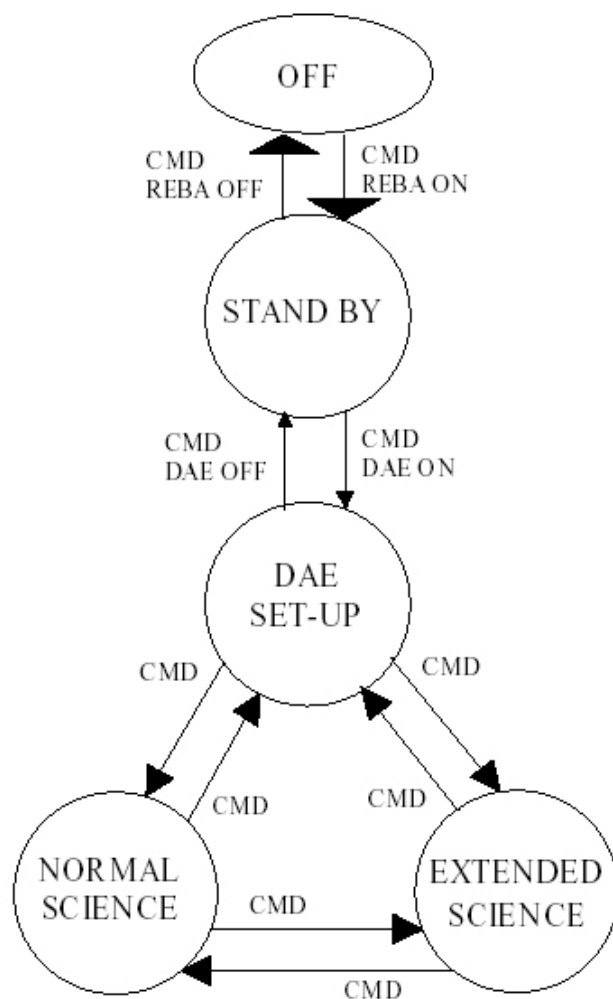


Figure 3-29 LFI Operating Modes and their nominal transitions

The Normal Science Mode is the normal mode of operation of the LFI with the REBA on, DAE and FEM's and BEM's on and the instrument producing scientific and housekeeping data. It should be noted that in this mode single FEM/BEM combinations can be configured separately or in groups not requiring a transition back to DAE Set-Up Mode for configuration changes. This allows continued scientific data acquisition while radiometer calibration adjustments are made in parallel.

Diagnostic activity is necessary on a limited number of radiometers while the instrument is performing the sky survey in its Normal Science Mode without stopping the sky survey with the majority of the radiometers.



3.4 DEPENDENCIES ON OTHER INSTRUMENTS

For the nominal functioning of LFI, it is required that the Sorption Cooler provides the necessary cooling capability to keep the focal plane at a temperature of about 20 K.

In addition HFI provides a stable 4 K environment used by the LFI 4 K loads.



4 INSTRUMENT CONFIGURATION

Scope of this chapter is to identify the configuration of the instrument. The LFI Configuration Item Data Lists (CIDLs) included in this paragraph refer to the products shown in the LFI Product Tree given in Figure 3.4-1, but limited to the Low Frequency Instrument (green boxes).

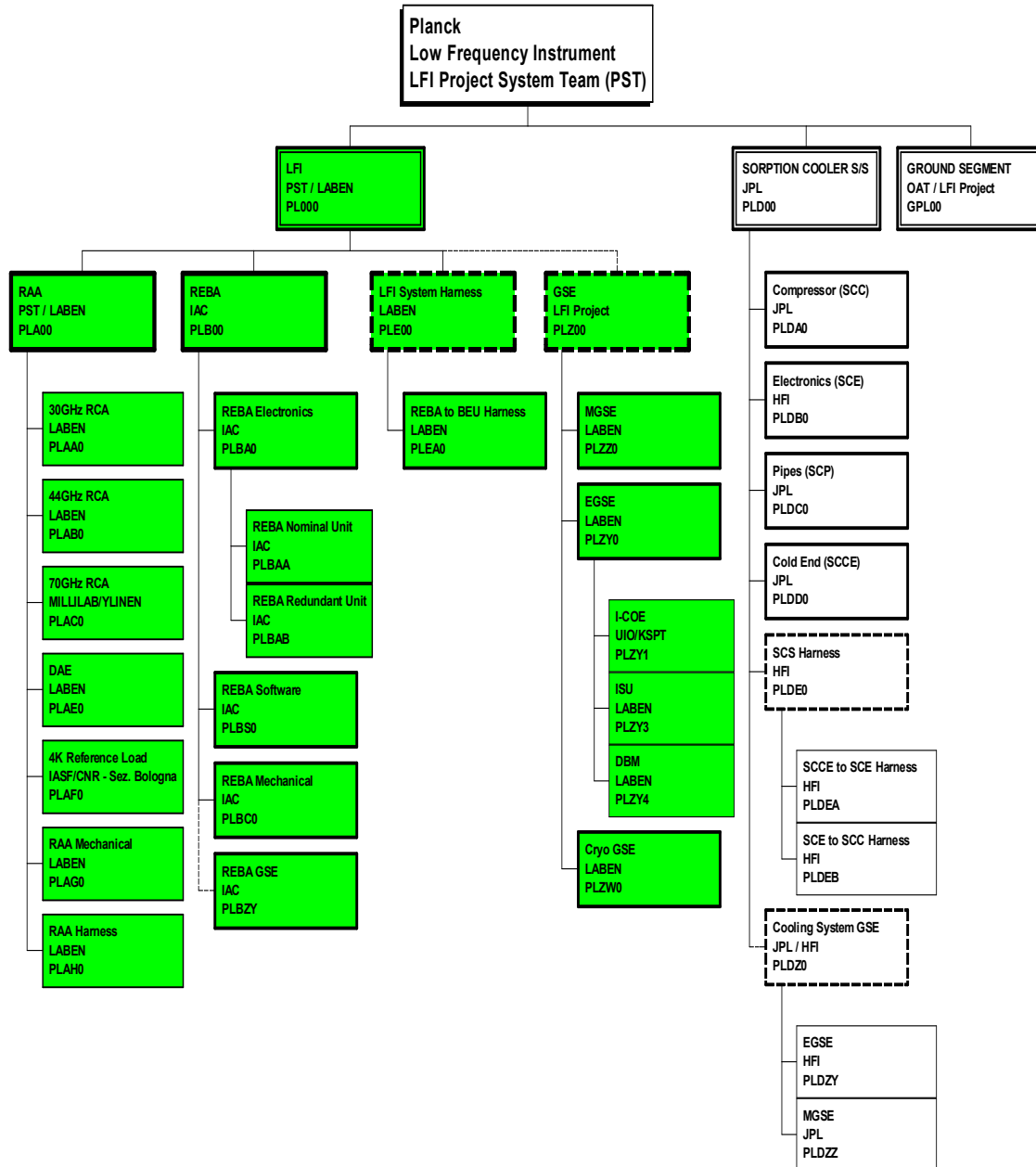


Figure 4-1 – LFI HIGH LEVEL PRODUCT TREE



The contents of the CIDL versus the LFI Product Tree (given above and in [RD22]) and the HW and SW Tree for the LFI Insgrument are explained in the following sections.

4.1 LFI DETAILED HW PRODUCT TREE

SUPPLIER	MODEL	LEVEL	LFI PROJECT REFERENCE CODE (P/N)	TITLE/DESCRIPTION	Qty xREMARKS Assy
LFI PST	FM	0	PL000-P	LOW FREQUENCY INSTRUMENT	1
LFI PST	FM	*1	PLA00-P	RADIOMETER ARRAY ASSEMBLY	1
LABEN	FM	**2	PLAA0/01-P	30GHz RADIOMETER CHAIN ASS.Y (RCA)	1 FPU Ref.: #27
LABEN	FM	***3	PLAAA-P	30GHz FEED HORN	1
LABEN	FM	***3	PLAAB-P	30GHz OMT	1
JBO	FM	***3	PLAAC-P	30GHz FRONT END MODULE (FEM)	1
SAN	FM	***3	PLAAD-P	30GHz BACK END MODULE (BEM)	1
LABEN	FM	***3	PLAAE/A-P	30GHz WAVE-GUIDE ASSEMBLY	1
LABEN	FM	****4	PLAAE/AC-P	30GHz COPPER WG SUB-ASS.Y	1 N. 4 Copper WGs per ass.y
LABEN	FM	****4	PLAAE/AS-P	30GHz SS WG SUB-ASS.Y	1 N. 4 SS WGs per ass.y
LABEN	FM	**2	PLAA0/02-P	30GHz RADIOMETER CHAIN ASS.Y (RCA)	1 FPU Ref.: #28
LABEN	FM	***3	PLAAA-P	30GHz FEED HORN	1
LABEN	FM	***3	PLAAB-P	30GHz OMT	1
JBO	FM	***3	PLAAC-P	30GHz FRONT END MODULE (FEM)	1
SAN	FM	***3	PLAAD-P	30GHz BACK END MODULE (BEM)	1
LABEN	FM	***3	PLAAE/B-P	30GHz WAVE-GUIDE ASSEMBLY	1
LABEN	FM	****4	PLAAE/BC-P	30GHz COPPER WG SUB-ASS.Y	1 N. 4 Copper WGs per ass.y
LABEN	FM	****4	PLAAE/AS-P	30GHz SS WG SUB-ASS.Y	1 N. 4 SS WGs per ass.y
LABEN	FM	**2	PLAB0/01-P	44GHz RADIOMETER CHAIN ASS.Y (RCA)	1 FPU Ref.: #24
LABEN	FM	***3	PLABA/01-P	44GHz FEED HORN	1
LABEN	FM	***3	PLABB-P	44GHz OMT	1
JBO	FM	***3	PLABC-P	44GHz FRONT END MODULE (FEM)	1
SAN	FM	***3	PLABD-P	44GHz BACK END MODULE (BEM)	1
LABEN	FM	***3	PLABE/A-P	44GHz WAVE-GUIDE ASSEMBLY	1
LABEN	FM	****4	PLAAE/AC-P	44GHz COPPER WG SUB-ASS.Y	1 N. 4 Copper WGs per ass.y
LABEN	FM	****4	PLAAE/AS-P	44GHz SS WG SUB-ASS.Y	1 N. 4 SS WGs per ass.y
LABEN	FM	**2	PLAB0/02-P	44GHz RADIOMETER CHAIN ASS.Y (RCA)	1 FPU Ref.: #25
LABEN	FM	***3	PLABA/02-P	44GHz FEED HORN	1
LABEN	FM	***3	PLABB-P	44GHz OMT	1
JBO	FM	***3	PLABC-P	44GHz FRONT END MODULE (FEM)	1
SAN	FM	***3	PLABD-P	44GHz BACK END MODULE (BEM)	1
LABEN	FM	***3	PLABE/B-P	44GHz WAVE-GUIDE ASSEMBLY	1
LABEN	FM	****4	PLABE/BC-P	44GHz COPPER WG SUB-ASS.Y	1 N. 4 Copper WGs per ass.y
LABEN	FM	****4	PLABE/AS-P	44GHz SS WG SUB-ASS.Y	1 N. 4 SS WGs per ass.y
LABEN	FM	**2	PLAB0/03-P	44GHz RADIOMETER CHAIN ASS.Y (RCA)	1 FPU Ref.: #26
LABEN	FM	***3	PLABA/02-P	44GHz FEED HORN	1
LABEN	FM	***3	PLABB-P	44GHz OMT	1
JBO	FM	***3	PLABC-P	44GHz FRONT END MODULE (FEM)	1
SAN	FM	***3	PLABD-P	44GHz BACK END MODULE (BEM)	1
LABEN	FM	***3	PLABE/C-P	44GHz WAVE-GUIDE ASSEMBLY	1
LABEN	FM	****4	PLABE/CC-P	44GHz COPPER WG SUB-ASS.Y	1 N. 4 Copper WGs per ass.y



LABEN	FM	****4	PLABE/AS-P	44GHz SS WG SUB-ASS.Y	1	N. 4 SS WGs per ass.y
LABEN	GSE	***3	PLAAZ	30/44GHz RCA Cryo-GSE	1	NOT DELIVERABLE
MIL/YLIN	FM	**2	PLAC0/01-P	70GHz RADIOMETER CHAIN ASS.Y (RCA)	1	FPU Ref.: #18
LABEN	FM	***3	PLACA/01-P	70GHz FEED HORN	1	
LABEN	FM	***3	PLACB-P	70GHz OMT	1	
MIL/YLIN	FM	***3	PLACC-P	70GHz FRONT END MODULE (FEM)	1	
MIL/YLIN	FM	***3	PLACD-P	70GHz BACK END MODULE (BEM)	1	
LABEN	FM	***3	PLACE/A-P	70GHz WAVE-GUIDE ASSEMBLY	1	
LABEN	FM	****4	PLACE/AC-P	70GHz COPPER WG SUB-ASS.Y	1	N. 4 Copper WGs per ass.y
LABEN	FM	****4	PLACE/AS-P	70GHz SS WG SUB-ASS.Y	1	N. 4 SS WGs per ass.y
MIL/YLIN	FM	**2	PLAC0/02-P	70GHz RADIOMETER CHAIN ASS.Y (RCA)	1	FPU Ref.: #19
LABEN	FM	***3	PLACA/02-P	70GHz FEED HORN	1	
LABEN	FM	***3	PLACB-P	70GHz OMT	1	
MIL/YLIN	FM	***3	PLACC-P	70GHz FRONT END MODULE (FEM)	1	
MIL/YLIN	FM	***3	PLACD-P	70GHz BACK END MODULE (BEM)	1	
LABEN	FM	***3	PLACE/B-P	70GHz WAVE-GUIDE ASSEMBLY	1	
LABEN	FM	****4	PLACE/BC-P	70GHz COPPER WG SUB-ASS.Y	1	N. 4 Copper WGs per ass.y
LABEN	FM	****4	PLACE/AS-P	70GHz SS WG SUB-ASS.Y	1	N. 4 SS WGs per ass.y
MIL/YLIN	FM	**2	PLAC0/03-P	70GHz RADIOMETER CHAIN ASS.Y (RCA)	1	FPU Ref.: #20
LABEN	FM	***3	PLACA/03-P	70GHz FEED HORN	1	
LABEN	FM	***3	PLACB-P	70GHz OMT	1	
MIL/YLIN	FM	***3	PLACC-P	70GHz FRONT END MODULE (FEM)	1	
MIL/YLIN	FM	***3	PLACD-P	70GHz BACK END MODULE (BEM)	1	
LABEN	FM	***3	PLACE/C-P	70GHz WAVE-GUIDE ASSEMBLY	1	
LABEN	FM	****4	PLACE/CC-P	70GHz COPPER WG SUB-ASS.Y	1	N. 4 Copper WGs per ass.y
LABEN	FM	****4	PLACE/AS-P	70GHz SS WG SUB-ASS.Y	1	N. 4 SS WGs per ass.y
MIL/YLIN	FM	**2	PLAC0/04-P	70GHz RADIOMETER CHAIN ASS.Y (RCA)	1	FPU Ref.: #21
LABEN	FM	***3	PLACA/03-P	70GHz FEED HORN	1	
LABEN	FM	***3	PLACB-P	70GHz OMT	1	
MIL/YLIN	FM	***3	PLACC-P	70GHz FRONT END MODULE (FEM)	1	
MIL/YLIN	FM	***3	PLACD-P	70GHz BACK END MODULE (BEM)	1	
LABEN	FM	***3	PLACE/D-P	70GHz WAVE-GUIDE ASSEMBLY	1	
LABEN	FM	****4	PLACE/DC-P	70GHz COPPER WG SUB-ASS.Y	1	N. 4 Copper WGs per ass.y
LABEN	FM	****4	PLACE/AS-P	70GHz SS WG SUB-ASS.Y	1	N. 4 SS WGs per ass.y
MIL/YLIN	FM	**2	PLAC0/05-P	70GHz RADIOMETER CHAIN ASS.Y (RCA)	1	FPU Ref.: #22
LABEN	FM	***3	PLACA/02-P	70GHz FEED HORN	1	
LABEN	FM	***3	PLACB-P	70GHz OMT	1	
MIL/YLIN	FM	***3	PLACC-P	70GHz FRONT END MODULE (FEM)	1	
MIL/YLIN	FM	***3	PLACD-P	70GHz BACK END MODULE (BEM)	1	
LABEN	FM	***3	PLACE/E-P	70GHz WAVE-GUIDE ASSEMBLY	1	
LABEN	FM	****4	PLACE/EC-P	70GHz COPPER WG SUB-ASS.Y	1	N. 4 Copper WGs per ass.y
LABEN	FM	****4	PLACE/AS-P	70GHz SS WG SUB-ASS.Y	1	N. 4 SS WGs per ass.y
MIL/YLIN	FM	**2	PLAC0/06-P	70GHz RADIOMETER CHAIN ASS.Y (RCA)	1	FPU Ref.: #23
LABEN	FM	***3	PLACA/01-P	70GHz FEED HORN	1	
LABEN	FM	***3	PLACB-P	70GHz OMT	1	
MIL/YLIN	FM	***3	PLACC-P	70GHz FRONT END MODULE (FEM)	1	
MIL/YLIN	FM	***3	PLACD-P	70GHz BACK END MODULE (BEM)	1	
LABEN	FM	***3	PLACE/F-P	70GHz WAVE-GUIDE ASSEMBLY	1	
LABEN	FM	****4	PLACE/FC-P	70GHz COPPER WG SUB-ASS.Y	1	N. 4 Copper WGs per ass.y



LABEN	FM	****4	PLACE/AS-P	70GHz SS WG SUB-ASS.Y	1	N. 4 SS WGs per ass.y
MIL/YLIN	GSE	***3	PLACZ	70GHz RCA Cryo-GSE	1	NOT DELIVERABLE
LABEN	FM	**2	PLAE0-P	DATA ACQUISITION ELECTRONICS	1	
LABEN	FM	***3	PLAEA-P	DAE BEU BOX	1	
LABEN	FM	***3	PLAEB-P	DAE LEFT BEM SUPPORT TRAY BOX	1	
LABEN	FM	***3	PLAEC-P	DAE RIGHT BEM SUPPORT TRAY BOX	1	
LABEN	FM	***3	PLAED-P	DAE LEFT FEM BIAS TRAY BOX	1	
LABEN	FM	***3	PLAEE-P	DAE RIGHT FEM BIAS TRAY BOX	1	
LABEN	FM	***3	PLAEF-P	DAE POWER BOX	1	
LABEN	GSE	***3	PLAEZ	DAE TEST EQUIPMENT	1	
IASF-BO	FM	**2	PLAF0-P	4K REFERENCE LOAD	1	
IASF-BO	FM	***3	PLAFA-P	UPPER SECTOR SUB-ASSEMBLY	1	
IASF-BO	FM	****4	PLAFA/A-P	U.S. MOUNTING STRUCTURE	1	
IASF-BO	FM	****4	PLAFA/B-P	70GHz REFERENCE TARGETS	12	
IASF-BO	FM	***3	PLAFB-P	LOWER SECTOR SUB-ASSEMBLY	1	
IASF-BO	FM	****4	PLAFB/A-P	L.S. MOUNTING STRUCTURE	1	
IASF-BO	FM	****4	PLAFB/B-P	30/44GHz REFERENCE TARGETS	10	
IASF-BO	FM	****4	PLAFB/C-P	30/44GHz REFERENCE HORNS	10	
IASF-BO	FM	***3	PLAFC-P	DUMMY for HFI	1	
IASF-BO	FM	****4	PLAFC/A-P	U.S. DUMMY LOAD for HFI	1	
IASF-BO	FM	****4	PLAFC/B-P	L.S. DUMMY LOAD for HFI	1	
IASF-BO	GSE	***3	PLAFZ/A	4K REFERENCE LOAD Cryo-GSE	1	NOT DELIVERABLE
IASF-BO	GSE	***3	PLAFZ/B	4K REFERENCE LOAD Radiometric GSE	1	NOT DELIVERABLE
IASF-BO	GSE	***3	PLAFZ/C	4K LOAD / HFI DUMMY I/F MGSE	1	NOT DELIVERABLE
LABEN	FM	**2	PLAG0-C	RAA MECHANICAL	1	
LABEN	FM	***3	PLAGA-P	FEU MAIN FRAME	1	
LABEN	FM	***3	PLAGB-P	FEU BIPODES	1	
LABEN	FM	***3	PLAGC-P	WG SUPPORT UPPER	1	
LABEN	FM	****4	PLAGC/A-P	RIGHT PANEL ASSEMBLY	1	
LABEN	FM	****4	PLAGC/B-P	LEFT PANEL ASSEMBLY	1	
LABEN	FM	****4	PLAGC/C-P	STRUT ASSY MID 1	1	
LABEN	FM	****4	PLAGC/D-P	STRUT ASSY MID 2	1	
LABEN	FM	****4	PLAGC/E-P	STRUT ASSY MID 3	1	
LABEN	FM	****4	PLAGC/F-P	STRUT ASSY MID 4	1	
LABEN	FM	****4	PLAGC/G-P	STRUT ASSY MID 4	1	
LABEN	FM	****4	PLAGC/H-P	EXTERNAL STRUT ASSEMBLY RIGHT	1	
LABEN	FM	****4	PLAGC/I-P	EXTERNAL STRUT ASSEMBLY LEFT	1	
LABEN	FM	***3	PLAGD-P	WG SUPPORT LOWER	1	
LABEN	FM	****4	PLSGD/A-P	MOUNTING FEET	1	
LABEN	FM	****4	PLSGD/B-P	PANELS	1	
LABEN	FM	****4	PLSGD/C-P	FRAME	1	
LABEN	FM	****4	PLSGD/D-P	STRUCTURE TUBES	1	
LABEN	FM	**2	PLAH0-P	RAA HARNESS	1	
LABEN	FM	***3	PLAHA-P	DAE S/S INTERNAL HARNESS	1	
LABEN	FM	****4	PLAHA/A-P	POWER BOX to BEU HARNESS	1	
LABEN	FM	*****5	PLAHA/AA-P	POWER BOX to DAE-BEU HARN.	2	
LABEN	FM	*****5	PLAHA/AB-P	POWER BOX to LATERAL TRAYS HARN.	2	
LABEN	FM	****4	PLAHA/B-P	DAE-BEU to LATERAL TRAYS HARN.	1	
LABEN	FM	*****5	PLAHA/BA-P	DAE BEU BOX to Lx/Rx BEM TRAY HARNESS	4	



LABEN	FM	*****5	PLAHA/BB-P	DAE BEU BOX to Lx/Rx FEM TRAY HARNESS	4	
LABEN	FM	***3	PLAHB-P	DAE FEMs CRYO HARNESS	1	
LABEN	FM	****4	PLAHB/A-P	FEM BIAS CABLE	6	
LABEN	FM	****4	PLAHB/B-P	PHASE SWITCH CABLE	6	
LABEN	FM	****4	PLAHB/C-P	TEMPERATURE SENSORS CABLE	2	
LABEN	QM	***3	PLAHC-P	FEU INTERNAL HARNESS	1	
IAC	FM	*1	PLB00-P	REBA	1	
IAC	FM	**2	PLBAA-P	REBA NOMINAL UNIT	1	
IAC	SW	**2	PLBS0	REBA SOFTWARE	1	
IAC	FM	**2	PLBC0-P	REBA MECHANICAL and HARNESS	1	
IAC	GSE	**2	PLBZY	REBA EGSE	1	NOT DELIVERABLE
LABEN	FM	*1	PLEA0-P	LFI SYSTEM HARNESS (REBA to BEU)	1	
LABEN	GSE	*1	PLZZ0	LFI MGSE	1	
LABEN	GSE	*1	PLZY0	LFI EGSE	1	
UIO/KSPT	GSE	**2	PLZY1	I-COE	1	
LABEN	GSE	**2	PLZY3	ISU	1	
LABEN	GSE	**2	PLZY4	DBM	1	
LABEN	GSE	*1	PLZW0	LFI CRYO-GSE	1	NOT DELIVERABLE

4.2 LFI DETAILED SW PRODUCT TREE

See paragraph 10, Figure 10-1.



5 INSTRUMENT FUNCTIONS

The LFI Instrument functions can be divided in three categories:

1. Nominal activities: all the functions the instrument is supposed to perform during nominal operations (i.e. TLM/TLC operation of the SW, synchronisation, processing of science data);
2. Nominal ancillary functions: all the additional functions the instrument is supposed to perform in support of the nominal operations;
3. Non nominal ancillary functions: all the additional functions of the instrument not included in the previous two categories. This will be used during non nominal operations (commissioning, CPV and contingency).

A complete list of the functions for each categories is the following.

1. Nominal activities
 - 1.1. Go to SUSW
 - 1.2. DPU ASW startup
 - 1.3. SPU ASW startup
 - 1.4. REBA synchronisation and verification
 - 1.5. DAE switch on connection and HK retrieval
 - 1.6. DAE synchronisation and verification
 - 1.7. Event packets enabling
 - 1.8. RCA default switch on
 - 1.9. REBA science processing configuration
 - 1.10. Science production
 - 1.11. Start calibration channel switching
 - 1.12. Start monitoring
2. Nominal ancillary functions
 - 2.1. Memory management
 - 2.1.1. Go to SUSW
 - 2.1.2. patch and dump activity
 - 2.1.3. Go to DAE setup
 - 2.1.4. Memory scrub
 - 2.2. RCA parameters exercising
 - 2.2.1. Go to DAE setup with RCA on
 - 2.2.2. Change RCA parameters
 - 2.3. Science processing modes
 - 2.3.1. Start LFI nominally up to science
 - 2.3.2. Go to extended science mode
 - 2.3.3. Change to processing type 0 for 1 channel in sub-mode A nothing on B
 - 2.3.4. Change to processing type 4 for 1 channel in sub-mode B nothing on A
 - 2.3.5. Change to all channels processing type 3 in sub-mode A and type 6 in sub-mode B
 - 2.3.6. Change to processing type 1 for all channels in sub-mode B nothing on A



- 2.3.7. Change to all channels processing type 5 in sub-mode A, and type 2 in sub-mode B
- 2.4. Fall back
- 3. Non nominal ancillary functions
 - 3.1. Non nominal synchronisation
 - 3.1.1. Go to SUSW
 - 3.1.2. DPU ASW Startup
 - 3.1.3. REBA Autosynchronisation
 - 3.2. Memories commissioning
 - 3.2.1. Go to standby with the ASW running
 - 3.2.2. Commissioning of REBA memories
 - 3.2.3. Startup RAA, connection and HK retrieval
 - 3.2.4. Connect SPU to DAE
 - 3.2.5. Commissioning of DAE memories
 - 3.3. Exercise Events and Autonomous functions
 - 3.3.1. Go to Nominal Science
 - 3.3.2. Enabling of Event TM
 - 3.3.3. Start monitoring
 - 3.3.4. Exercise Autonomous function
 - 3.3.5. Exercising Event TM
 - 3.4. Exercise the different blanking time
 - 3.5. Diagnostic and reset
 - 3.5.1. Go to Nominal science
 - 3.5.2. Exercise diagnostic TM
 - 3.5.3. Low level reset (SA28R)

See chapter 13 for the complete procedures.



6 INSTRUMENT INTERFACES

6.1 EXTERNAL INTERFACES

6.1.1 IDENTIFICATION AND LABELLING

Each individual instrument unit is allocated two unique identification codes:

- a project, WBS driven, code which is the normal reference used for routine identification in correspondence and technical descriptive material (see RD9).

The whole LFI instrument is functionally split into five sub-systems labelled as in the following table:

Project Code	S/S Name & Acronym
PLRAA	Radiometer Array Assembly (RAA)
PLSCS	Sorption Cooler Subsystem (SCS) (shared with HFI - see ICD, Annex 4)
PLREB	Radiometer Electronics Box Assembly (REBA)
PLIH	Harness

The elements of these subsystems are “units” and are defined below with their WBS Code and a project code.

The project codes allocated to the LFI units are:

Project Code	WBS Code	
PLFEU	== (*)	FRONT END UNIT (FEU)
		PLAGA Front End Structure
		PLAGA/A – Main Frame PLAGA/B – Bipodes
		PLAHB DAE-FEMs Cryo-Harness
		PLAHC FEU Internal Harness
		PLAAA 30 GHz Feed horns
		PLABA 44 GHz Feed horns
		PLACA 70 GHz Feed horns
		PLAAB 30 GHz OMTs
		PLABB 44 GHz OMTs
		PLACB 70 GHz OMTs
		PLAAC 30 GHz Front End Modules
		PLABC 44 GHz Front End Modules



		PLACC	70 GHz Front End Modules
PL4K	PLAF0	4K REFERENCE LOAD	
PLWG	===	Wave-guide (WG)	
	PLAAE	30 GHz Wave-guide	
	PLABE	44 GHz Wave-guide	
	PLACE	70 GHz Wave-guide	
	PLAGC	Wave-guide Support	
		PLAGC/A	High Level WG Support
		PLAGC/B	Low Level WG Support

Project Code	WBS Code		
PLBEU	=== (*)	BACK END STRUCTURE (BEU)	
		PLAHA	BEU Internal Harness
			PLAHA/A – Power Box to BEU Box Harness
			PLAHA/B – Power Box to Lateral Trays Harness
			PLAHA/C – DAE BEU Box to Lateral Trays Harness
		PLAE0	Data Acquisition Electronics (DAE)
			PLAEA – DAE BEU Box
			PLAEB – DAE Lx BEM Tray Box
			PLAEC – DAE Rx BEM Tray Box
			PLAED – DAE Lx FEM Tray Box
			PLAEE – DAE Rx FEM Tray Box
			PLAEF – DAE Power Box
		PLAAD	30 GHz Back End Modules
		PLABD	44 GHz Back End Modules
		PLACD	70 GHz Back End Modules
PLREB	PLBA0	REBA electronics	
PLREN		PLBAA	REBA nominal unit
PLRER		PLBAB	REBA redundant unit
PLIH	PLE00	LFI Interconnect Harness	
		PLEA0	REBA to BEU Harness

Note: (*) The WBS Code for FEU and BEU is the one applied to RAA, therefore PLA00



6.1.2 COORDINATE SYSTEM

The coordinate system is compliant with requirements in IID-A (UM SATELLITE). LFI units specific definition are shown in the External Configuration Drawings.

The Spacecraft X-axis nominally coincides with the longitudinal launcher axis (= the nominal antisun direction, i.e. the spin axis).

The Planck telescope line of sight, which is defined as the direction in which the projection of the main mirror rim is circular, is tilted 85° from the satellite X-axis in the Z direction.

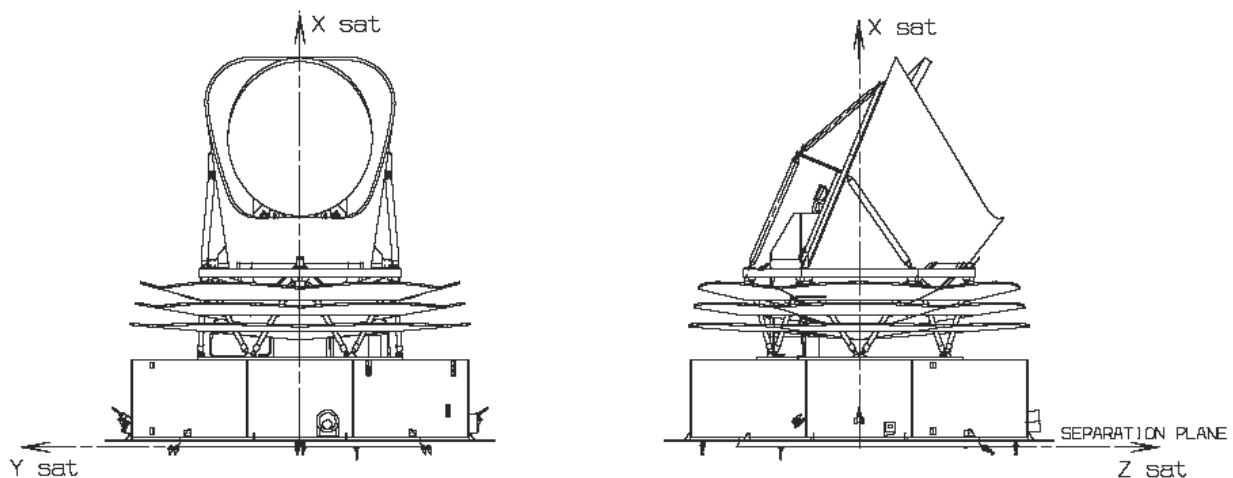
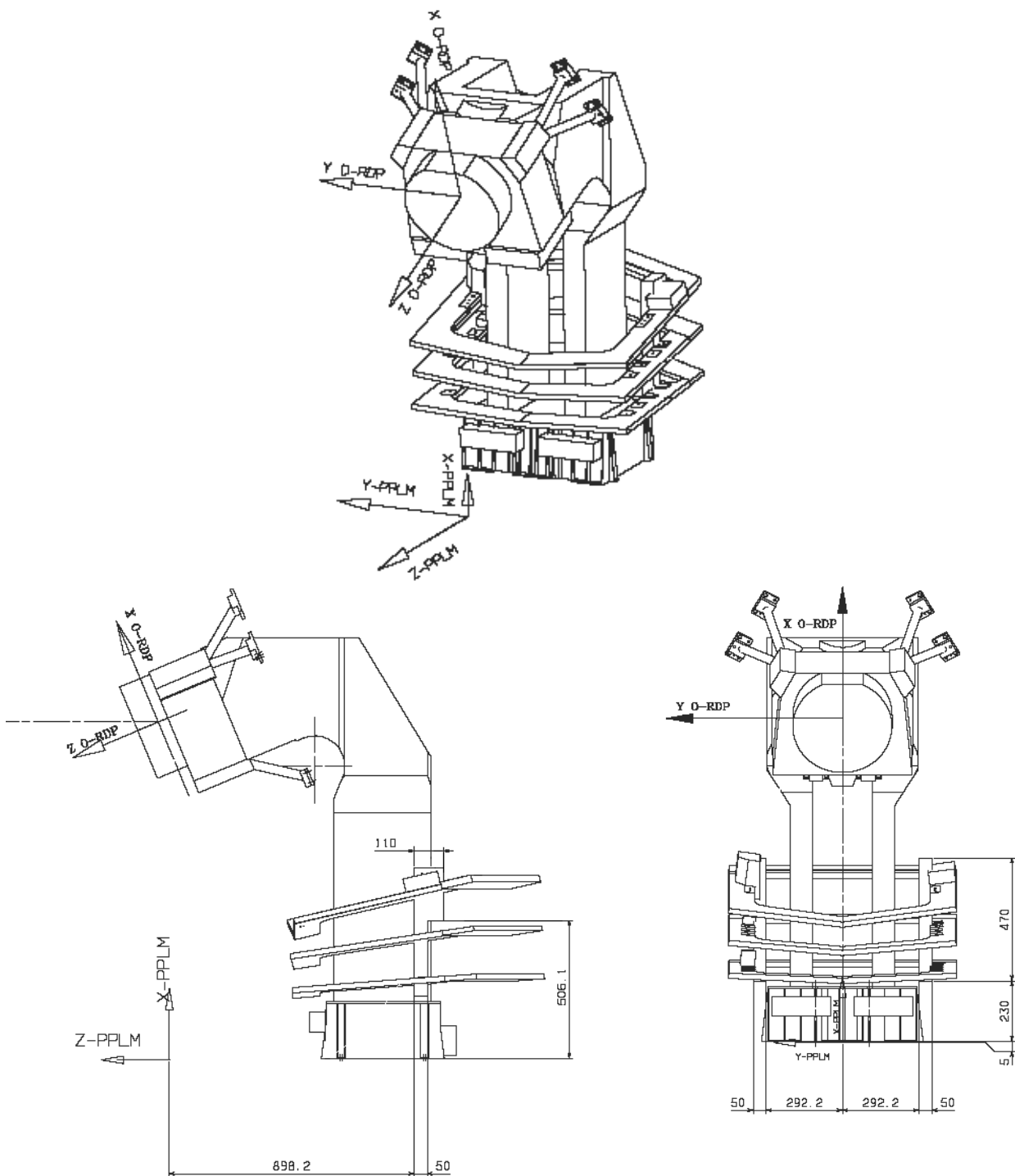


Figure 6-1 Definition of Planck spacecraft axes

There are 3 additional frames associated to the PPLM, to the Telescope, and to the FPU, having their origins respectively in Opplm, Otel, and Ordpc (see Figure 6.1-2).



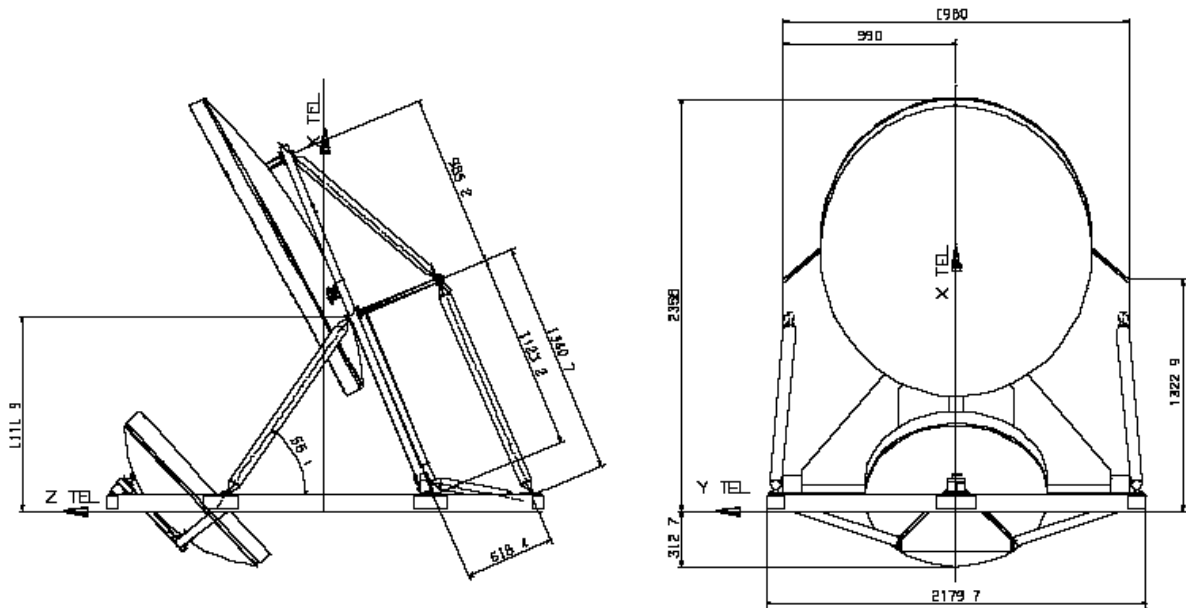


Figure 6-2 Definition of 3 additional frames associated to the PPLM, to the Telescope, and to the FPU (respectively PPLM, TEL and RDP)

6.1.3 LOCATION AND ALIGNMENT

6.1.3.1 INSTRUMENT LOCATION

6.1.3.1.1 On SVM

It is foreseen that the following LFI units are installed onto the SVM:

- PLREN and PLRER (or Main and Redundant REBA)
- BEU and DAE Power Box on SVM upper platform

6.1.3.1.2 On Planck P/L Module (PPLM)

PLFEU, integrated in the LFI/HFI FPU, is mounted with three bipods to the telescope structure.

The relative position of PLFEU and PLBEU is fixed by the waveguides that connect the two units together.

Other units:

- PLWG: waveguides connects PLFEU (FEU) with PLBEU (RF link),
- PLAGC: supports of the waveguides

6.1.3.2 INSTRUMENT ALIGNMENT

The main alignment and alignment stability requirements are for the LFI/HFI Focal Plane Unit (FPU) with respect to the telescope. Relative alignment internal to the Focal Plane Unit, i.e. between PLFEU (FEU) and the HFI Focal Plane Unit, is ensured by a common LFI-HFI Instrument Integration Plan (contained in the LFI/HFI ICD [AD8], see also [AN21]).



6.1.3.2.1 Absolute Requirements

The absolute alignment requirements of LFI/HFI FPU to the Planck optical bench at operating conditions are covered in the Planck Alignment Plan which is an annex [AN21].

The alignment of the LFI FEU to the telescope is foreseen at the level of the interface of the FEU structure to the S/C, i.e. the telescope structure.

6.1.3.2.2 Stability Requirements

The alignment stability requirements at operating conditions are also covered in the Planck Alignment Plan, which is annex [AN21].

6.1.4 EXTERNAL CONFIGURATION DRAWINGS

The drawings are provided in annex 1, 2 and 3 of [AD2].

	Reference	Issue	Date
REBA	FPL-ID-REB-00002-CRS	4/0	23/09/2003
BEU	ICD751000102	B	18/07/2005
DAE power box	ICD740800115	A	27/10/2004
RAA	ICD 701 000039 sheet 1/4	A	30/01/2006
FPU and bipods	ICD 701 000039 sheet 2/4	A	30/01/2006
WG Upper Structure	ICD 701 000039 sheet 3/4	A	30/01/2006
WG Lower Structure	ICD 701 000039 sheet 4/4	A	30/01/2006

6.1.5 SIZES AND MASS PROPERTIES

The nominal mass of LFI instrument is 93.97 kg.

The table below shows for each unit its size, nominal mass and the allocated mass.

The mass of the bolts at the interfaces to the PPLM and SVM are not included in the budget.

Project code	Instrument unit	# of	Dimensions (lxdxh mm)(3)	Nominal Mass (kg)	Allocated Mass (kg)
PLFEU	Front End Unit including 4K load, cryo-harness, and FEU internal harness (LFI part of common LFI/HFI FPU)	1	See ICD 701 000039 sheet 2/4	24.864	
PLWG	Waveguides (2 bundles) and support structure	1 set	See ICD 701 000039 sheet 2/4 and 3/4	23.005	



PLBEU	Back End Unit (BEU)	1	See ICD 701 000039 sheet ¼	25.542	
	BEU internal harness	1set		0.949	
	Power box to BEU and BEM harness	1set		3.540	
	DAE Power Box	1	240.8x216x138	4.510	
PLREN	REBA nominal (2)	1	270 x 232.5 x 108	4.240	
PLRER	REBA redundant (2)	1	270 x 232.5 x 108	4.240	
PLIH	REBA to BEU harness	1 set		3.495	
TOTAL				89.875	89

(2) Dimensions do not include internal harness. See drawing in annex 1, 2 and 3 of [AD2].

(3) Dimensions includes feet and connectors. Detailed dimensions described in ICD in annex of [AD2]. In case of inconsistency between this table and the drawings, the drawings take precedence on the table.

(4) Cable length is given here for mass estimation only. This is not a constraint.

6.1.6 MECHANICAL INTERFACES

6.1.6.1 ON SVM

“Warm” units mounted on the SVM have attachment points for fixation to the equipment platform as described on interface drawings in annexed ICD of [AD2].

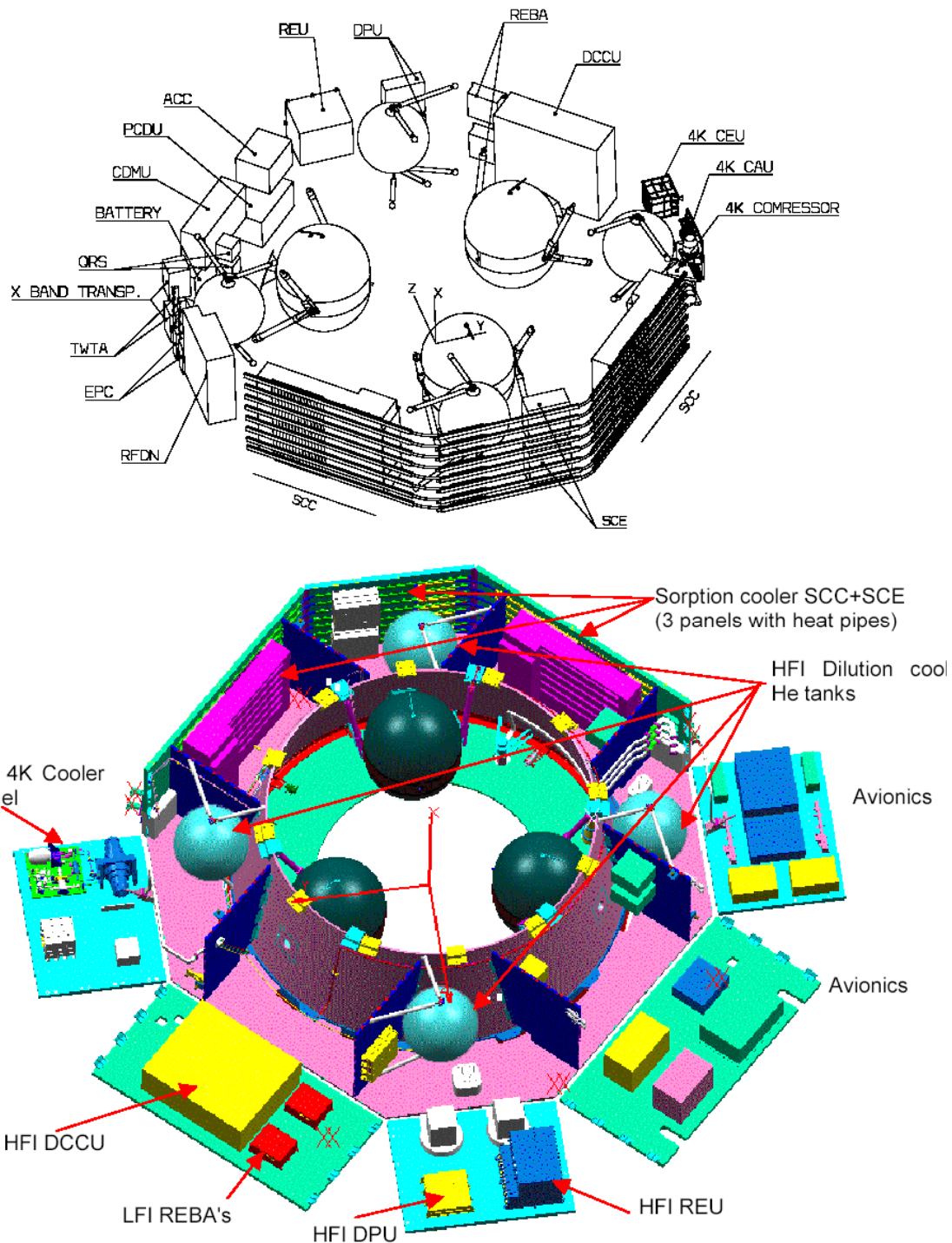


Figure 6-3 Planck Instrument deployment on SVM



6.1.6.2 ON PLANCK PAYLOAD MODULE (PPLM)

The mechanical support of the FPU on the PPLM is achieved with a set of struts which minimises the thermal load on the 20K stage and is compliant with the LFI and HFI requirements for stiffness and alignment. This mechanical support is considered part of the LFI instrument.

6.1.7 THERMAL INTERFACES

6.1.7.1 ON SVM

The table below shows the required operating, non-operating and switch on temperatures at the interface of the instrument unit with the mounting platform or parts thereof:

Project code		Operating (Nominally)		Start-up	Non-operating	
		Min. °C	Max. °C	°C	Min. °C	Max. °C
PLREN	REBA Nom.	-20	+50	-30	-30	+50
PLRER	REBA Red.	-20	+50	-30	-30	+50
PLAEF	DAE Power box	-20	+50	-30	-30	+50
PLBEU	BEU	-20	+40	-30	-30	+50

6.1.7.2 ON PLANCK P/L MODULE (PPLM)

The table below shows the temperatures at the interface of the instrument unit with the mounting platform.

In particular, the PLFEU temperatures, listed in the table, are the nominal temperatures, at the mounting platform, of the fixation bolts for the struts supporting the PLFEU unit.

Project code		Operating (Nominally)		Start-up	Non-operating	
		Min. K	Max. K	°C	Min. °C	Max. °C
PLFEU	FEU	40	65***	< 50****	NA	+50****

*** For power reasons, 50 K is the preferred temperature

**** There is no minimum temperature for operating the PLFEU, instead it is not advisable to operate at temperatures above +50 °C.

The LFI waveguides exhibit thermal interfaces to each of the V-grooves. The table below gives the required temperatures at these interfaces.

Interface temperature (K)	Comments



Interface		
Warmest Thermal Shield	<170	Requirement at interface, 50K goal
Intermediate Thermal Shield	<120	
Coldest Thermal Shield	<60	

6.1.7.3 TEMPERATURE CHANNELS

The table below shows information relevant to the measurement of instrument temperatures. The column «Power» indicates whether the relevant channel is part of the instrument HK or of the S/C HK. In the latter case temperature information would also be available when the instrument is in its OFF state.

Unit	Location & Acronym	Number	Temp. (K)		TM Ref.
			Min	Max	
PLFEU	High sensitivity	5	14	26	TM(3,25): Packet ID 120102369 parameters LM205332, LM206332, LM304332, LM305332, LM306332
	Wide range	7	14	95	TM(3,25): Packet ID 120102369 parameters LM201332 to LM204332, LM301332 to LM303332
PLBEU	BEU	2	240	353	TM(3,25): Packet ID 120102369 parameters LM207332 to LM211332, LM307332 to LM311332
	Lateral trays	8	240	353	
PLREN	SVM – REBA Nom.	3	240	353	TM(3,25): Packet ID 120202369 parameters LM211342, LM212342, LM213342
PLRER	SVM – REBA Red.	3	240	353	TM(3,25): Packet ID 120202369 parameters LM211342, LM212342, LM213342
PLAEF	DAE Power box	5	240	353	TM(3,25): Packet ID 120102369 parameters



					LM101332, LM102332, LM108332, LM111332, LM114332

Figure 6-4 shows the position of the PLFEU temperature sensors.

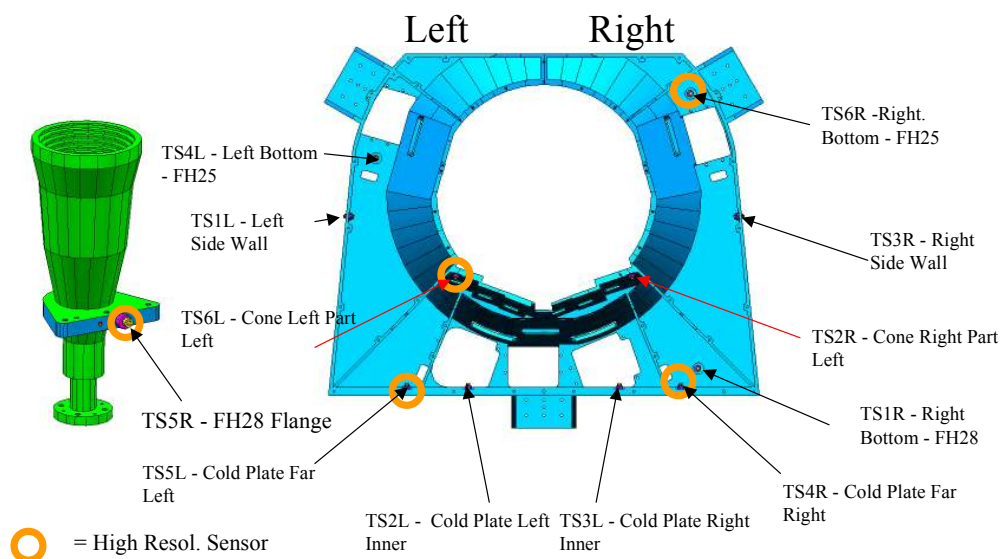


Figure 6-4 Focal Plane Temperature Sensor Position

The temperature sensors needed for the S/C thermal control of the Instruments equipment are not presented here.

6.1.8 OPTICAL INTERFACES

6.1.8.1 STRAYLIGHT

The Low Frequency Instrument is coupled to the Planck Telescope by an array of corrugated feed horns. The coupling between the feeds and the external environment constitutes the LFI Optical Interface. In the ideal case, the external environment is composed by the Planck Telescope only. In reality, the environment is constituted of all the satellite surfaces (including the telescope) and celestial objects which can emit, reflect, or scatter radiation that is detected by the LFI radiometers. “Straylight” is defined for the Planck instruments as the radiative power that reaches a detector within its RF bandwidth, and that does not originate from sources in the main beam. Straylight induces a signal that is indistinguishable from signals induced by sources located in the main beam. Variations in straylight are a source of systematic error. In the context of PLANCK-LFI we can consider two main types of straylight, according to its origin: external straylight, i.e. stray radiation coming from astrophysical sources; and internal straylight, i.e. radiation generated by emissive surfaces of the satellite itself.



The basic optical interface requirement for LFI with respect to the PLANCK PPLM is the acceptable level of straylight.

6.1.8.1.1 External straylight

Any celestial source could be a source of external straylight, due to the imperfect off-axis rejection of the entire optical system.

Actually, the Sun, the Moon, the Earth, the Planets, the HII regions, the diffuse Galactic emission, the CMB dipole are sources of straylight which contributes in different ways and levels to the different portions of the full detection beam pattern. This type of signal is inherently spin synchronous.

6.1.8.1.2 Internal straylight

Thermal emission from all components of the spacecraft produces a signal which is not easily distinguishable from signals due to sources in the main beam. The time variation of the straylight signal from these sources is due to fluctuations in the temperature of emissive components.

We can identify three main sub units in the satellite that can give a contribution to the internal straylight, i.e.: (i) the telescope, (ii) the baffle, (iii) the 50K V-Groove.

In general we divide the different straylight contributions into three different categories, i.e.: (i) random thermal fluctuations of emissive surfaces, that will have the main effect of increasing the radiometer noise, (ii) periodic spin-synchronous thermal fluctuations, that will generate signal oscillations that will not be damped by the measurement strategy, and (iii) periodic non spin synchronous thermal fluctuations, that will generate signal oscillations that will be reduced in amplitude by the measurement strategy and by destriping/map-making algorithms.

6.1.8.2 BEAM PROFILES

The distortion of the beam shape results in a degradation of the nominal LFI performance mainly through four effects:

- a) Degradation of the angular resolution, which has been quantified by simulations.
- b) Loss of accuracy and sensitivity in averaging beams with different distortions.
- c) Loss of capability in applying destriping algorithms
- d) Degradation of polarisation measurements

The LFI is particularly affected by these effects since the feed horns are arranged around the HFI instrument, at a significant distance from the telescope optical axis.

6.1.8.3 HORN POSITION AND ORIENTATION

The arrangement of the 11 LFI Dual Profiled Corrugated Feed Horn is reported in Figure 6-5. Each FH is represented with a part number defined in [RD22], and an identification number, ID, (from 18 to 28)¹. In Figure 6-5 the FH locations are shown in the Reference Detector Plane (RPD) System² with the Z-axis pointing outside the paper. The main reflector is on the +X direction.

¹ The ID number must be used as a reference number for optical calculation purposes only

² For the definition of the RDP system see [RD23]

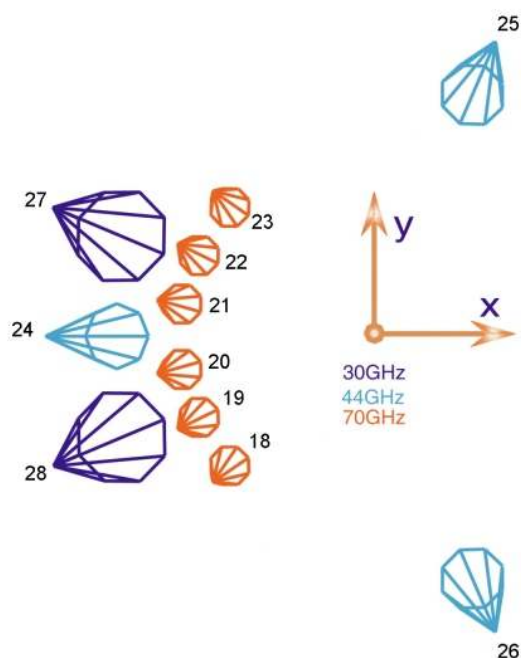


Figure 6-5 LFI Feed Horn location and Identification

The overall block definition is extensively reported in [RD22]. Three blocks are defined for the LFI Feed Horns.

- PLAAA: 30 GHz Feed Horns
- PLABA: 44 GHz Feed Horns
- PLACA: 70 GHz Feed Horns

In this section the coordinates for each feed horn are reported ³.

For each Feed Horn a local coordinate system (LCS) is defined starting from the RDP system. The Z-axis of the LCS is pointing toward the secondary reflector. The LCS defines the nominal location of the phase centre of each FH in the FPU.

The θ , ϕ and ψ values are defined according to the GRASP8 definition [RD24].

FEED HORN @ 30GHZ – PLAAA

Part Number	ID	X_{LCS} [mm]	Y_{LCS} [mm]	Z_{LCS} [mm]	θ [deg]	ϕ [deg]	ψ [deg]
PLAAA	27	-136.95	54.94	18.60	15.56	-23.01	-19.22
PLAAA	28	-136.95	-54.94	18.60	15.56	23.01	19.22

³ These coordinates are representative for the optical calculation only and do not constitute the reference systems for integration, which are reported in [AD1], Section 5.2.2.



FEED HORN @ 44 GHZ – PLABA

Part Number	ID	X _{LCS} [mm]	Y _{LCS} [mm]	Z _{LCS} [mm]	θ [deg]	φ [deg]	ψ [deg]
PLABA/01	24	-138.41	0.00	21.29	14.85	0.00	0.00
PLABA/02	25	55.32	133.27	-17.90	16.44	-113.42	-106.18
PLABA/02	26	55.32	-133.27	-17.90	16.44	113.42	106.18

FEED HORN @ 70 GHZ – PLACA

Part Number	ID	X _{LCS} [mm]	Y _{LCS} [mm]	Z _{LCS} [mm]	θ [deg]	φ [deg]	ψ [deg]
PLACA/01	18	-76.38	-69.37	14.54	11.93	46.04	18.26
PLACA/02	19	-92.41	-43.29	18.66	11.63	28.71	19.84
PLACA/03	20	-101.86	-17.69	20.86	11.38	11.22	21.29
PLACA/03	21	-101.86	17.69	20.86	11.38	-11.22	-21.29
PLACA/02	22	-92.41	43.29	18.66	11.63	-28.71	-19.84
PLACA/01	23	-76.38	69.37	14.54	11.93	-46.04	-18.26

For each part the phase centre location (PCL) is defined from the plane of the FH-OMT flange (see Figure 6-6)⁴. In Table 6.1-1, the distance between the plane of this flange and the phase centre location (i.e. the intersection between the axis of the FH and the focal surface of the Planck telescope) is reported.

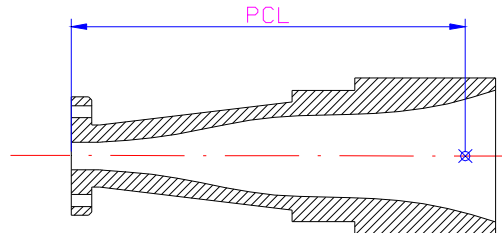


Figure 6-6 Definition of the Phase Centre Location (PCL)

Part Number	PCL [mm]
PLAAA	143.73
PLABA/01	142.14
PLABA/02	103.74
PLACA/01	59.18
PLACA/02	63.63
PLACA/03	66.13

Table 6.1-1 Phase Centre Location for the LFI Feed Horns

6.1.8.3.1 Location and alignment

The coordinate system for all drawings and alignment purposes are given in [AD1], Section 5.2.2.

⁴ The phase centre is defined as the point where the phase variations of the far field pattern is minimised with respect a spherical wave front (constant phase), within a cone with an aperture angle where the average amplitude pattern is up to 20dB below the peak. The weight shall be constant for each point ($w_i=1$)



The location of each part within LFI is given in [RD4].

6.1.9 POWER

6.1.9.1 ON SVM

The table below shows the heat dissipation of the units mounted on the SVM (see Ref.H-P-LFI-CR-0053 Issue 2, May 29th 2006):

Project code	Instrument Unit	Sub-Unit	Nominal Power Dissipation (W)
PLREN	REBA Nominal		22.7
PLRER	REBA Redundant		0
PLBEU	Back End Unit	-Y BEM/FEM tray	8.9
		+Y BEM/FEM tray	9.9
		Central box	9.9
	DAE Power Box		16.9
	TOTAL		68.3 (*)
	Allocation		120

(*) The power shown for the FEM/BEM trays includes a total of 0.350 W all of which is actually dissipated in the LFI focal plane during Normal or Extended Science Modes Operation.

The REBA is cold redundant.

6.1.9.2 ON PLANCK PAYLOAD MODULE (PPLM)

6.1.9.2.1 Planck Payload module “Cold”

Instrument Unit	Nominal Power Dissipation (mW)
HEMT	346
Waveguides	249
LFI harness	3
Radiant	2
Struts	23
TOTAL	623



6.1.9.2.2 Thermal Table Radiometer Array Assembly

As a result of thermal analysis the following loads (mainly conductive) are calculated for the various interfaces of LFI with the PPLM «cold». The heatloads are calculated from the reference temperature set provided in IIDA [AD1] §5.9.2, and to be compared with the heatload allocation in the same paragraph of IID-A.

	Interface	Reference Temperature [K]	Heat Loads [mW]	Allocated Heatloads [mW]
VG3	Coldest shield	51.4 and 57.6 K	463	710
VG2	Intermediate shield	106.2 K	337	560
VG1	Warmest shield	166.2 K	2939	5370

6.1.9.3 SUPPLY VOLTAGES

6.1.9.3.1 28 Volt main-bus

6.1.9.3.1.1 Load on main-bus

LFI requires four 28 V power lines from the Power Control Subsystem(PCDU). They are used thus:

- one LCL protected line to the nominal REBA
- one LCL protected line to the redundant REBA
- two LCL protected line to the DAE Power box

The LCL's are designed to avoid a failure in the closed position to allow the use of the redundant units of the REBA.

The power load on the main-bus for the RAA and the REBA is as follows (see Ref.H-P-LFI-CR-0053 Issue 2, May 29th 2006):

Operating mode	Power Line	Average BOL (W)	Average EOL (W)	Peak (W)
Standby	Total	22.1	22.1	24.4
	REBA	22.1	22.1	24.4
	RAA	0	0	0
DAE Set-up	Total	67.7	67.7	70.0
	REBA	22.1	22.1	24.4
	RAA	45.6	45.6	45.6
Normal Science	Total	68.3	68.3	72.0
	REBA	22.7	22.7	26.4
	RAA	45.6	45.6	45.6
Extended Science	Total	68.3	68.3	72.0
	REBA	22.7	22.7	26.4



	RAA	45.6	45.6	45.6

The difference between the load on main bus and the power dissipation on SVM is due to the dissipation in the FPU.

6.1.10 ELECTRICAL INTERFACE

6.1.10.1 INTERFACE CIRCUITS

See annex 1 of [AD2].

6.1.10.1.1 REBA

Each unit of the REBA receives:

- A single primary power line from the Spacecraft PCS at the PSU (see Sec. 6.1.9).
- One on-board clock (OBC-Nominal and Redundant) signal from the CDMS
- The CDMS 1553B Data Bus A at the DPU
- The CDMS 1553B Data Bus B at the DPU

Each of these interfaces has been allocated to a separate connector on the REBA to ensure separation of EMC classes and reliability at the connector level.

This configuration of interfaces also avoids the propagation of failure across the interface between the CDMS and the REBA. That is in the case of failure in the REBA it would not be necessary to switch to the redundant CDMU, or in case of switch-over of the CDMU, the redundant CDMU would be able to take over operations of the REBA and thus control and monitor LFI.

The REBA is connected to the MIL 1553B CDMS communication bus for all telemetry and telecommand functions. The interface used is a "long stub" version.

6.1.10.1.1.1 Input Interface Circuit Diagram

The on-board clock and the CDMS 1553 interfaces and the Power Supply Circuit Diagrams are reported in the figures below.

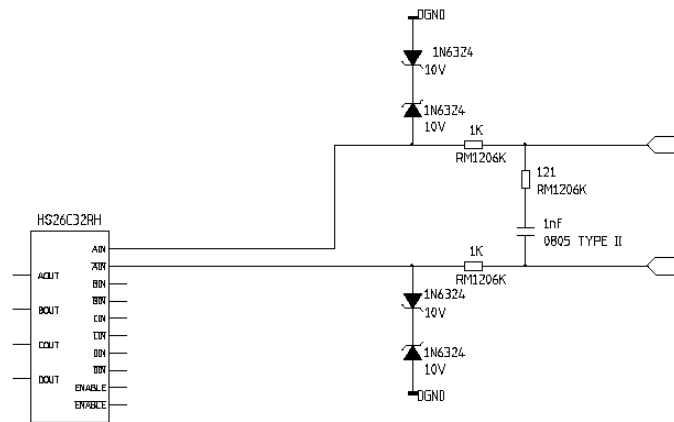


Figure 6-7 131 kHz Clock I/F

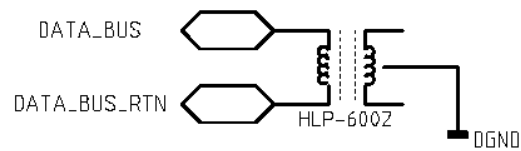


Figure 6-8 1553 I/F

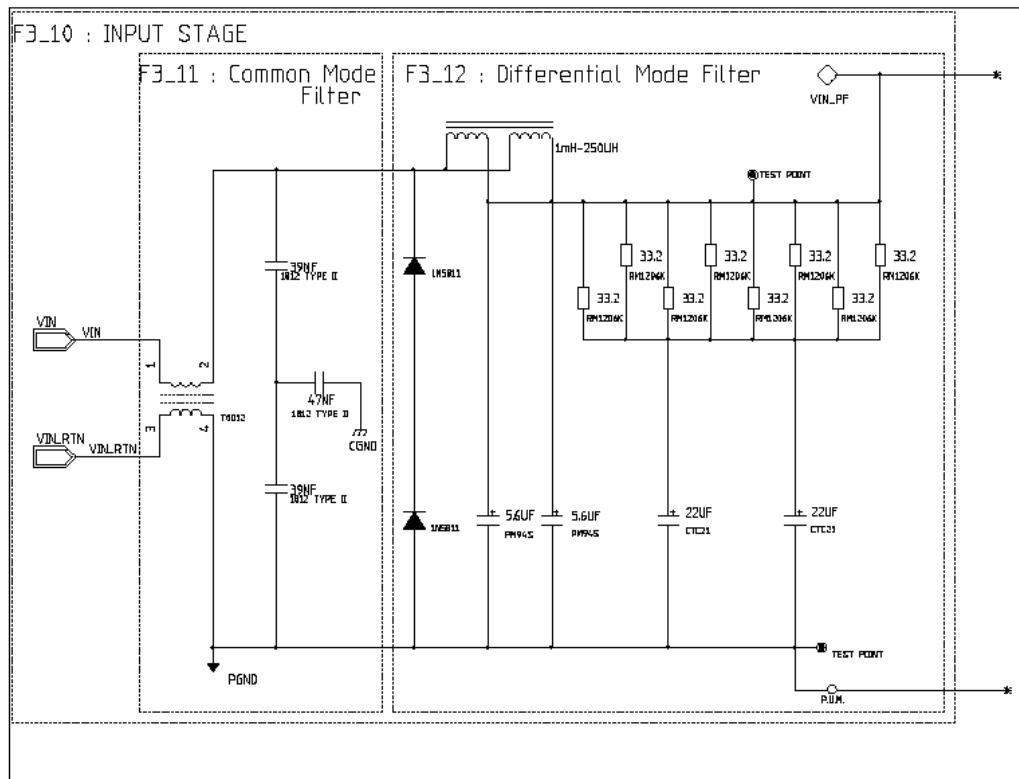


Figure 6-9 Power supply

6.1.10.1.1.2 Output Interface Circuit Diagram

TBW

6.1.10.1.2 Data Acquisition Electronics

The DAE receives:

- Two primary power lines (one nominal and one redundant) from the Spacecraft PCDU at the DAE Power Box (see Sec. 6.1.9).
- Two on-board clock lines (one nominal and one redundant) from the CDMS at the DAE BEU Box.

Each of these interfaces has been allocated to a separate connector to ensure separation of EMC classes and reliability at the connector level.

6.1.10.1.2.1 Power Interface

The DAE receives the primary power from the S/C and converts it into suitable isolated voltages for supplying the entire RAA.



The overall power consumption of the DAE, including the inefficiency due to the fraction of power delivered to the RCA, is 31.986 W.

6.1.10.1.2.2 Power and Voltage Data Sheet

TBW

6.1.10.1.2.3 Current Limiters

No current limiters are required at the primary power input of the DAE because those are foreseen on the S/C side of the connection.

The foreseen protections are:

- Input undervoltage
- Output Overcurrent

6.1.10.1.2.4 Inrush Current

The inrush is compatible with the specification given in [AD1].

6.1.10.1.2.5 Converter Frequency and Synchronisation

The DC/DC converters are not externally synchronised. Their nominal switching frequency is around 131 kHz.

The 131072kHz-clock line provided to the DAE is used to clock the DAE OBT.

6.1.10.1.2.6 Electrical Interface Circuits

6.1.10.1.2.6.A Primary power interface

Both the redundant primary power lines are wired-OR immediately after the input connectors in the DAE.

6.1.10.1.2.6.B Synchronisation line

A standard RS422 receiver (26C32) at physical level is foreseen for the synch line.

6.1.10.1.2.6.C 1553 lines

A standard Mill 1553B interface is implemented.



6.1.10.1.2.7 Electrical Interface Circuits Characteristics

TBW

6.1.10.1.2.8 Electrical Interface Data Sheets

TBW

6.1.11 CONNECTOR, HARNESS, GROUNDING, BONDING

6.1.11.1 CONNECTORS

Selection of connectors and pin function allocation is according to ESA standards.

6.1.11.2 HARNESS

The overall harness configuration of LFI is shown in Figure 6-10.

Note: due to editorial problem, the following changes in the connector names has not been performed in the following figure:

- J02 on the DAE power box should be J84
- J03 on the DAE BEU should be J09
- J04 on the DAE BEU should be J83

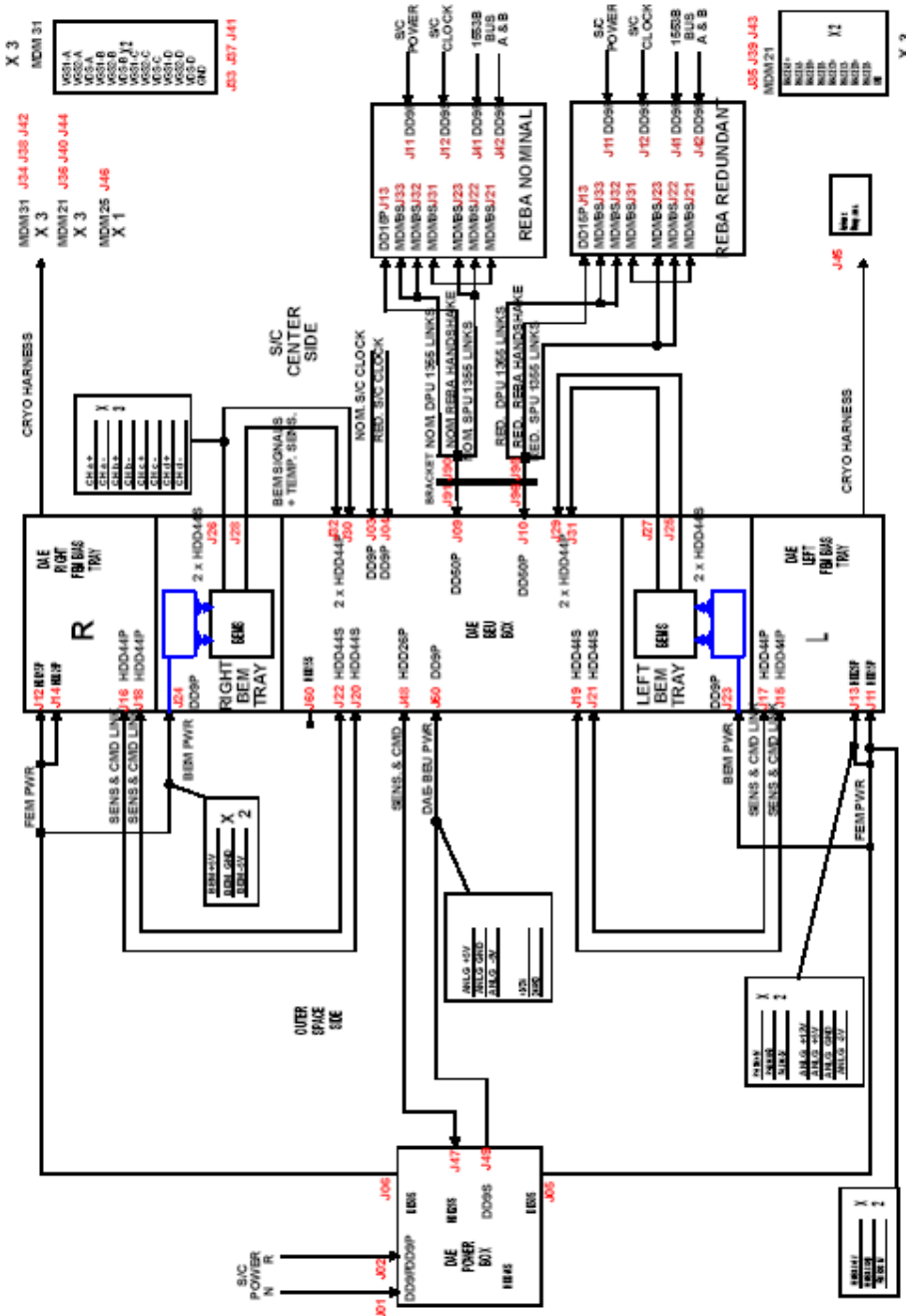


Figure 6-10 The overall harness configuration of LFI

6.1.11.2.1 S/C Harness

The S/C harness provides the interconnection between the instrument and the S/C subsystems, i.e., the Power subsystem and the Data Handling subsystem.

The harness is supplied through ASPI.



On the instrument side, pin functions are given below.

6.1.11.2.1.1 S/C to REBA Harness

A harness is necessary for each of the two REBA units (nominal and redundant) The connectors and their pin functions are identical on each REBA unit.

EQUIPMENT: REBA (Applies to both the nominal and redundant unit)		
CONNECTOR TYPE	CONNECTOR NAME	CONNECTOR FUNCTION
DEM9PNMB1AON	J11	PRIMARY POWER BUS
DEM9SNMB1AON	J12	SATELLITE OBC (NOMINAL AND REDUNDANT)
DEM9PNMB1AON	J41	1553 TM/TC A
DEM9PNMB1AON	J42	1553 TM/TC B

Table 6.1-2 Connector list S/C to REBA (REBA side)

6.1.11.2.1.1.A Primary Power Bus Connector J11

The pin functions of the REBA connector for receipt of power from the spacecraft are given below.

EQUIPMENT:	REBA
CONNECTOR TYPE:	DEM9PNMB1AON
CONNECTOR FUNCTION:	PRIMARY POWER BUS
CONNECTOR NAME:	J11
PIN NUMBER	SIGNAL/LINE NAME
1	PWR_IN
2	PWR_IN
3	SPARE
4	PWR_RTN
5	PWR_RTN
6	SPARE
7	SPARE
8	CHASSIS
9	CHASSIS

6.1.11.2.1.1.B On Board Clock Distribution Connector J12

The pin functions of the REBA connector for receipt of the OBC signal (both nominal and redundant) are given below.



EQUIPMENT:	REBA
CONNECTOR TYPE:	DEM9SNMB1AON
CONNECTOR FUNCTION:	SATELLITE OBC
CONNECTOR NAME:	J12
PIN NUMBER	SIGNAL/LINE NAME
1	CHASSIS
2	SPARE
3	SPARE
4	CLOCK_TRUE
5	CLOCK_COMP
6	SPARE
7	SPARE
8	SPARE
9	CHASSIS

6.1.11.2.1.1.C MIL STD 1553 BUS A connector J41

The pin functions on the REBA connector for the TM/TC interface to Bus A are the following.

EQUIPMENT:	REBA
CONNECTOR TYPE:	DEM9PNMB1AON
CONNECTOR FUNCTION:	1553B TM/TC A
CONNECTOR NAME:	J41
PIN NUMBER	SIGNAL/LINE NAME
1	CHASSIS
2	DATA_BUS_A
3	SPARE
4	SPARE
5	SPARE
6	DATA_BUS_A_RTN
7	SPARE
8	SPARE
9	CHASSIS

6.1.11.2.1.1.D MIL STD 1553 BUS B connector J42

The pin functions on the REBA connector for the TM/TC interface to Bus B are the following.



EQUIPMENT:	REBA
CONNECTOR TYPE:	DEM9PNMB1AON
CONNECTOR FUNCTION:	1553B TM/TC B
CONNECTOR NAME:	J42
PIN NUMBER	SIGNAL/LINE NAME
1	CHASSIS
2	DATA_BUS_B
3	SPARE
4	SPARE
5	SPARE
6	DATA_BUS_B_RTN
7	SPARE
8	SPARE
9	CHASSIS

6.1.11.2.1.2 S/C Harness to the DAE Control Box

The Table below gives the connector list on the Back End Unit.

EQUIPMENT:	BEU	
CONNECTOR TYPE	CONNECTOR NAME	CONNECTOR FUNCTION
DEMA-9P-NMBFO	J01	PRIMARY POWER BUS to DAE POWER BOX
DEMA-9P-NMBFO	J84	REDUNDANT POWER BUS to DAE POWER BOX
DEM-9P-NMBFO	J09	SATELLITE OBC to DAE BEU BOX NOMINAL !/F
DEM-9P-NMBFO	J83	SATELLITE OBC to DAE BEU BOX REDUNDANT !/F

Table 6.1-3 Connector list S/C to BEU

6.1.11.2.1.2.A S/C to DAE Power Box Harness

The pin functions of the DAE Power Box connector for receipt of power from the spacecraft nominal power line are given below.

EQUIPMENT:	DAE POWER BOX
CONNECTOR TYPE:	DEMA-9P-NMBFO
CONNECTOR FUNCTION:	PRIMARY POWER BUS (NOMINAL)
CONNECTOR NAME:	J01
PIN NUMBER	SIGNAL/LINE NAME
1	+28 V primary power
2	+28 V primary power
3	Connected to chassis



4	Connected to chassis
5	Connected to chassis
6	Return of primary power
7	Return of primary power
8	Connected to chassis
9	Connected to chassis

The pin functions of the DAE Power Box connector for receipt of power from the spacecraft redundant power line are given below.

EQUIPMENT:	DAE POWER BOX
CONNECTOR TYPE:	DEMA-9P-NMBFO
CONNECTOR FUNCTION:	PRIMARY POWER BUS (REDUNDANT)
CONNECTOR NAME:	J84
PIN NUMBER	SIGNAL/LINE NAME
1	+28 V primary power
2	+28 V primary power
3	Connected to chassis
4	Connected to chassis
5	Connected to chassis
6	Return of primary power
7	Return of primary power
8	Connected to chassis
9	Connected to chassis

6.1.11.2.1.2.B S/C to DAE BEU Box Harness

The pin functions of the DAE BEU Box nominal interface connector for receipt of the satellite OBC Synchronisation signal are given below.

EQUIPMENT:	DAE BEU BOX
CONNECTOR TYPE:	DEMA-9P-NMBFO
CONNECTOR FUNCTION:	SATELLITE OBC to DAE BEU BOX NOMINAL !/F
CONNECTOR NAME:	J09
PIN NUMBER	SIGNAL/LINE NAME
1	OBC line
2	Connected to chassis
3	Connected to chassis
4	Connected to chassis
5	Connected to chassis



6	OBC line negated
7	Connected to chassis
8	Connected to chassis
9	Connected to chassis

The pin functions of the DAE Power Box redundant interface connector for receipt of the satellite OBC Synchronisation signal are given below.

EQUIPMENT:	DAE BEU BOX
CONNECTOR TYPE:	DEMA-9P-NMBFO
CONNECTOR FUNCTION:	SATELLITE OBC to DAE BEU BOX REDUNDANT !/F
CONNECTOR NAME:	J83
PIN NUMBER	SIGNAL/LINE NAME
1	OBCLine
2	Connected to chassis
3	Connected to chassis
4	Connected to chassis
5	OBC line negated
6	Connected to chassis
7	Connected to chassis
8	Connected to chassis
9	Connected to chassis

6.1.11.3 GROUNDING

A preliminary grounding diagram is shown in Figure 6-11. The LFI grounding diagram is under revision and a new grounding diagram will be defined in agreement with the other instrument and ASPL.

All the LFI units are designed in compliance with ESA grounding requirements.

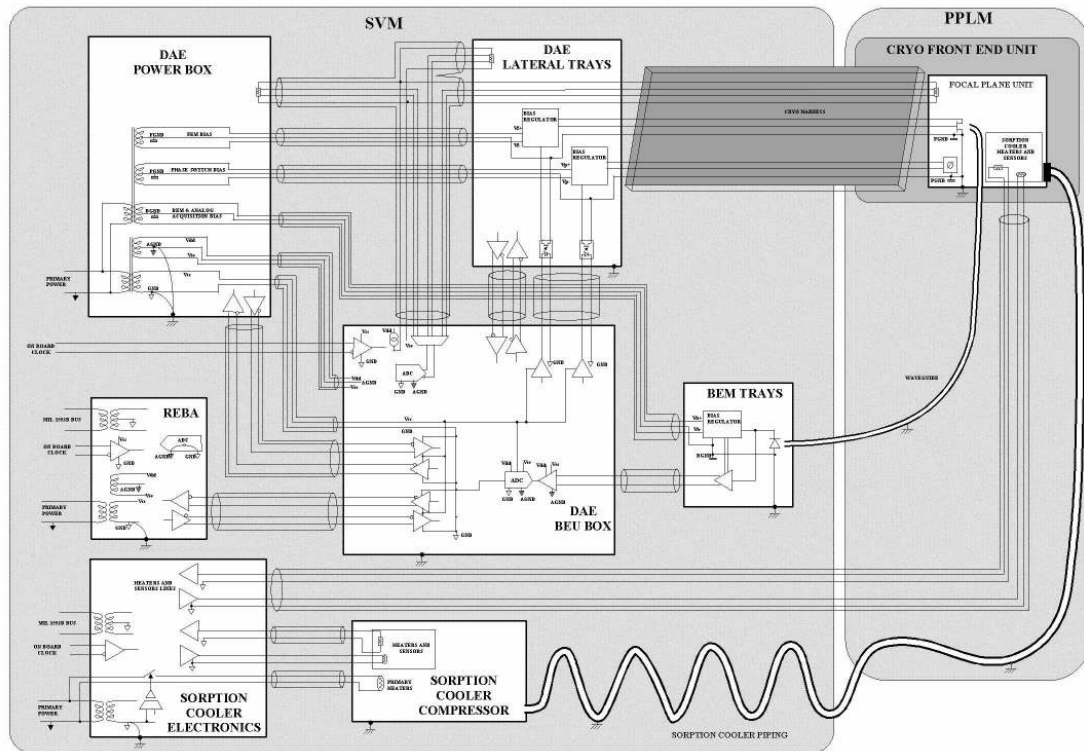


Figure 6-11 LFI grounding and shielding diagram

6.1.11.4 BONDING

All the LFI units are designed in compliance with IID-A [AD1] Par. 5.10.4.10 bonding requirements.

6.1.12 COMMUNICATION INTERFACE

The communication interface is based on the 1553 bus according to the specifications [RD10].

6.1.12.1 STATUS POLLING

The CDMS is in charge to poll the LFI bus interface for its status.

If the Packet Count received in TM packet transfer confirmation is not the same of the last TM packet request or flow flags are not "11", the DPU_ASU shall signal an error on the 'unit status data (SA 1T)' indicating that there was a TM transfer confirmation error and shall also include in 'unit status data (SA1T)' the invalid TM transfer confirmation as well as the RT internal subframe count value.



The DPU_ASW shall update the 'unit status data (SA 1T)' information every subframe with the following data:

- word1 = SF counter, range 0000h to 003Fh
- word2 = Data Link and Transfer Levels Error information:1
 - Bit 15 (LSB): Unexpected subframe counter (1 = error, 0 = no error)
 - Bit 14: Unexpected TC packet count (1 = not sequential, 0 = no error)
 - Bit 13: TM transfer confirmation error (1 = error, 0 = no error)
 - Bit 12: Reserved, set to 0 (TNC, originally reserved for Event TM confirmation)
 - Bit 11: Format error in incoming message (1 = error, 0 = no error)
 - Bit 10: Loop back error in outgoing message (1 = error, 0 = no error)
 - Bit 9: Time Out error in transmission (1 = error, 0 = no error)
 - Bit 8: Handshake error in DPRAM (1 = error, 0 = no error)
 - Bits 0 to 7(MSB): not used
- word3 = Copy of the TM Packet Transfer Confirmation of the last invalid TM confirmation.
- word4 = RT internal subframe count for the last invalid TM packet confirmation
- word5 = Housekeeping information:
 - Bits 8 to 15(LSB): Last TM packet confirmed counter
 - Bits 0 to 7 (MSB): not used
- word6 = Application Level Error information:
 - Bit 15 (LSB): General TM queue is full (1 = error, 0 = no error)
 - Bit 14: Science TM queue is full (1 = error, 0 = no error)
 - Bit 13: TC queue is full (1 = error, 0 = no error)
 - Bit 12: No free TM map blocks (1 = error, 0 = no error)
 - Bit 11: No free TC map blocks (1 = error, 0 = no error)
 - Bit 10: TM queue resource access time out (1 = error, 0 = no error)
 - Bit 9: TM packet size is not valid (1 = error, 0 = no error)
 - Bit 8: TM packet pointer is not valid (1 = error, 0 = no error)
 - Bit 7: TC packet size is not valid (1 = error, 0 = no error)
 - Bit 6: TC packet pointer is not valid (1 = error, 0 = no error)
 - Bit 5: 2 ms window time out (1 = error, 0 = no error)
 - Bit 4: TM counter 600 is not valid (1 = error, 0 = no error)
 - Bit 3: TM counter 602 is not valid (1 = error, 0 = no error)
 - Bit 2: TM counter 604 is not valid (1 = error, 0 = no error)
 - Bit 1: Spare (1 = error, 0 = no error)
 - Bit 0 (MSB): SF time out (1 = error, 0 = no error)

Note 1: The returned SF counter shall correspond to the DPU_ASW internally implemented SF counter, not to the one received from the CDMS; however, the DPU_ASW will verify that both of them are identical.

Note 2: All error bits shall be set when the corresponding event occurs, and shall be cleared after a BC SA 1T message processed.

The Health & Status data of the LFI is made available at the subaddress 1R at the frame sync at the beginning of each new second.

6.1.12.2 ASYNCHRONOUS TC PACKET TRANSFER

No asynchronous TC packets are foreseen for LFI.



6.1.12.3 ASYNCHRONOUS TM PACKET TRANSFER

No asynchronous TM packets are foreseen for LFI.

6.1.12.4 LOW LEVEL COMMANDING

Low Level Commanding for PLANCK – LFI, that is writing any data at 28R subaddress, provides a HW reset of the DPU.

Another kind of low level action is the synchronisation of the REBA. Since the On Board Time of the satellite is distributed within the communication protocol between Bus Controller and Remote Terminals, a procedure is available for the automatic synchronisation of the REBA every second. This feature, that is normally disabled and can be activated by TC, is intended to be used only in case of failure of the nominal synch procedure that uses the protocol service 9.

6.1.12.5 TELEMETRY FORMAT

Telemetry is sent to the CDMS according to the Herschel/Planck Packet Structure ICD (RD10).

6.1.12.6 TIMING

The signal received from the CDMS to synchronise the on board time in instrument with respect to that of the spacecraft has a maximum absolute error less than +/- 250 μ s.

6.1.12.7 TELE-COMMAND FORMAT

The telecommands to the REBA comply with the telecommand standards of ESA.

Telecommands are received from the CDMU by the REBA according to the Herschel/Planck Packet Structure ICD (RD10).

6.1.12.8 SPECIAL SIGNALS

6.1.12.8.1 On Board Clock Synchronisation Signal

It is required by the instrument to receive from the spacecraft (CDMS) the on board spacecraft clock at a frequency of 131072 Hz to allow the instrument to generate its internal clocks. This same clock shall be distributed from the CDMS to the other instruments and SCS. The long term frequency stability of this clock shall be no worse than 1×10^{-6} over a period of 30 days. The short term frequency stability of this clock shall be no worse than 1×10^{-6} over a period of 100 seconds.

LFI requires four On Board Clock (OBC) synchronisation signals. They are allocated thus:

- one OBC synchronisation signal to the nominal REBA
- one OBC synchronisation signal to the redundant REBA



- two OBC synchronisation signal to the DAE

A cross coupling between nominal and redundant clock generators is performed on the S/C side to ensure that the redundancy of the signal is assured.

6.1.12.9 APPLICATION PROCESS IDENTIFIERS

The set of Application Process Identifiers (APIDs) available to the instrument is given in the Herschel/Planck Packet Structure ICD (RD10).

The APIDs of LFI are the following:

Description	APID
Telecommands	0x600
TM packets for TC acceptance non periodic TM packets Essential HK packets	0x600
TM type 3 packets (HK & diagnostic telemetry)	0x602
TM type 21 packets (Science telemetry including calibration)	0x604

Table 6.1-4 Available APIDs for LFI

Note: no redundant APIDs are used by LFI. Both nominal and redundant interfaces use the same APIDs since they are never ON simultaneously.

6.1.13 ATTITUDE AND ORBIT CONTROL/POINTING

6.1.13.1 ATTITUDE AND ORBIT CONTROL

The uncertainty in beam position on the sky from the sum of all errors should be no greater than 1/10 of the smaller beam width.

Calibration and measurements of the LFI beam patterns is obtained in-flight using the signal from external planets, as they fall in the field of view of the instrument. Jupiter and Saturn, in particular, provide an adequate microwave source for beam calibration. This places a requirement on the flight plan: each of the two full sky surveys shall include at least one passage in the field of view of LFI, for each array beam, of these two external planets.

6.1.13.2 POINTING

The pointing accuracy required by the LFI is slightly more relaxed than that required by the HFI due to the different maximum angular resolution but during the sky survey mode the Planck Pointing requirements, as specified in the Table 6.1-5, applies for both LFI and HFI.

They are applicable to any detector LoS of the instruments. The LoS of an instrument is defined as the direction on the observed sky of the radiometric centre of a detector's far field pattern as rejected by the telescope.



Instrument teams perform LoS calibrations wrt ACMS sensor LoS by receiving ACMS raw attitude information, and correlate the data with own data. The output is a bias estimation with a residual error less than 0.15 arcmin. This calibration is performed weekly, and its contribution to AME is excluded from the values in the Table 6.1-5.

ERROR	Line of sight (arcmin)	Around line of sight (arcmin)
APE	< 37	< 37
PDE (24 hours)	< 6.2	< 6.2
RPE (55 min)	< 1.5	< 10
AME (see note 2)	< 0.5	< 6
PRE (20 days) (see note 1)	< 2.5	-

Table 6.1-5 The Pointing Direction Requirements of LFI

Note 1: The PRE applies only to the spin axis after redirection and with in the spin axis pointing domain of up to +/- 10 degrees from the anti-Sun pointing direction, and not to the single repointings foreseen after every 55 minutes whose inter-relation is governed by the APD.

Note 2: The pointing direction data available on the ground post-facto must allow the pointing direction of each LFI data sample to be calculated within the AME. The time scale for each data sample is 9.3 milliseconds.

The nominal spin axis motion about the spacecraft +X-axis pointing to the Anti-Sun is at constant rate of +1 rpm (6 °/sec).

The spacecraft is capable of re-pointing the spin axis to +/- 10° away from the sun.

Between 2 consecutive re-orientation manoeuvres, the spin rate drift or fluctuation over one hour is less than 10^{-4} rpm

The Absolute Rate Error (ARE) about the satellite spin axis is better than 5.4 arcmin/s.

6.1.14 ON-BOARD HARDWARE/SOFTWARE AND AUTONOMY FUNCTIONS

6.1.14.1 ON-BOARD HARDWARE

TBW

6.1.14.2 ON-BOARD SOFTWARE

On board S/W is written in C language and follows the pertinent requirements in IID-A (Section 5.13.2) concerning process control, on-board memory loading, dumping and autonomy functions.

On-board software is compliant with the ESA software standard PSS-05-02 and amended by the "Guide to applying the ESA software engineering standards to small projects" BSSC(96)2.

Both the DPU and the SPU contain their own separate PROM SW activated during switchon of the REBA. The ASW of both the DPU and the SPU are stored in EEPROM in the DPU. After initialisation at switch-on using the PROM SW in both units, under ground control, the DPU ASW



is downloaded into RAM. The SPU ASW is then download and transferred to the SPU RAM under ground control using the DPU ASW.

The switch-on procedure for the LFI REBA showing the relationship between the REBA PROM SW and ASW during this process is shown in the flow diagram Figure 13-1.

6.1.14.2.1 Prom Software

6.1.14.2.1.1 DPU Prom Software

The DPU PROM SW is either started at power-on, EDAC, processor watchdog, or software resets. The DPU PROM SW performs the initialisation and checking of the health of the unit including, at least, the following functions:

During initialisation from switch-on

- PROM check self-test
- RAM consistency checking
- EEPROM checking.
- EDAC checking
- execution of self-tests on all other hardware devices that support it.
- configuration and initialisation of the MIL-STD-1553B link to communicate with the CDMS.
- storing of the results of the start-up sequence in a specific memory area to be available for a further request from the CDMS.
- At the end of initialisation it shall be capable of
- processing a predefined set of commands from the CDMS
- send REBA HK packets to the CDMS
- download the DPU ASW, on ground command, from EEPROM to RAM
- pass control to the DPU ASW on ground command

6.1.14.2.1.2 SPU Prom Software

The SPU PROM SW is either started at power-on, EDAC, processor watchdog, or software reset.

The SPU PROM SW performs the initialisation and checking of the health of the unit including, at least, the following functions:

- PROM check self-test
- RAM consistency checking
- EDAC checking
- execution of self-tests on all other hardware devices that support it.
- configuration and initialisation of the IEEE 1355 which communicates with the DPU_ASW.
- storing the results of the start-up sequence in a specific memory area to be available for a further request from the DPU_ASW.
- At the end of initialisation it is capable of
- processing a predefined set of commands from the DPU_ASW
- pass control to the SPU ASW on ground command

6.1.14.2.2 Application Software (ASW)

The REBA_ASW performs the following functions:

SPU_ASW

- reception of raw science data from DAE
- reduction of raw science data



- lossless compression of the science data to fit the data rate and TM packet size
- transfer of the compressed and reduced data to the DPU_ASW for further transmission to CDMS
- control of the DAE SMCS chip which sends the scientific raw data.

DPU_ASW

- synchronise the instrument with the on board time (OBT) of the spacecraft.
- packetize the science and HK data and transfer it to the CDMS
- performs the monitoring of the instrument by comparing the HK with some nominal values, taking corrective actions and sending event reports to the CDMS when necessary
- performs the reception, acceptance and execution of TCs received from the CDMS.

These commands are originated in ground or in the CDMS, but all they arrive to the REBA through the CDMS.

- control of the different LFI operation modes
- control of the DAE SMCS chip which sends HK and receive instrument commands.
- maintenance software, in the sense that replaces or patch part of the on board software.
- control of overall LFI data rate and data volume towards the CDMS.
- communication with the SPU_SUSW to manage the start-up of the SPU_ASW

6.1.14.3 AUTONOMY FUNCTIONS

The operations of the LFI are designed to be automatic and require little if any intervention from the ground. Commands are up-linked occasionally for diagnostic and reconfiguration purposes.

Time tagged commands are sent to the instrument by the CDMS at the time that the time tag falls due and the instrument immediately executes the command. The instrument does not operate time tags internally.

LFI is dimensioned to allow 48 hours of continuous scientific operations without intervention from the ground. Thus in the case of a single missed visibility period, no potential loss of scientific data and thus degradation of the scientific mission would occur.

The following Autonomy Functions are foreseen:

- To allow REBA to switch off the FEMs on the basis of temperature measured on the structure of the 20K cold FPU by the LFI temperature sensors
- To overwrite science telemetry in case the REBA is not readout
- To manage science telemetry output to not overflow CDMS storage space that has been allocated
- To not hang in case of SPU-CPU load overload
- To reconnect the 1355 links to the DAE in case of soft errors

6.1.14.3.1 Satellite Survival and Standby Modes

The table below describes the subsystems and instruments modes associated to each satellite mode.

Spacecraft Mode	Instruments Mode
Launch Mode	OFF except 4K cooler in Launch Lock
Sun Acquisition Mode (SAM)	OFF, Standby or Science
Nominal Mode (NM)	OFF, Standby or Science
Earth Acquisition Mode (EAM)	OFF, Standby or Science



Survival Mode (SM) | OFF

NB: the table specifies the status at entry or re-entry into the mode. It remains possible, via relevant telecommand, to individually change the subsystems or instrument mode while in any of the S/C mode.

As it clearly appears :

- The instruments science activities can happen not only when the spacecraft is in Nominal Mode but also when in Sun or Earth acquisition;
- When the satellite is in Launch Mode, only the 4K cooler electronics is ON, in Launch Lock;
- When the satellite is in SM all the instruments are turned OFF..

The consequences from instruments operation point of view are:

- The transition to Earth Acquisition Mode is accompanied by a loss of all CDMU functions; no TM acquisition, TC distribution, time distribution will be performed during this time. The Science Mission cannot be continued. Anyway the instrument is not harmed by this configuration. At return from this «dead time», in EAM the instruments will be polled in «HK only» mode (see Par. 14.2), and could therefore be commanded in «standby».
- In case of transition from Nominal Mode to Sun Acquisition Mode, the Science Mission cannot be continued as planned, and at entry into SAM, the instruments telemetry will be acquired again. No lack of power from main power supply is expected.

6.1.15 EMC

6.1.15.1 CONDUCTED EMISSION/SUSCEPTIBILITY

Note that the REBA primary power is modulated by the operations of the application software. See PL-LFI-PST-RFW-012 Issue 1, October 13th 2006.

6.1.15.2 RADIATED EMISSION/SUSCEPTIBILITY

Radiation emission and susceptibility in line with spacecraft interface specifications.

6.1.15.3 FREQUENCY PLAN

6.1.15.3.1 FEM

- 4096 Hz Phase Switch (50% duty cycle)

6.1.15.3.2 DAE

DAE Power box:

- 100 kHz DC/DC converters PWM frequency
- 1 MHz Command link from the BEU Box

DAE BEU Box and Lateral Trays:

- 131072 Hz On Board Clock signal



- 1 Hz Synchronisation signal from the REBA
- 4096 Hz Phase Switch frequency
- 8192 Hz Science data sampling frequency
- 20 MHz Sequencer internal clock
- 1 Hz HK acquisition frequency
- 10/80 MHz 1355 serial data digital interface
- 1 MHz Internal transfer of digital data

6.1.15.3.3 REBA

- 100 kHz DC/DC converters PWM frequency
- 131072 Hz On Board Clock signal
- 1 Hz Synchronisation signal to the DAE
- 1 MHz Mil 1553B Bus frequency
- 10/80 MHz 1355 serial data digital interface
- 18 MHz Clock frequency of the DSP

6.2 INTERNAL INTERFACES

6.2.1 RAA

6.2.1.1 RADIOMETER ARRAY ASSEMBLY INTERFACE CHARACTERISTICS

6.2.1.1.1 Mechanical Interface

6.2.1.1.1.1 Venting

The RAA is vented in all of its parts, including FEMs, BEMs and Waveguides. See details of the venting in the ICDs of the various components of the RAA.

6.2.1.1.1.2 Viewing, Location and Alignment

The RAA is locked to the telescope structure by means of the three bipods and a waveguide support structure, whereas the BEU is positioned on top of the SVM and the DAE Power Box is located on the bottom side of the SVM top cover.

The alignment of the FPU with HFI and the telescope is provided by means of suitable mechanical tolerances. The final alignment is also tested at LFI+HFI level.

6.2.1.1.2 Thermal Interface

6.2.1.1.2.1 Thermal Interface Control Drawing



The RAA is composed by three main units: the Front End Unit (FEU), the Back End Unit (BEU) and the DAE Power Box. The BEU components are mounted on top of the Planck Service Module at about 300 K.

All the FEMs are connected to the BEU (@ T= 300 K) by means of waveguides (WGs), which carry the microwave signals from the HEMTs and by means of the cryo harness that carries the bias currents for the RF amplifiers and phase switches. Both the WGs and the Cryo harness are connected to the V-grooves in order to dissipate the heat coming from the BEU interface. Materials, dimensions and treatments of the WGs and the cryo harness are selected considering the performances and the level of thermal insulation of the FEU that has to minimise the heat load on the 20 K stage.

The following figure shows a schematic picture of the configuration of the 44 LFI WGs in the RAA that connect the 20K FEU to the BEU. The picture also shows the location of the three shields, to which the WGs are thermally (and mechanically) linked. The positions of the thermal links are defined in the table below.

The thicknesses of the various materials are the following:

- Stainless Steel = 254 μm
- Gold plating = 2 μm
- Copper = 400 μm

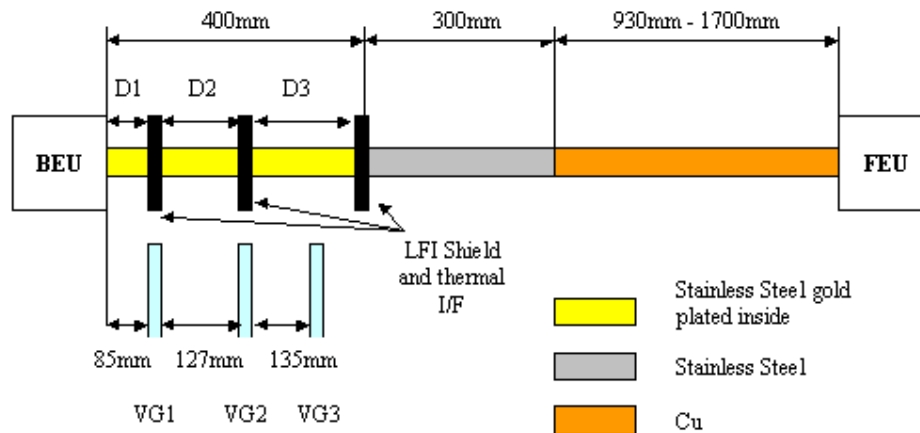


Figure 6-12 WG configuration

Interface point	Position	Temperature
BEU starting point	On the relevant BEM flanges	313.16 K
1 st V-groove	Through the first strap at a distance d1 = 83mm	166.2 K
2 nd V-groove	Through the first strap at a distance d2 = 130mm	106.2 K
3 rd V-groove	Through the first strap at a distance d3 = 187mm	51.4 K and 57.6 K
FEU ending point	On relevant FEM flanges	20 K



6.2.1.1.3 Electrical Interface

6.2.1.1.3.1 Power Interface

The RAA is powered with a redundant primary power line connected to the DAE Control Box.

6.2.1.1.3.1.A Power Supply For Science Chains

For each power group DAE shall provide an independent DC/DC converter having the following outputs.

- +5(6)Vdc for DAE electronics that generate the bias of the HEMTs housed in the FEMs
- 5V(6)dc for DAE electronics that generate the bias of the HEMTs housed in the FEMs
- Ground reference

- +5(6)Vdc for DAE electronics that generate the controls for the Phase Switches housed in the FEMs

- +5(6)Vdc for DAE electronics that generate the controls for the Phase Switches housed in the FEMs
- Ground reference

- +5(6)Vdc for: BEM power supply;
- -5V(6)Vdc for: BEM power supply;
- Ground reference

6.2.1.1.3.1.B "Service" Power Supply

The DAE provides a dedicated DC/DC Converter to supply digital and analogue devices (including science data acquisition chains) of the DAE Data Acquisition.

It provides the following power lines

- +5(6)Vdc for digital electronics of the DAE Data Acquisition
- Ground reference

- +12 Vdc for analogue electronics of the DAE Data Acquisition (FPA Temperature measurements)
- +5(6)Vdc for analogue electronics of the DAE Data Acquisition
- -5(6)Vdc for analogue electronics of the DAE Data Acquisition
- Ground reference

6.2.1.1.3.1.C Expected Loads On Science DC/DC



Power demand on DC/DC of RCAs is different in case LFI is operated at warm temperature (FPU @ 300 K) rather than at nominal temperature (20K). In that case the power demand of the FEMs and of the relevant drivers provided by the DAE Data Acquisition is higher.

The expected power loads for cold operation are here below shown:

Power Load @ 20K (mW)

	PWR	30				44				70			
		Qty	BEM	FEM	ΦS W	Qty	BEM	FEM	ΦS W	Qty	BEM	FEM	ΦS W
	DEMAND		2677	27	4		2388	34	4		604	24	4
Pwr g. 1	2882	0	0	0	0	1	2388	34	4	1	604	24	4
Pwr g. 2	3443	1	2677	27	4	0	0	0	0	2	1208	48	8
Pwr g. 3	5693	1	2677	27	4	1	2388	34	4	2	1208	48	8
Pwr g. 4	2882	0	0	0	0	1	2388	34	4	1	604	24	4
TOT.	14900												

Note: Power demand of the FEMs @ 20 K has been computed assuming 8 mA for each drain line of each FEM according to LFI Interface Control Document

The expected power load for warm operation are shown below:

These values have to be considered TBC because they tightly depend on the philosophy approach and configuration that will be adopted in Radiometer Array Assembly operations.

Power Load @ 300K (mW)

	PWR	30				44				70			
		Qty	BEM	FEM	ΦS W	Qty	BEM	FEM	ΦS W	Qty	BEM	FEM	ΦS W
	DEMAND		2677	280	4		2388	280	4		604	280	4
Pwr g. 1	3384	0	0	0	0	1	2388	280	4	1	604	280	4
Pwr g. 2	4208	1	2677	280	4	0	0	0	0	2	1208	560	8
Pwr g. 3	6704	1	2677	280	4	1	2388	280	4	2	1208	560	8
Pwr g. 4	3384	0	0	0	0	1	2388	280	4	1	604	280	4
TOT.	17680												

Note: Power demand of the FEMs @ 300 K has been computed assuming 50 mA for each drain line of each FEM according to LFI Interface Control Document.

A scheme of the Feed Horns arrangement on focal plane and relevant power grouping and numbering is shown in Figure 6-13.

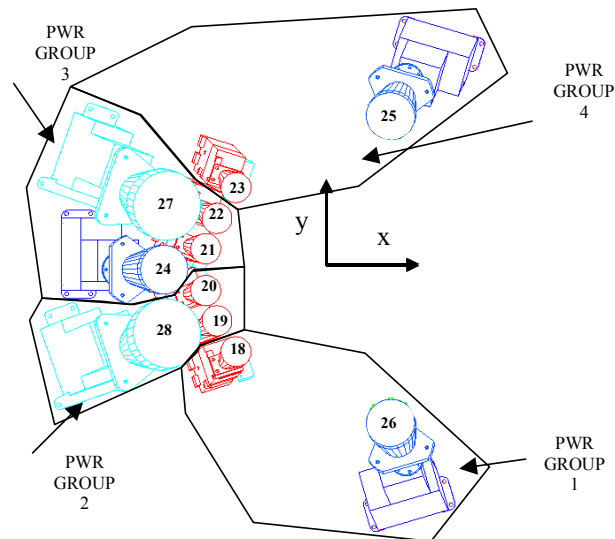


Figure 6-13 Feed Horns arrangement on focal plane and relevant grouping and numbering

6.2.1.1.3.1.D Expected Loads On Service DC/DC

Service DC/DC (mW)

Service DC/DC	15000

6.2.1.1.3.2 Power and Voltage Data Sheet

TBW

6.2.1.1.3.3 Current Limiters

Current limiters are foreseen for the drain bias lines toward the FEMs. The drain bias lines is limited to a maximum of about 60mA per line.

6.2.1.1.3.4 Electrical Interface Circuits

6.2.1.1.3.4.A 1355 lines

The 1355 lines are interfaced with standard LVDS drivers (90C31) and receivers (90C32) in Figure 6-14 and Figure 6-15.

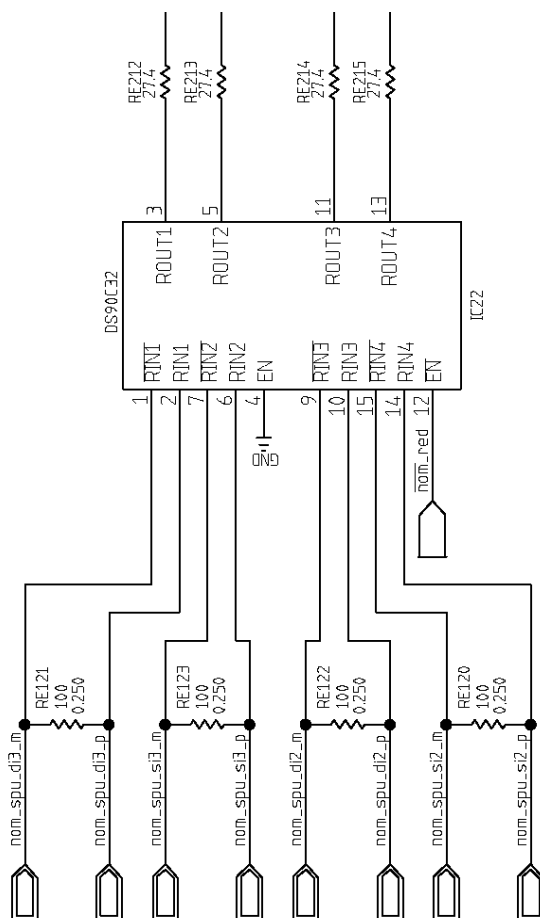


Figure 6-14 1355 receiver interface circuit

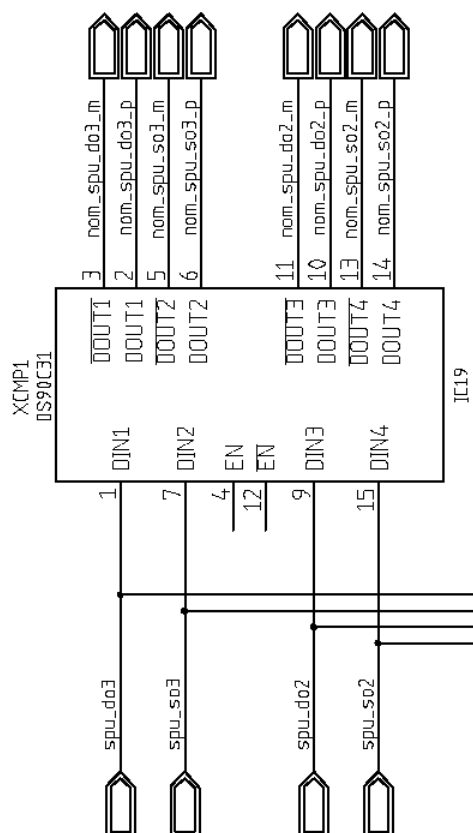


Figure 6-15 1355 driver interface circuit

6.2.1.1.3.4.B RS422 lines

The RS422 lines between the DAE and the REBA are interfaced on the DAE side by means of standard RS422 drivers (26C31) and receivers (26C32) in Figure 6-16 and Figure 6-17.

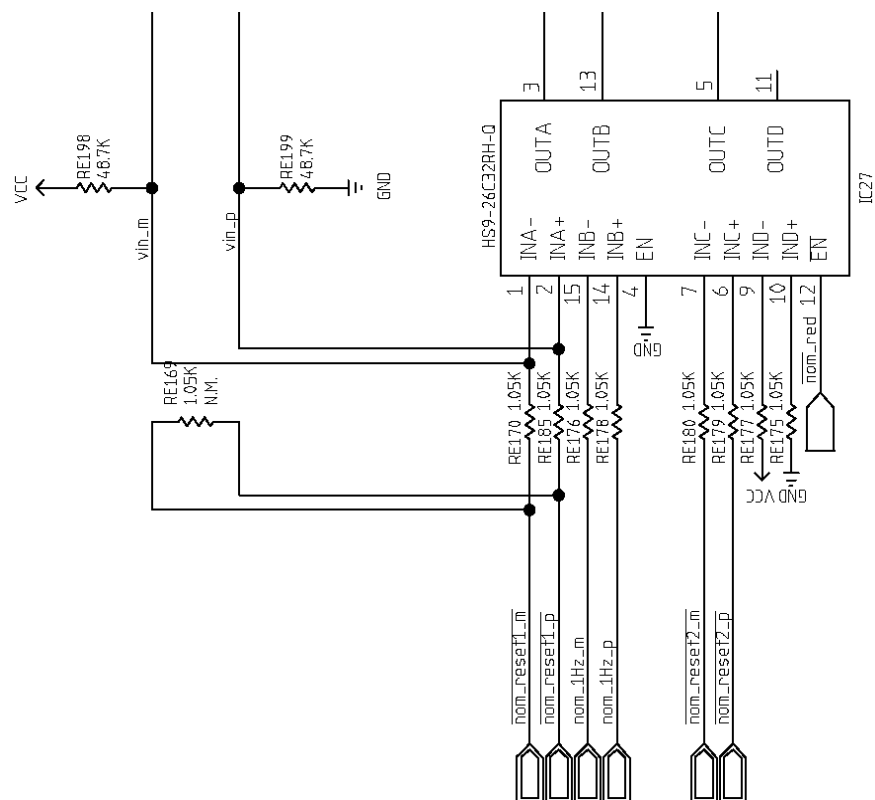


Figure 6-16 RS422 receiver interface circuit

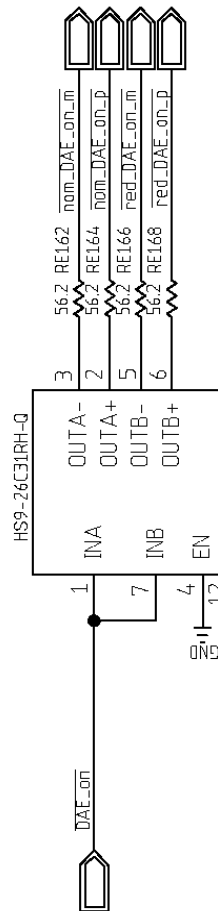


Figure 6-17 RS422 driver interface circuit

6.2.1.1.3.4.C FEM LNAs bias lines

The FEM LNAs is biased providing 1 drain line per channel (that is 4 per FEM) and 2 gate lines per channel (that is 8 per FEM) as shown in Figure 6-18 and Figure 6-19.

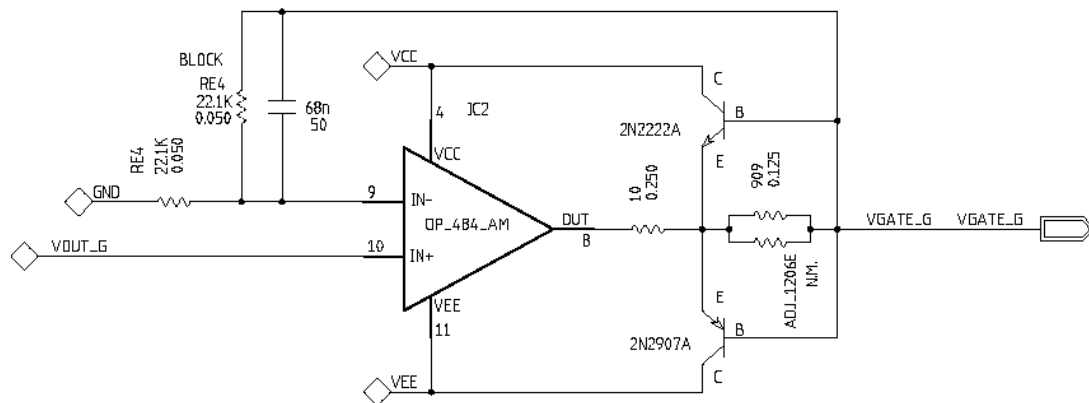


Figure 6-18 Gate bias interface circuit

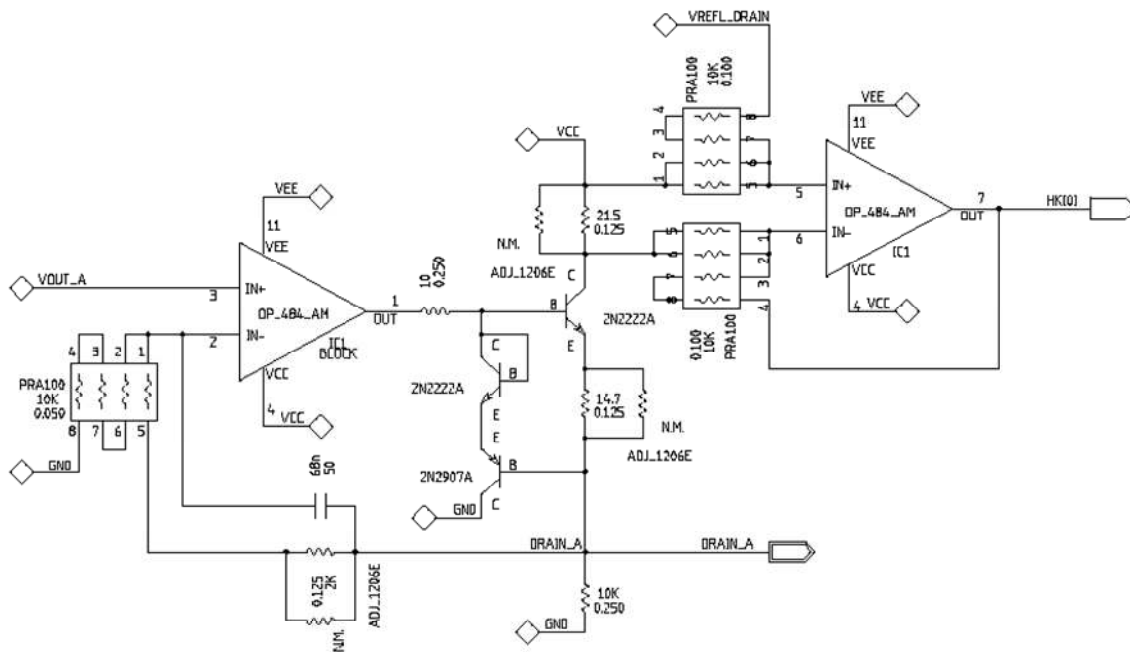


Figure 6-19 Drain bias interface circuit

6.2.1.1.3.4.D FEM Phase switches bias lines

The FEM Phase switches, shown in Figure 6-20, is biased providing 2 lines per channel (that is 8 per FEM) each capable of providing a direct bias current or a reverse bias voltage.

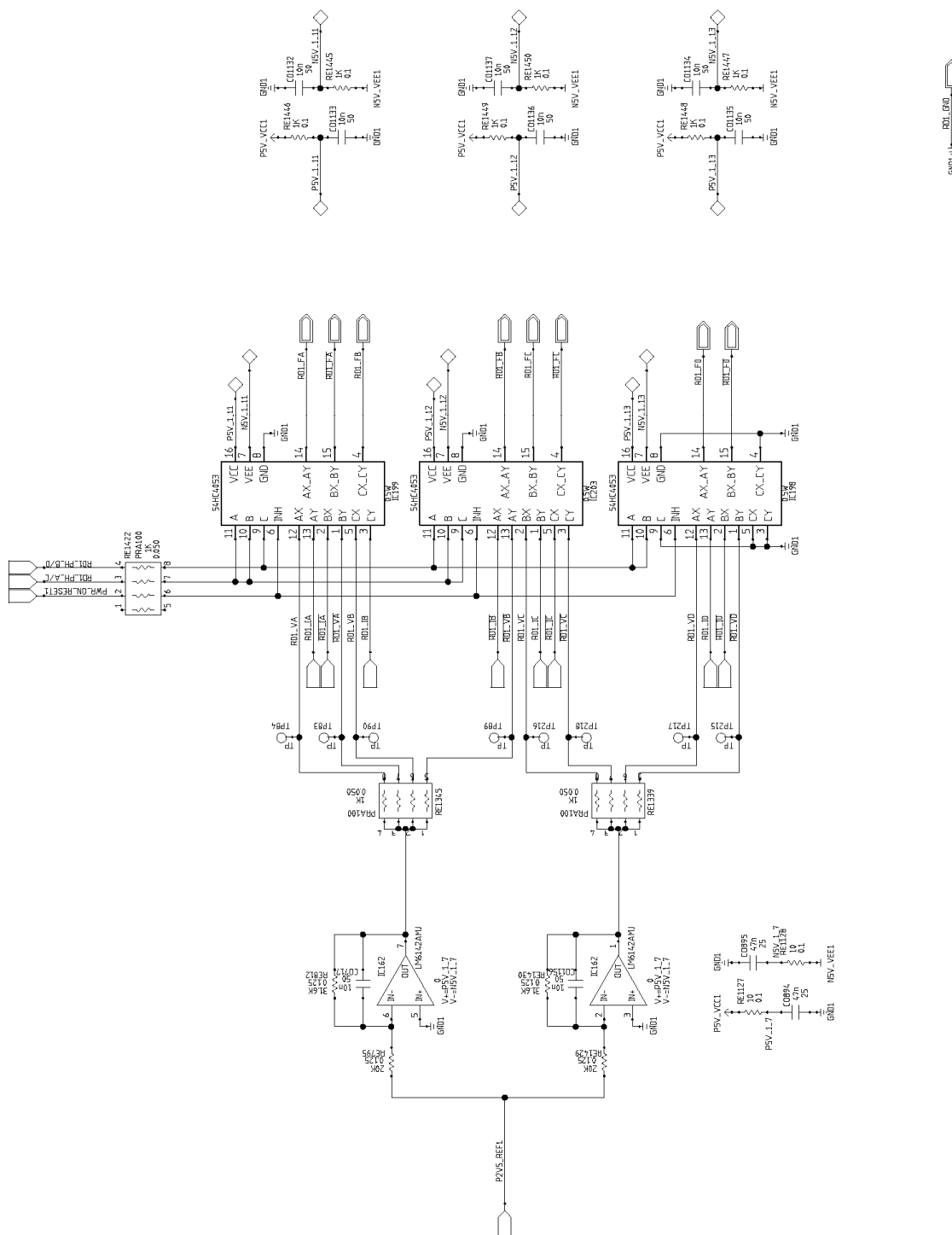


Figure 6-20 Phase switch bias interface circuit

6.2.1.1.3.4.E *BEM bias lines*



The BEM bias lines are taken directly from the output of the secondary winding of the DC/DC converter, after filtering.

The provided lines carry the +5V, -5V and the reference ground that is connected to chassis locally into the BEMs.

6.2.1.1.3.4.F *Analog acquisition chain lines*

The analog acquisition chains, shown in Figure 6-21, are fed by the output of the BEMs and are devoted to condition and digitize the science data. One differential line per channel (4 couples per BEM) is provided.

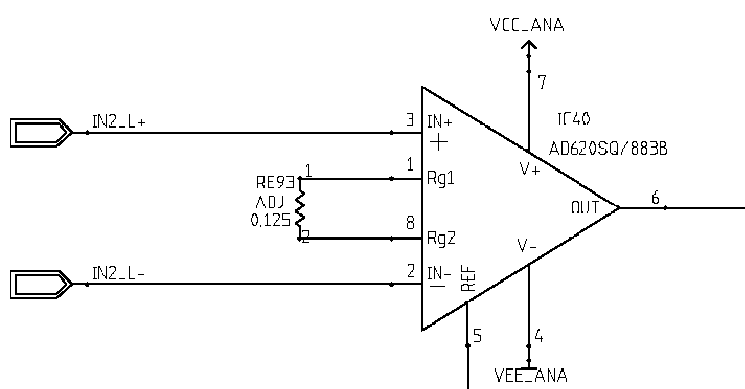


Figure 6-21 *Analog acquisition chain input interface circuit*

6.2.1.1.3.4.G *Temperature sensor lines*

TBW

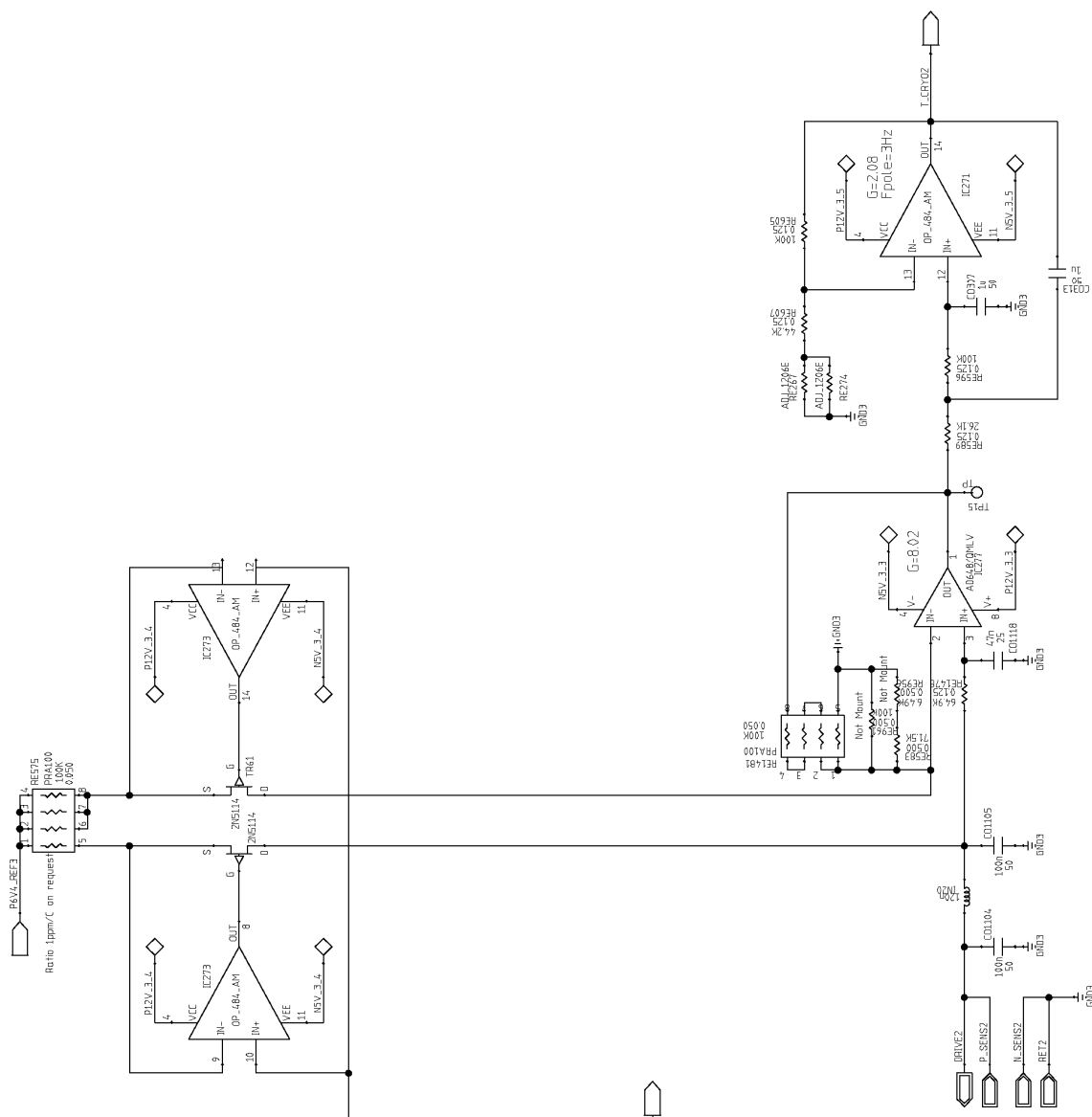


Figure 6-22 Temperature sensor

6.2.1.1.3.4.H 30 GHz FEM INPUT CIRCUITS

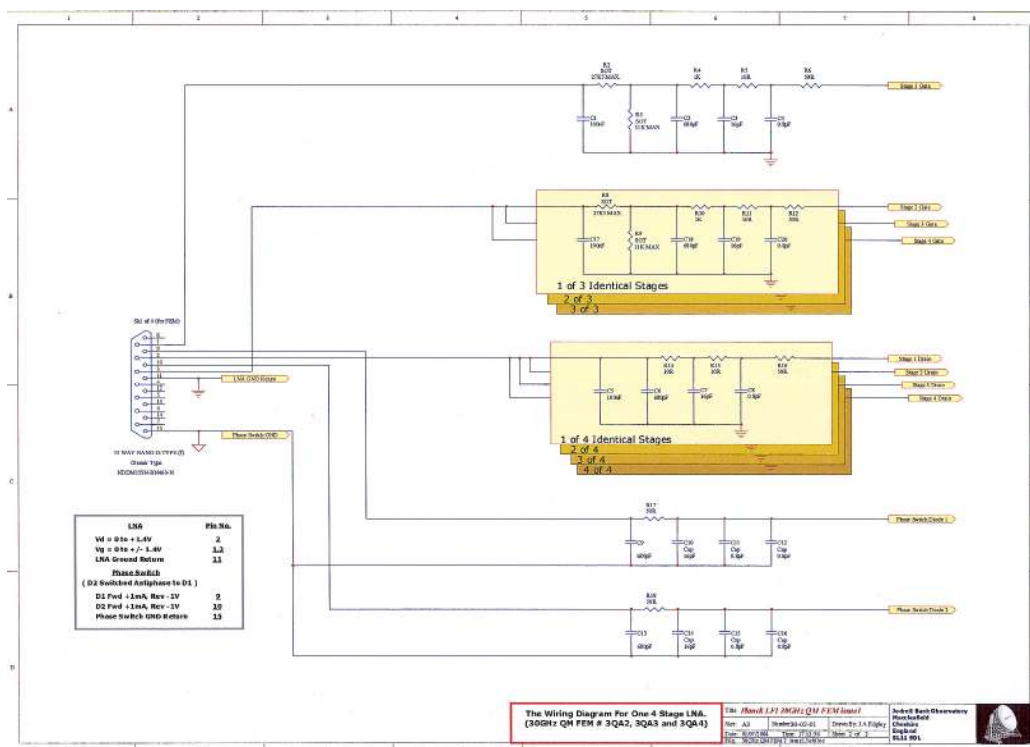


Figure 6-23 30 GHz FEM Wiring Diagram for One 4 Stage LNA

6.2.1.1.3.4.I 44 GHz FEM INPUT CIRCUITS

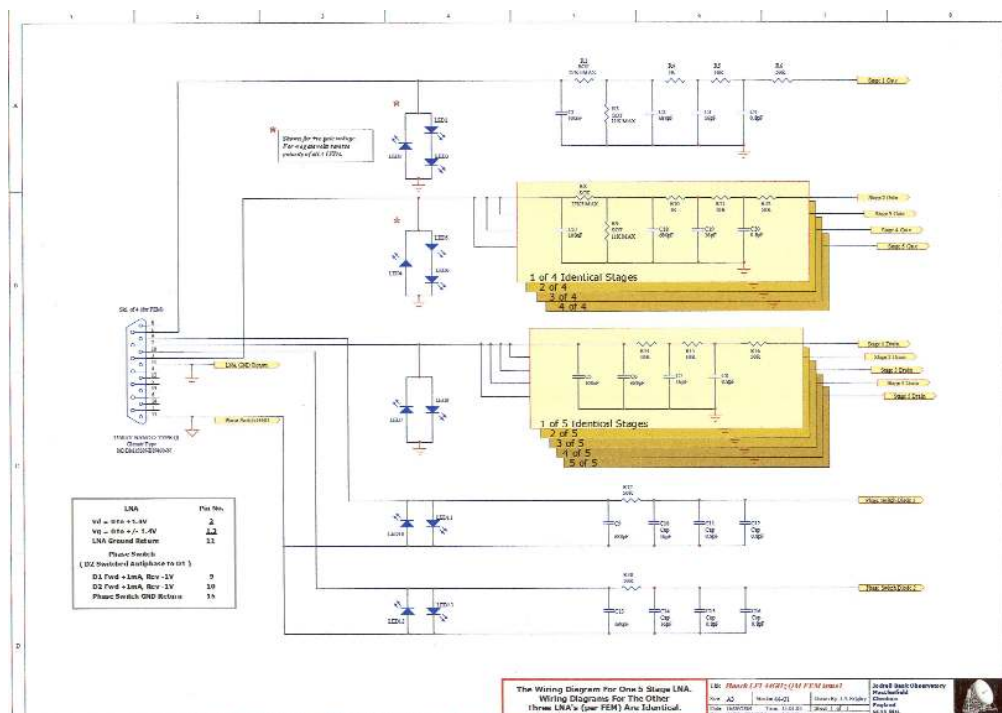


Figure 6-24 44 GHz FEM Wiring Diagram for One 4 Stage LNA

6.2.1.1.3.4.J 70 GHz FEM INPUT CIRCUITS

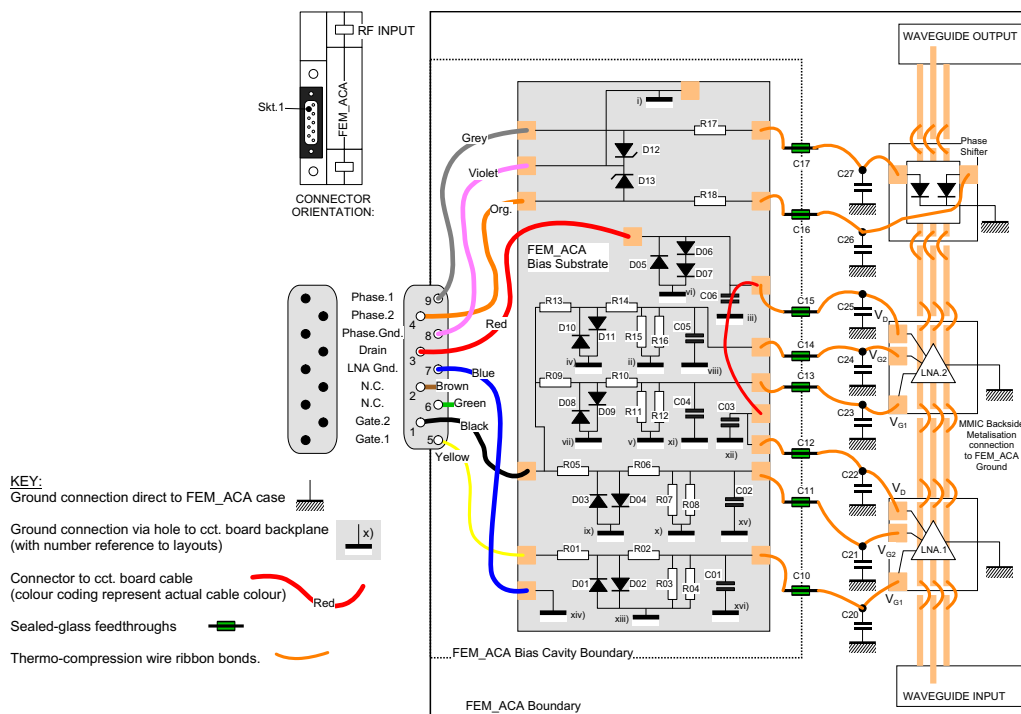


Figure 6-25 70 GHz FEM Wiring Diagram for One 4 Stage LNA



6.2.1.1.3.4.K 30 GHz and 44 GHz BEM I/F CIRCUITS

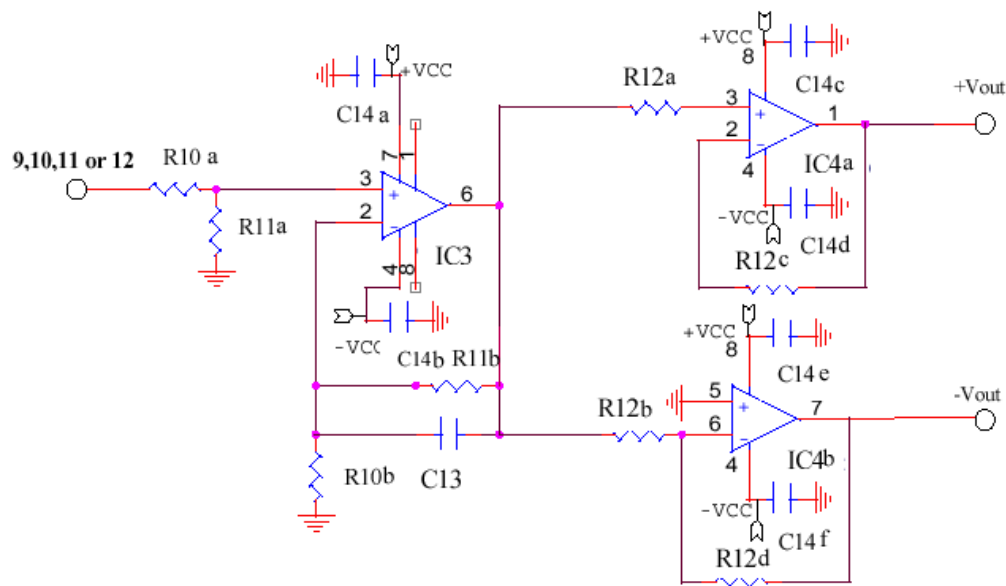


Figure 6-26 30 GHz and 44 GHz BEM Output circuit

6.2.1.1.3.4.L 70 GHz BEM I/F CIRCUITS

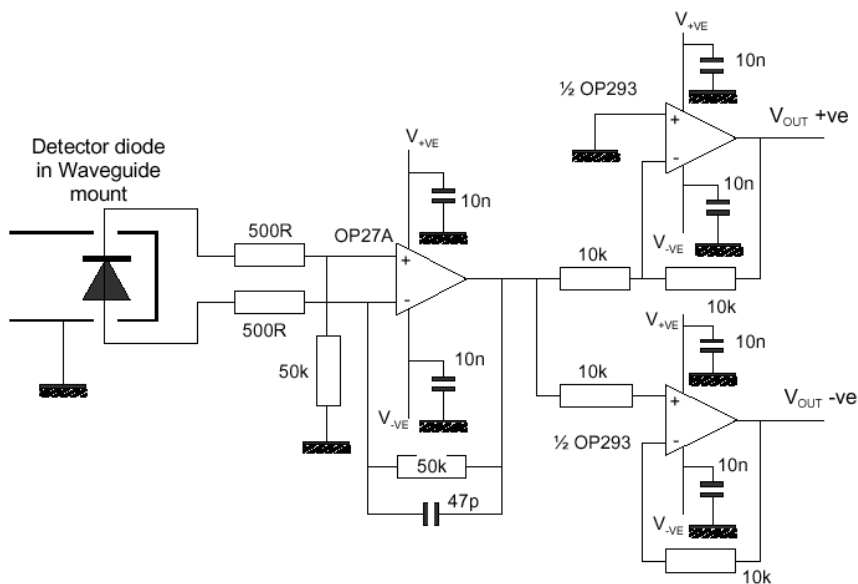


Figure 6-27 70 GHz BEM Output circuit

6.2.1.1.3.4.M REBA TO DAE I/F CIRCUITS



TBW

6.2.1.1.3.5 Harness Interface

In the following table is reported the name, description, location and part number of the connectors located on the surfaces of all the boxes that compose the DAE.

J01	Nominal Primary Power (PWBOX)	DEM 9P
J02	Redundant Primary Power (PWBOX)	DEM 9P
J03	Nominal OBC (DAE-BEU)	DEM 9P
J04	Redundant OBC (DAE-BEU)	DEM 9P
J05	Left Tray Power (PWBOX)	DD 3401-001-01B-DBMA50SNMB1A7N
J06	Right Tray Power (PWBOX)	DD 3401-001-01B-DBMA50SNMB1A7N
J09	Nom. REBA Link (DAE-BEU)	DD 3401-001-01B-DDM50PNMB1A7N
J10	Red. REBA Link (DAE-BEU)	DD 3401-001-01B-DDM50PNMB1A7N
J11	Left BIAS Pwr (Tray)	HD 3401-001-02B-DEM15PNMB1A7N
J12	Right BIAS Pwr (Tray)	HD 3401-001-02B-DEM15PNMB1A7N
J13	Left PHSW Pwr (Tray)	HD 3401-001-02B-DAM26PNMB1A7N
J14	Right PHSW Pwr (Tray)	HD 3401-001-02B-DAM26PNMB1A7N
J15	Left BIAS Cmd Link (Tray)	HD 3401-001-02B-DBM44PNMB1A7N
J16	Right BIAS Cmd Link (Tray)	HD 3401-001-02B-DBM44PNMB1A7N
J17	Left PHSW Cmd Link (Tray)	HD 3401-001-02B-DBM44PNMB1A7N
J18	Right PHSW Cmd Link (Tray)	HD 3401-001-02B-DBM44PNMB1A7N
J19	Left BIAS Cmd Link (DAE-BEU)	HD 3401-001-02B-DBM44SNMBOL3
J20	Right BIAS Cmd Link (DAE-BEU)	HD 3401-001-02B-DBM44SNMBOL3
J21	Left PHSW Cmd Link (DAE-BEU)	HD 3401-001-02B-DBM44SNMBOL3
J22	Right PHSW Cmd Link (DAE-BEU)	HD 3401-001-02B-DBM44SNMBOL3
J23	Left BEM Tray Power (Tray)	DD 3401-002-01B-DEMA9PNMBFO
J24	Right BEM Tray Power (Tray)	DD 3401-002-01B-DEMA9PNMBFO
J25	FH 21-27-24 BEM Sign. (L Tray)	HD 3401-002-02B-DBMA44SNMBFO
J26	FH 19-28-20 BEM Sign. (R Tray)	HD 3401-002-02B-DBMA44SNMBFO
J27	FH 22-25-23 BEM Sign. (L Tray)	HD 3401-002-02B-DBMA44SNMBFO
J28	FH 18-26 BEM Sign. (R. Tray)	HD 3401-002-02B-DBMA44SNMBFO
J29	FH 21-27-24 BEM Sign. (L DAE-BEU)	HD 3401-001-02B-DBM44PNMB1A7N
J30	FH 19-28-20 BEM Sign. (R DAE-BEU)	HD 3401-001-02B-DBM44PNMB1A7N
J31	FH 22-25-23 BEM Sign. (L DAE-BEU)	HD 3401-001-02B-DBM44PNMB1A7N
J32	FH 18-26 BEM Sign. (R. DAE-BEU)	HD 3401-001-02B-DBM44PNMB1A7N
J33	FH 27-21 BIAS (Tray)	MWDM-5L-31P-BRR3T.150
J34	FH 28-19 BIAS (Tray)	MWDM-5L-31P-BRR3T.150
J35	FH 27-21 PHSW (Tray)	MWDM-5L-21P-BRR3T.150
J36	FH 28-19 PHSW (Tray)	MWDM-5L-21P-BRR3T.150
J37	FH 24-22 BIAS (Tray)	MWDM-5L-31P-BRR3T.150
J38	FH 20 BIAS (Tray)	MWDM-5L-31P-BRR3T.150
J39	FH 24-22 PHSW (Tray)	MWDM-5L-21P-BRR3T.150
J40	FH 20 PHSW (Tray)	MWDM-5L-21P-BRR3T.150



J41	FH 25-23 BIAS (Tray)	MWDM-5L-31P-BRR3T.150
J42	FH 26-18 BIAS (Tray)	MWDM-5L-31P-BRR3T.150
J43	FH 25-23 PHSW (Tray)	MWDM-5L-21P-BRR3T.150
J44	FH 26-18 PHSW (Tray)	MWDM-5L-21P-BRR3T.150
J45	LEFT FPU Temp. Sens. (Tray)	MWDM-5L-25P-BRR3T.150
J46	RIGHT FPU Temp. Sens. (Tray)	MWDM-5L-25P-BRR3T.150
J47	PWBOX CMD Link (PWBOX)	HD 3401-001-02B-DAMA26SNMB1A7N
J48	PWBOX CMD Link (DAE-BEU)	HD 3401-001-02B-DAM26PNMBOL3
J49	DAE-BEU PWR (PWRBOX)	DD 3401-001-01B-DEMA9SNMB1A7N
J50	DAE-BEU PWR (DAE_BEU)	DD 3401-001-01B-DEM9PNMBOL3

Table 6.2-1 DAE Connectors list

6.2.1.1.3.6 Electrical Interface Data Sheets

The electrical interfaces toward the RCAs show the following feature.

Vgate1

Nominal (Max.) voltage:	1V (2V)
Voltage range:	-4.0V to +2.0V
Voltage programmable steps:	8 bit, ~ 25 mV/step
Differential linearity	± 0.5 LSB
Absolute maximum ratings	-4.0V to +2.0V
Nominal (Max.) Current	100µA (100µA)

Vgate2

Nominal (Max.) voltage:	1V (2V)
Voltage range:	-4.0V to +2.0V
Voltage programmable steps:	8 bit, ~ 25 mV/step
Differential linearity	± 0.5 LSB
Absolute maximum ratings	-4.0V to +2.0V
Nominal (Max.) Current	100µA (100µA)

Vdrain

Nominal (Max.) voltage:	1V (1.4V)
Voltage range:	0V to +1.4V
Voltage programmable steps:	8 bit, ~ 8 mV/step
Differential linearity	± 0.5 LSB
Absolute maximum ratings	-0.1V to +1.4V
Nominal (Max.) Current	50mA (50mA)

Φswitch

	Line 2, pos.	Line 2, neg.
Nominal (Max.) voltage	+0.7V	-3.0V



Absolute maximum ratings	+0.8V	-4.0V
Nominal (Max.) Current	500 μ A (1mA)	0 μ A (20 μ A)
Programmability boundaries	0 – 1000 μ A	N/A
Current programmability steps	8 bit, $\sim$ 4 μ A/step	N/A

Table 6.2-2 FEM bias interface characteristics

+5V line	
Voltage:	+5 Vdc
Accuracy:	$\pm$ 10%
Nominal current:	depending on the BEM
Max. Curr.	
Ripple	40mV peak
Spikes	100mV peak

-5V line	
Voltage:	-5 Vdc
Accuracy:	$\pm$ 10%
Nominal current:	depending on the BEM
Max. Curr.	
Ripple	40mV peak
Spikes	100mV peak

Table 6.2-3 BEM power supply interface characteristics

The REBA to DAE I/F are standard digital interfaces as already described before.

6.2.1.1.3.7 Connector and Cable Arrangements (CCAs)

All the connector interfaces of the RAA toward the REBA and the S/C are reported in Planck – LFI – Data Acquisition Electronic Interface Control Document [RD8] (refer to Figure 6.2-11).

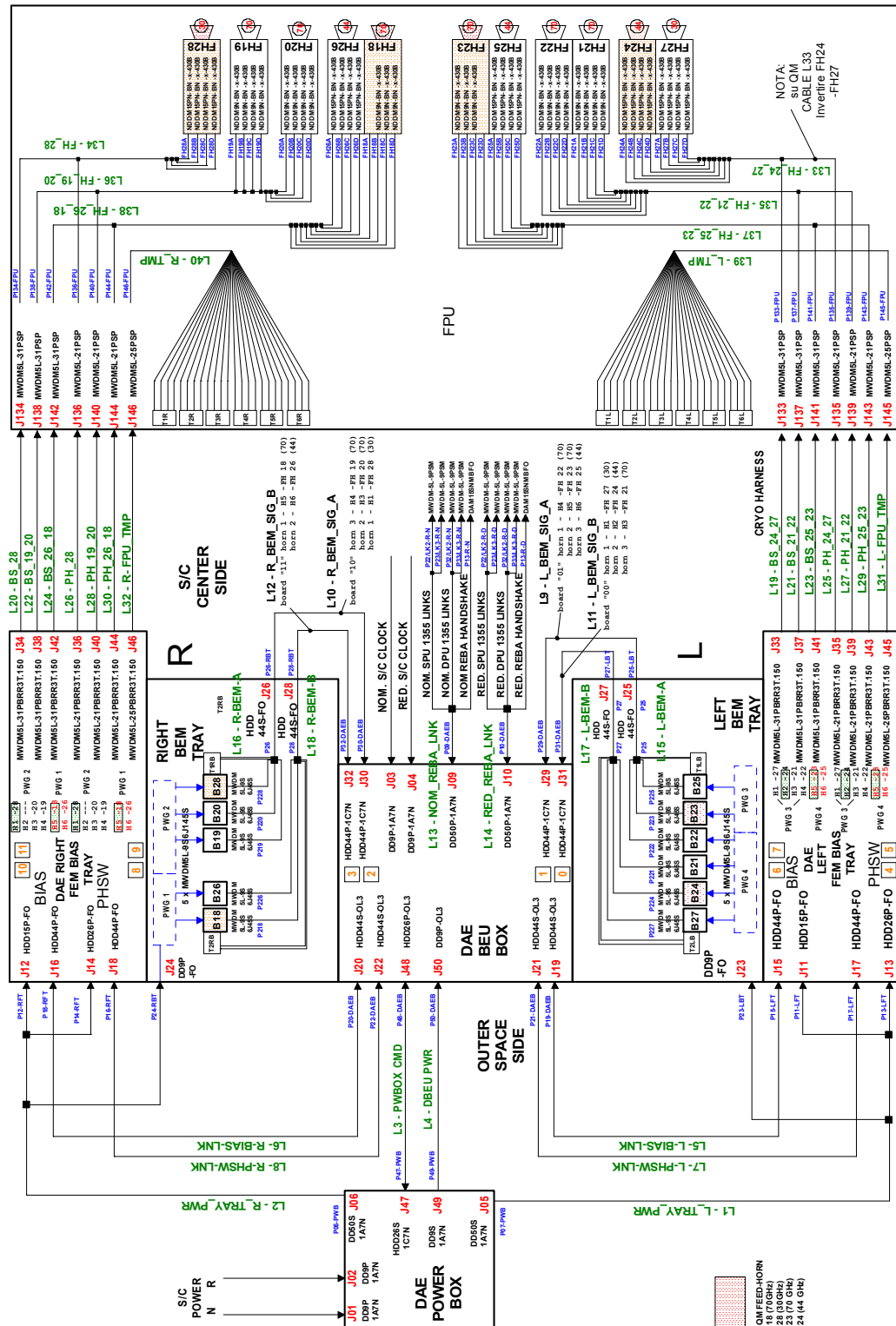


Figure 6-28 Schematic diagram of the connectors



6.2.1.1.4 Electromagnetic Compatibility

6.2.1.1.4.1 Twisting, Shielding and Grounding

Refer to the Figure 6-11.

6.2.1.1.4.2 Bonding

Due to the structure and the composition, the bonding of the RAA to the SVM is obtained through the bonding studs provided by both the BEU box and the Power Box to be connected to the bonding straps provided by SVM according to AD1. The Power Box connects to ground the secondary of the DC/DC converter that powers the logic of the DAE. The RCA DC/DC converter returns are connected to chassis at the Focal Plane that is electrically connected to the SVM reference mainly through the WGs, the structure of the BEU and its bonding lug. Other far less important current paths are provided by the SCS pipes and the thermal straps that connects the WG to the V-grooves.

In the table below the waveguide resistance values are given.

WG bundle	Resistance (m Ω)	
	@20 K	@300 K
30	11.8	27.3
44	14.7	34.1
70	26.2	60.5

6.2.1.1.4.3 Susceptibility & Emission

TBW

6.2.1.2 FRONT END UNIT INTERFACE CHARACTERISTICS

6.2.1.2.1 Mechanical Interface

6.2.1.2.1.1 Unit Identification and Location

The FEU is constituted from Feed-horns, OMT and FEMs. It is located in the instrument so that the feed-horns phase centres lies on the Focal Plane of the telescope

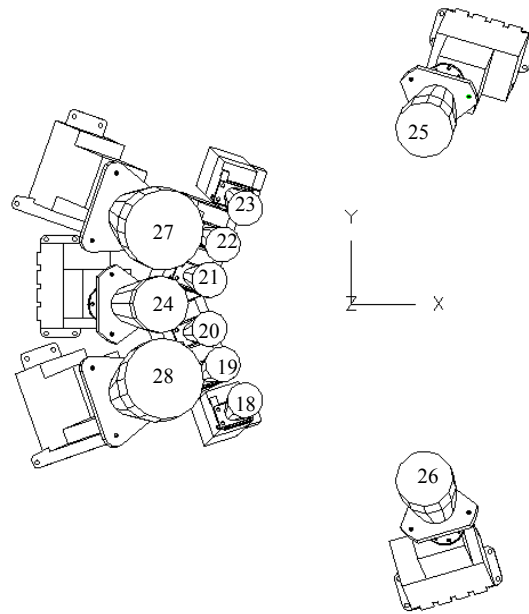


Figure 6-29 FEU drawing sketching the disposition of horns, OMT and FEMs

6.2.1.2.1.2 Unit Mechanical Drawings

See ICDs of the components at the various frequencies.

6.2.1.2.1.3 Mass Properties Data Table

LFI MASS BUDGET						BUDGET				
Project Code	WBS Code	Sub System	Unit	Ass.y	Sub-Ass.y	#	Unit [kg]	Est. [kg]	Cont. [%]	Total [kg]
PLFEU	===	FEU						22.935	1%	23.185
	PLAGA	FE Structure + Bipodes + FEU internal wiring						17.680	1%	17.857
	PLAGA/A + PLAGA/B + PLAHC		Main Frame					17.680	1%	17.857
		FEED HORN + OMTs						2.825	1%	2.853
	PLAAA+PLAAB		30 GHz			2		0.842	1%	0.850
	PLABA+PLABB		44 GHz			3		0.908	1%	0.917
	PLACA+PLACB		70 GHz			6		1.750	1%	1.086
	===	FEM's						2.478	2%	2.561
	PLAAC	30 GHz				2	0.405	0.810	1%	0.818
	PLABC	44 GHz				3	0.386	1.110	1%	1.121
	PLACC	70 GHz				6	0.085	0.510	5%	0.536
LFI MASS BUDGET						BUDGET				
Project Code	WBS Code	Sub System	Unit	Ass.y	Sub-Ass.y	#	Unit [kg]	Est. [kg]	Cont. [%]	Total [kg]
PLFEU	===	FEU						22.965	10%	25.341
	PLAGA	FE Structure						17.807	10%	19.588
	PLAGA/A	Main Frame						14.540	10%	15.994



	PLAGA/B	Bipodes		1.089	3.267	10%	3.594
	===	FEED HORNS			1.200	5%	1.260
	PLAAA	30 GHz	2	0.201	0.402	5%	0.422
	PLABA	44 GHz	3	0.106	0.318	5%	0.334
	PLACA	70 GHz	6	0.080	0.480	5%	0.504
	===	OMTs			1.401	5%	1.471
	PLAAB	30 GHz	2	0.228	0.456	5%	0.479
	PLABB	44 GHz	3	0.195	0.585	5%	0.614
	PLACB	70 GHz	6	0.060	0.360	5%	0.378
	===	FEM's			2.557	18%	3.022
	PLAAC	30 GHz	2	0.416	0.832	18%	0.982
	PLABC	44 GHz	3	0.375	1.125	20%	1.350
	PLACC	70 GHz	6	0.100	0.600	15%	0.690

Table 6.2-4 FEU mass subdivided by its components

6.2.1.2.1.4 Viewing, Location and Alignment

The FEUs are directly connected to the mainframe structure so the alignment is provided by the RAA alignment (see above in 6.2.1.1.1.2).

6.2.1.2.2 Thermal Interface

6.2.1.2.2.1 Thermal Interface Control Drawing

The FEU is composed by 11 sub units; each of these is formed by: feed horn, orthomode transducer (OMT) and front end module (FEM). Each FEM is interfaced with an external reference load, which provide a stable blackbody reference signal at about 4 K (called '4K Reference Load').

From the thermal point of view the FEU is the most challenging unit of the LFI because it has to be cooled at 20 K by means of the Planck Sorption Cooler Subsystem (SCS). A high level of thermal insulation from the Equipment Platform at 300 K and from the telescope structure at about 50K is required.

An aluminium main frame (MF) supports all the FEU components and the Cold End units of the SCS. Moreover the MF has to support the HFI, ensuring the right electrical, thermal and mechanical interfaces. The MF is connected to the telescope by means of three bipods that support it against mechanical loads during the satellite launch phase. The bipods are also in charge of the thermal decoupling between the FEU (@ 20K) and the telescope structure (@ 50 K).

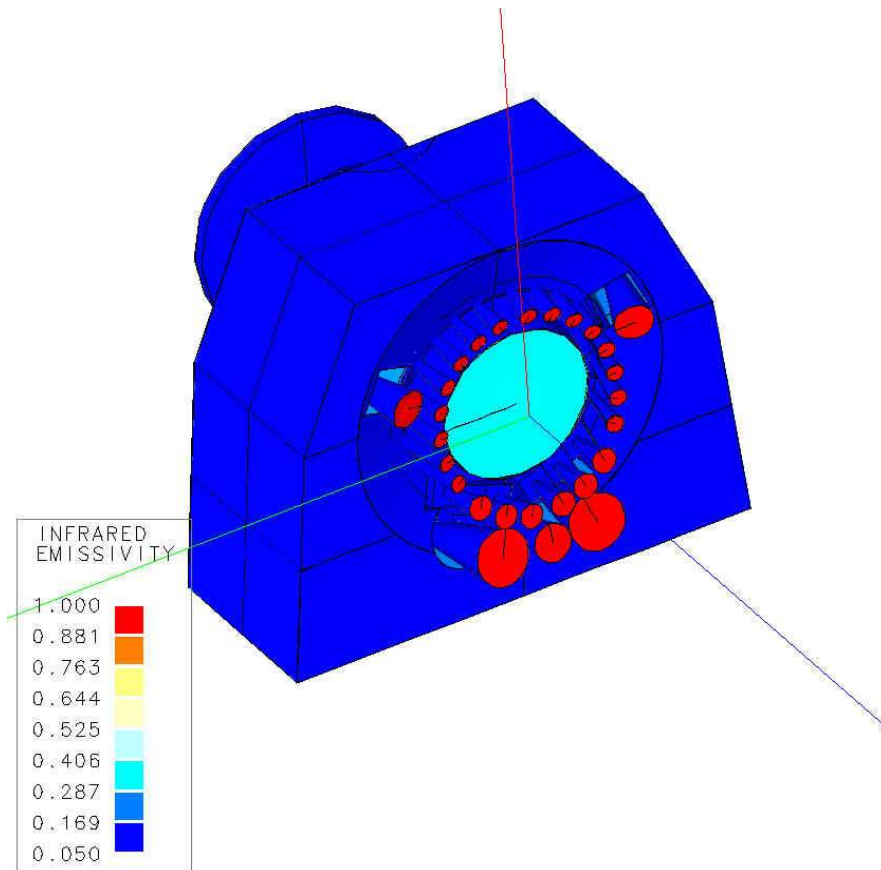


Figure 6-30 Esarad FPU thermal model

The FEU scientific performances depend strictly from its thermal behaviour. Then, the following thermal requirements are identified for the FEU:

- Maximum operative temperature for the HEMT devices has to be less than 25 K
- The thermal stability requests that temperature variations synchronous with spacecraft spin (1 min.) has to be below 0.050 mK for feed horns and 0.2 mK for HEMTs.

The maximum power dissipated in the FEU and the total heat flux received on the FPU is limited by the cooling power of the Sorption Cooler.

6.2.1.2.2.2 Unit Qualification and Acceptance Temperature Limits

The LFI FPU is qualified as a single unit, but the interface temperature requirements has been tested separately on the RCAs.

6.2.1.2.3 Electrical Interface

6.2.1.2.3.1 Harness Interface



The BEU to FEU harness (named also 'cryo-harness') interconnects the 20K to 300K instruments parts (FEM to BEM respectively).

The number of signals to be considered in defining the cryo-harness are the following:

- each FEM module is composed by 4 channels and for each of them the following signal are foreseen:
 - DRAIN bias line
 - GATE 1 bias line
 - GATE 2 bias line
 - 8192Hz Clock line (a)
 - 8192Hz Clock line (NOTa)
- moreover for each FEM are foreseen the following ground lines:
 - GND return bias line
 - 8192Hz Clock lines Return

A total of 22 signals are foreseen for each FEM module.

The signals must be divided into EMC categories since power supply variations or noise can induce changes in the HEMT (High Electron Mobility Transistor) performance leading to instability of the signals.

The signal categories (considering the EMC immunity requirements) for each channel are the following:

- DRAIN bias line - GATE 1 bias line - GATE 2 bias line - GND Return Power line - Shield	Group 1 EMC Class (Power lines)
- 8192Hz Clock line (a) - 8192Hz Clock line (!a) - 8192Hz Clock lines Return - Shield	Group 2 EMC Class (Digital lines)

In the cryo-harness also the temperature sensors cables for the Front End Unit are considered. They are part of the Group 1 EMC class and allocated on dedicated connectors.

6.2.1.2.3.2 Connector and Cable Arrangements (CCAs)

Refer to Table 6.2-1 for the DAE connectors list.



The cryo-harness connectors on mainframe side are wall-mounted connectors on the two lateral panes of the mainframe as indicated in the conceptual picture here below.

The routing of the lines from these connectors to the FEMs is achieved with the FEU internal harness. This has the purpose of re-distributing the lines to the relevant FEM connectors but it has no thermal gradients across thus it isn't critical from the thermal point of view.

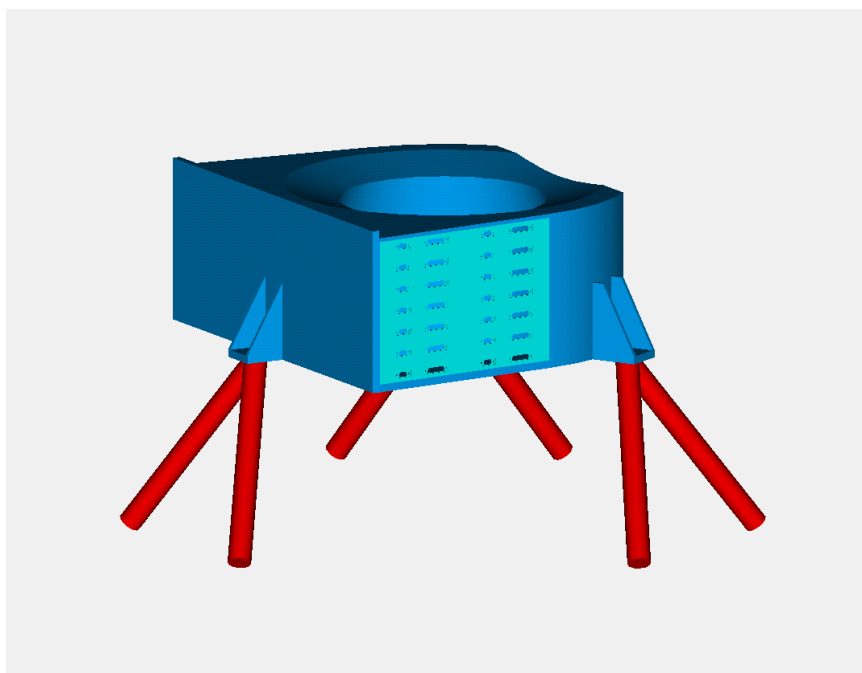


Figure 6-31 Concept of LFI main frame with wall mounted cryo harness connectors



6.2.1.2.4 Electromagnetic Compatibility

6.2.1.2.4.1 Twisting, Shielding and Grounding

See the overall grounding diagram of the RAA in Figure 6-11.

6.2.1.2.4.2 Isolation

No electrical isolation is possible for the FEU. The active parts (RF amplifiers) are bonded to the chassis by means of their semiconductor supporting substrate therefore the reference wires cannot be isolated.

6.2.1.2.4.3 Bonding

The FEU is bonded to the SVM satellite structure by means of the chassis interconnection of the FEMs with the mainframe and toward the BEU by means at least of the waveguide.

Other less effective bonding paths toward the SVM are through the Sorption Cooler pipes, but their characteristics are outside the scope of this document.

Notice that the bonding of the Mainframe to the PPLM structures and the telescope is not guaranteed or controlled but just obtained through the mounting of the carbon fibre bipods that become electrically conductive at 20 K.

6.2.1.2.4.4 Susceptibility & Emission

TBW

6.2.1.3 BACK END UNIT INTERFACE CHARACTERISTICS

6.2.1.3.1 Mechanical Interface

TBW

6.2.1.3.1.1 Unit Identification and Location

TBW

6.2.1.3.1.2 Unit Mechanical Drawings

TBW



6.2.1.3.1.3 Baseplate Flatness

The baseplate flatness is 0.1 / 100.

6.2.1.3.1.4 Mass Properties Data Table

LFI MASS BUDGET						BUDGET				
Project Code	WBS Code	Sub System	Unit	Ass.y	Sub-Ass.y	#	Unit [kg]	Est. [kg]	Cont. [%]	Total [kg]
PLBEU	===	BEU						25.542	1%	25.834
	PLAE0		DAE					23.130	1%	23.361
	PLAEA				DAE BEU Box			6.830	1%	6.898
	PLAEB				Lx BEM Tray Box			6.040	1%	6.100
	PLAEC				Lx FEM Tray Box					
	PLAED				Rx BEM Tray Box			5.750	1%	5.808
	PLAEE				Rx FEM Tray Box					
	PLAEF				Power Box			4.510	1%	4.555
	===		BEM's					2,412	3%	2,473
	PLAAD				30 GHz	2		0,624	1%	0,630
	PLABD				44 GHz	3		0,864	1%	0.873
	PLACD				70 GHz	6		0,924	5%	0.970
LFI MASS BUDGET						BUDGET				
Project Code	WBS Code	Sub System	Unit	Ass.y	Sub-Ass.y	#	Unit [kg]	Est. [kg]	Cont. [%]	Total [kg]
PLBEU	===	BEU						25.542	1%	25.834
	PLAE0		DAE					23.130	1%	23.361
	PLAEA				DAE BEU Box			6.830	1%	6.898
	PLAEB				Lx BEM Tray Box			6.040	1%	6.100
	PLAEC				Lx FEM Tray Box					
	PLAED				Rx BEM Tray Box			5.750	1%	5.808
	PLAEE				Rx FEM Tray Box					
	PLAEF				Power Box			4.510	1%	4.555
	===		BEM's					2,412	3%	2,473
	PLAAD				30 GHz	2		0,624	1%	0,630
	PLABD				44 GHz	3		0,864	1%	0.873
	PLACD				70 GHz	6		0,924	5%	0.970

Table 6.2-5 BEU mass subdivided by its components

6.2.1.3.1.5 Dynamic Characteristics

TBW

6.2.1.3.1.6 Venting

Each component of the BEU is vented through small holes present on the walls of each closed box.



6.2.1.3.2 Thermal Interface

6.2.1.3.2.1 Thermal Interface Control Drawing

TBW

6.2.1.3.2.2 Unit Thermal Data

TBW

6.2.1.3.3 Electrical Interface

TBW

6.2.1.3.4 Electromagnetic Compatibility

6.2.1.3.4.1 Twisting, Shielding and Grounding

Each of the DC/DC converters devoted to supplying the groups of RCAs provides at least three isolated output power group lines. One for the FEM amplifiers, one for the phase switches and one for the BEMs and acquisition chains. The chassis connection of the reference ground of each power line is done at the RF circuits locations. Therefore within each FEM for FEM amplifiers and phase switches supplies and within each BEM for the BEM power supply.

A total of four DC/DC converters are foreseen for supplying the 11 RCAs. Thus each DC/DC converter is dedicated to 2 to 4 RCAs. The corresponding channels are given in the table below.

Power group	frequency	RCA
1	70 GHz:	18
	44 GHz:	26
2	70 GHz:	19-20
	30 GHz:	28
3	70 GHz:	21-22
	44 GHz:	24
	30 GHz:	27
4	70 GHz:	23
	44 GHz:	25

Another DC/DC converter is inside the DAE Power Box for supplying the digital circuitry. Its reference ground is connected to chassis, as usual, locally to the DC/DC converter by means of an external bonding stud.

See Figure 6-13 for a scheme of the power group arrangement and numbering.



6.2.1.3.4.2 Bonding

The bonding of the BEU is obtained by means of a connection between the bonding lugs provided by each box of the BEU and the bonding strap provided by the SVM.

6.2.1.3.4.3 Susceptibility & Emission

TBW

6.2.1.4 RAA SUB-ASSEMBLIES AND UNITS INTERFACES

The table below reports the reference documents.

Ref.	ICD Annex	Document Title	Document Reference
[RD5]	Annex 2	30 GHz RCA Interface Control Document	PL-LFI-PST-ID-005
[RD6]	Annex 3	44 GHz RCA Interface Control Document	PL-LFI-PST-ID-006
[RD7]	Annex 4	70 GHz RCA Interface Control Document	PL-LFI-PST-ID-007
[RD8]	Annex 6	Data Acquisition Electronics Interface Control Document	PL-LFI-PST-ID-009
[RD25]	Annex 7	4K Reference Load Interface Control Document	PL-LFI-PST-ID-010
[RD26]	Annex 8	REBA Interface Control Document	FPL-IC-1214-02-CRS

Table 6.2-6 RAA S/A and Units ICDs Annexed to the LFI ICD

6.2.1.4.1 30 GHz RCA I/F

TBW

6.2.1.4.2 44 GHz RCA I/F

TBW

6.2.1.4.3 70 GHz RCA I/F

TBW

6.2.1.4.4 4 K I/F

TBW

6.2.2 REBA

TBW



6.2.3 HARNESS

All the LFI subsystems are interfaced with harness, whose architecture is described in the present document. The cables are presented according to the PLANCK LFI product tree, as summarised by the next block diagram.

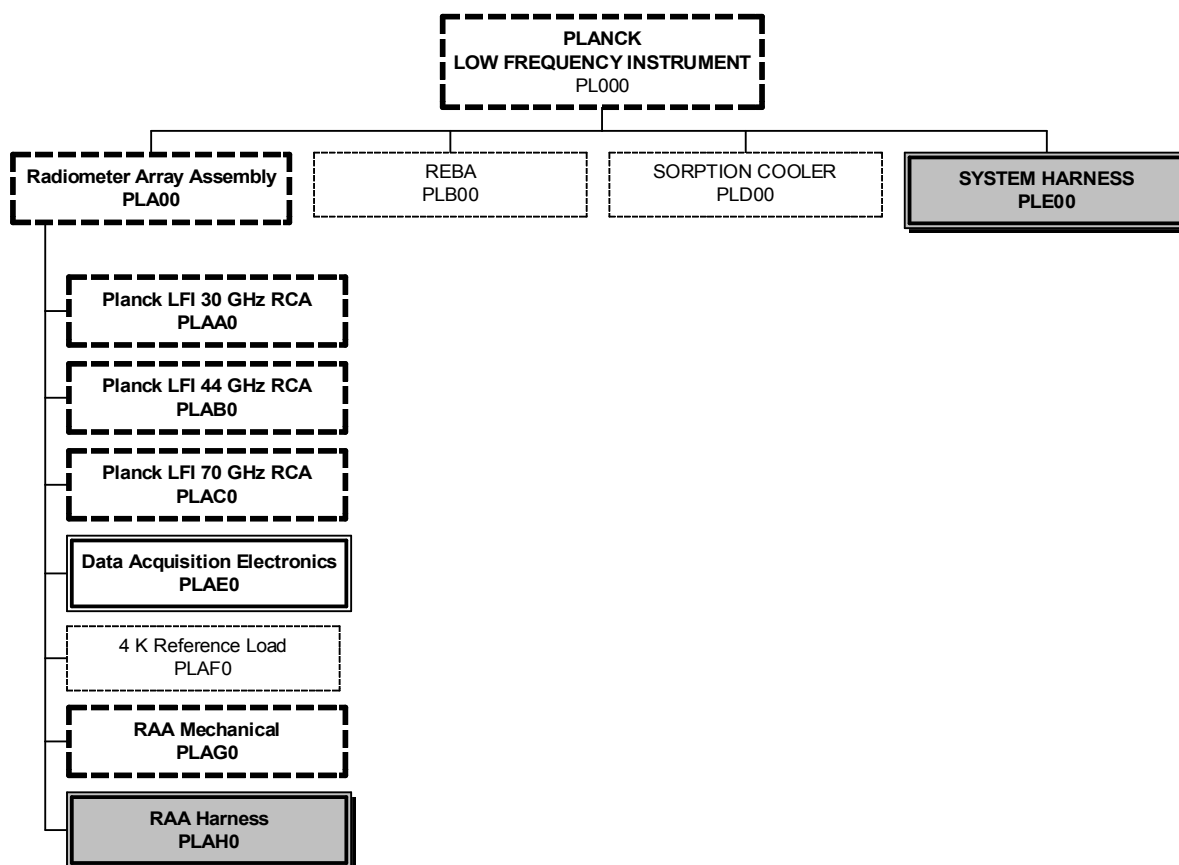


Figure 6-32 PLANCK LFI Product Tree

Two kinds of harnesses are treated, as shown in the diagram: the SYSTEM HARNESS (PLE00) and the RAA HARNESS (PLAH0). The first interfaces two subsystems, i.e. the REBA and the Radiometer Array Assembly, while the latter is internal to the RAA.

According to the baseline the DAE electronics is fully contained within the BEU and consists of 6 different boxes, the DAE BEU box, the POWER box and four Lateral Trays. The DAE interfaces with the FPU through the cryo-harness and with the REBA through the System Harness.

In the following discussion, odd connector identification numbers are used to identify connectors on the right side of the DAE, while even numbers identify the connections on the left side (see Figure 6-28).



1 cable plus its redundant is actually required for the system harness, as shown in the following table. Notice that a bracket is present along the cable but it is not indicated in the table.

CABLE NAME	ROLE	from	Conn. Type	to	Conn. Type	Wires
L13 - NOM-REBA-LNK	Data Link Nom. REBA	J09	DD DDMA50S	J13	DD DAMA15S	5 x TP 26 AWG 26
				J22	MWDM-5L-9PSM	4 x TP AWG 26
				J23	MWDM-5L-9PSM	4 x TP AWG 26
				J32	MWDM-5L-9PSM	4 x TP AWG 26
				J33	MWDM-5L-9PSM	4 x TP AWG 26
L14 - RED-REBA-LNK	Data Link Red. REBA	J10	HD DDMA50S	J13	DD DAMA15S	5 x TP 26 AWG 26
				J22	MWDM-5L-9PSM	4 x TP AWG 26
				J23	MWDM-5L-9PSM	4 x TP AWG 26
				J32	MWDM-5L-9PSM	4 x TP AWG 26
				J33	MWDM-5L-9PSM	4 x TP AWG 26

Table 6.2-7 System Harness overview

The DAE internal harness, the cryo-harness and the connections inside the FPU mainframe, routing the power lines from the cryo-harness to each FEM are grouped in the RAA Harness, which is also represented in the previous figure.

Power Box to BEU

CABLE NAME	ROLE	from	Conn. Type	to	Conn. Type	Wires
L1 - L_TRAY_PWR	Left Tray Power Supply	J05	DD DDMA50P	J11	HD DEMA15S	2 x TT AWG 24
				J13	HD DAMA26S	2 x TT AWG 24
				J23	DD DEMA9S	3 x TT AWG 24
L2 - R_TRAY_PWR	Right Tray Power Supply	J06	DD DDMA50P	J12	HD DEMA15S	
				J14	HD DAMA26S	
				J24	DD DEMA9S	
L3 - PWBOX CMD	PWR BOX CMD Link	J48	HD DAMA26S	J47	HD DAMA26P	4 x TP + 1 x TSP + 8 S AWG 26
L4 - DBEU PWR	DAE-BEU Pwr	J50	DD DEMA9S	J49	DD DEMA9P	1 x TT + 2 x TP AWG 22

DAE BEU to Lateral Trays

CABLE NAME	ROLE	from	Conn. Type	to	Conn. Type	Wires
L7 - L-PHSW-LNK	Left FEM PHSW b. CMD Link	J19	HD DBMA44P	J17	HD DBMA44S	
L8 - R-PHSW-LNK	Right FEM PHSW b. CMD Link	J20	HD DBMA44P	J18	HD DBMA44S	
L9 - L-BIAS-LNK	Left FEM Bias b. CMD	J21	HD DBMA44P	J15	HD DBMA44S	



	Link					
L10 - L-BIAS-LNK	Right FEM Bias b. CMD Link	J22	HD DBMA44P	J16	HD DBMA44S	

Lateral Trays to DAE-BEU

CABLE NAME	ROLE	from	Conn. Type	to	Conn. Type	Wires
L9 - L-BEM-SIG-A	Left BEM A Science Signals	J25	HD DBMA44P	J29	HD DBMA44S	12 x TSP + 1 TP AWG 26
L11 - L-BEM-SIG-B	Left BEM B Science Signals	J27	HD DBMA44P	J31	HD DBMA44S	12 x TSP + 1 TP AWG 26
L-10-R-BEM-SIG-A	Right BEM A Science Signals	J26	HD DBMA44P	J30	HD DBMA44S	12 x TSP + 1 TP AWG 26
L-12-R-BEM-SIG-B	Right BEM B Science Signals	J28	HD DBMA44P	J32	HD DBMA44S	12 x TSP + 1 TP AWG 26

BEM Trays to BEMs

CABLE NAME	ROLE	from	Conn. Type	to	Conn. Type	Wires
L15 - L-BEM-A	FH 22-25-23 BEM Sign. (L Tray)	J25	HD DBMA44S	BEM 23 Sign.	MWDM5L-09P-6J145L	
				BEM 25 Sign.	MWDM5L-09P-6J145L	
				BEM 22 Sign.	MWDM5L-09P-6J145L	
L16 - R-BEM-A	FH 19-28-20 BEM Sign. (R Tray)	J26	HD DBMA44S	BEM 20 Sign.	MWDM5L-09P-6J145L	
				BEM 28 Sign.	MWDM5L-09P-6J145L	
				BEM 19 Sign.	MWDM5L-09P-6J145L	
L17 - L-BEM-B	FH 21-27-24 BEM Sign. (L Tray)	J27	HD DBMA44S	BEM 24 Sign.	MWDM5L-09P-6J145L	
				BEM 27 Sign.	MWDM5L-09P-6J145L	
				BEM 21 Sign.	MWDM5L-09P-6J145L	
L18 - R-BEM-B	FH 18-26 BEM Sign. (R. Tray)	J28	HD DBMA44S	BEM 18 Sign.	MWDM5L-09P-6J145L	
				BEM	MWDM5L-09P-	



			26 Sign.	6J145L	

from FEM Bias Trays to FPU

CABLE NAME	ROLE	from	Conn. Type	to	Conn. Type	Wires
L19 - BS_24-27	FH 24-27-BIAS	J33	MWDM-5L-31S-x-J1xxM	J133	MWDM-5L-31S-x-J1xxM	
L21 - BS-21-22	FH 21-22 BIAS	J37	MWDM-5L-31S-x-J1xxM	J137	MWDM-5L-31S-x-J1xxM	
L23 - BS-25-23	FH 25-23 BIAS	J41	MWDM-5L-31S-x-J1xxM	J141	MWDM-5L-31S-x-J1xxM	
L25 - PH-24-27	FH 24-27-PHSW	J35	MWDM-5L-21S-x-J1xxM	J135	MWDM-5L-21S-x-J1xxM	
L27 - PH-21-22	FH 21-22-PHSW	J39	MWDM-5L-21S-x-J1xxM	J139	MWDM-5L-21S-x-J1xxM	
L29 - PH25-23	FH 25-23-PHSW	J43	MWDM-5L-21S-x-J1xxM	J143	MWDM-5L-21S-x-J1xxM	
L31 - L-FPU-TMP	LEFT-FPU-TEMP-SENS	J45	MWDM-5L-25S-x-J1xxM	J145	MWDM-5L-25S-x-J1xxM	
L20 - BS_28	FH 28-BIAS	J34	MWDM-5L-31S-x-J1xxM	J134	MWDM-5L-31S-x-J1xxM	
L22 - BS-19-20	FH 19-20 BIAS	J38	MWDM-5L-31S-x-J1xxM	J138	MWDM-5L-31S-x-J1xxM	
L24 - BS-26-18	FH 26-18 BIAS	J42	MWDM-5L-31S-x-J1xxM	J142	MWDM-5L-31S-x-J1xxM	
L26 - PH_28	FH 28-PHSW	J36	MWDM-5L-21S-x-J1xxM	J136	MWDM-5L-21S-x-J1xxM	
L28 -PH-19-20	FH 19-20-PHSW	J40	MWDM-5L-21S-x-J1xxM	J140	MWDM-5L-21S-x-J1xxM	
L30 - PH-26-18	FH 26-18-PHSW	J44	MWDM-5L-21S-x-J1xxM	J144	MWDM-5L-21S-x-J1xxM	
L32 - R-FPU-TMP	RIGHT-FPU-TEMP-SENS	J46	MWDM-5L-25S-x-J1xxM	J146	MWDM-5L-25S-x-J1xxM	

Table 6.2-8 RAA Harness overview

6.2.3.1 ENVIRONMENT

With the exception of the cryo-harness and the FEU internal harness, all other connections operate at the same temperature of the DAE.

6.2.3.1.1 REBA TO BEU Harness (PLEA0)

6.2.3.1.1.1 Overview

The REBA to BEU Harness, that constitutes the System Harness, routes the Science Link 1355 Bus for the transmission of the scientific data and the handshake (HK) and command (CMD) signals. Both are driven differentially by means of LVD and RS422 drivers respectively.



6.2.3.1.1.2 Science Link 1355

The connections are based on the chip SMCS332, which utilises 3 full-duplex links for the data transmission. The DAE implementation exploits only two of them (link no. 3 and 2) for the DAE to REBA connection while the third is connected between the two SMCS chips of the DAE.

Each output is followed by an LVD driver that reduces the power consumption and improve the data transmission speed.

6.2.3.1.1.3 HK & CMD 1355

The handshake and command signals between the DAE and the REBA DPU are exchanged by means of a dedicated 1355 link. As before this feature uses only two of the three available links while the third is connected to the other SMCS chip on the DAE. These handshake commands include the bits set on the GPIO ports on DAE side. Both the SMCS chips mounted on the DAE are in "Controlled by Link" configuration that allow the REBA to have the complete control on their configuration and operation.

6.2.3.1.1.4 HK & CMD RS422

Other handshake signals are required for the communication between the REBA and the BEU box. They are differentially driven using the RS422 electrical protocol. The signals are listed in the following table.

Connection	Wires
DAE ON FLAG	RS422 Driver
DATA BUFFER READY	RS422 Driver
1 Hz PULSE	RS422 Receiver
SMCS 1 CHIP RESET (DAE RESET)	RS422 Receiver
SMCS 2 (SCIENCE) CHIP RESET	RS422 Receiver

The DAE On flag signals to the REBA that the DAE is "On" and ready to be operated.

The data buffere ready signals to the REBA that one of the Ping/Pong buffers for science data is full and ready to be downloaded by REBA.

The 1 Hz pulse is actually a clock signal with a period of 1 second locked in phase with the On Board Clock signal coming from the S/C. This signal is used by the DAE during the synchronisation process.

The SMCS 1 reset signals resets only the relevant chip and allow a restart of DPU-DAE link.

The SMCS 2 reset signal not only resets the SMCS chip but also switch off all the scientific acquisition functions including the reset of the handshake protocol for the download of the data from the DAE to the REBA.

6.2.3.1.2 DAE – FEU Cryo-Harness (PLAHB)

The cryo-harness, interconnecting the PLFEU to the PLBEU is part of the instrument The cryo harness is mounted as part of the RAA and is integrated before delivery and should be kept integrated. Any handling/deintegration of this special harness is done by LFI instrument support.

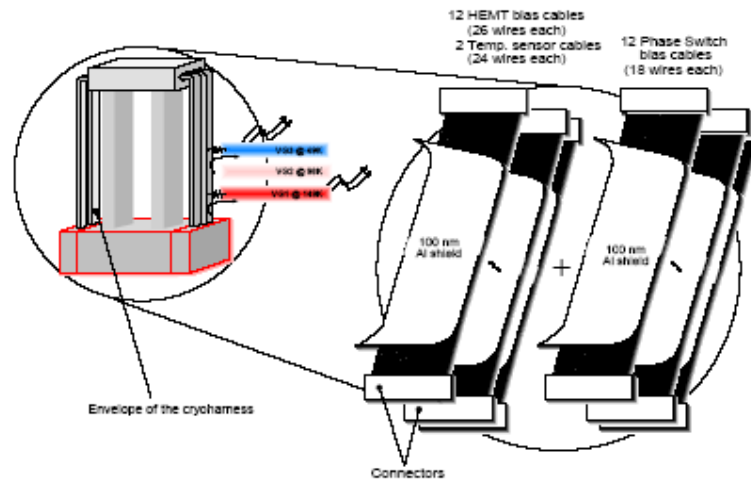


Figure 6-33 Outline Configuration of the LFI Cryo Harness

The cryo harness cables are subdivided into three groups according to the EMC class of signals they carry.

To optimise the connections wires going to different FEMs are grouped into the same cable.

The following tables report the composition of each of the three types of cable.

Cable Type	FEM no.	Bias line	# wires
HEMT	1, channel 1	Drain, Gate 1, Gate 2	3
	1, channel 2	Drain, Gate 1, Gate 2	3
	1, channel 3	Drain, Gate 1, Gate 2	3
	1, channel 4	Drain, Gate 1, Gate 2	3
	1, common	GND	1
	2, channel 1	Drain, Gate 1, Gate 2	3
	2, channel 2	Drain, Gate 1, Gate 2	3
	2, channel 3	Drain, Gate 1, Gate 2	3
	2, channel 4	Drain, Gate 1, Gate 2	3
	2, common	GND	1
TOTAL			26

Cable Type	FEM no.	Bias line	# wires
Φ switch	1, channel 1	Line 1, Line 2	2
	1, channel 2	Line 1, Line 2	2
	1, channel 3	Line 1, Line 2	2



	1, channel 4	Line 1, Line 2	2
	1, common	GND	1
	2, channel 1	Line 1, Line 2	2
	2, channel 2	Line 1, Line 2	2
	2, channel 3	Line 1, Line 2	2
	2, channel 4	Line 1, Line 2	2
	2, common	GND	1
TOTAL			18

Cable Type	FEM no.	Bias line	# wires
Temp. sensors	1, channel 1	4 wire sensing	4
	2, channel 2	4 wire sensing	4
	3, channel 3	4 wire sensing	4
	4, channel 4	4 wire sensing	4
	5, common	4 wire sensing	4
	6, channel 1	4 wire sensing	4
TOTAL			24

The following table reports the electrical characteristics of the conductors inside the cables and the materials and gauges chosen for the purpose in order to optimise their features and feasibility.

Wire	El. resistance (ambient temperature)	Material	AWG
HEMT GND	5.28 Ω $\pm$ 5%	Copper	38
HEMT Drain	19.30 Ω $\pm$ 10%	Nickel	38
HEMT Gate 1	218 Ω $\pm$ 10%	Manganin	40
HEMT Gate 2	218 Ω $\pm$ 10%	Manganin	40
Φ switch	11.70 Ω $\pm$ 10%	Phosphor Bronze	34
Φ switch GND	11.70 Ω $\pm$ 10%	Phosphor Bronze	34
Temp sensors	218 Ω $\pm$ 10%	Manganin	40

Finally the following table reports the list of cables with the relevant connectors on the BEU. The fixation points for these cables to the satellite structures are none.



6.2.3.1.2.1 DAE - FEU CRYO Harness ROUTING

The cryo-harness is routed along the wave-guide bundles from the back-end to the front-end.

6.2.3.1.3 FEU Internal Harness (PLAHC)

6.2.3.1.3.1 FEU INTERNAL Harness ROUTING

TBW



7 INSTRUMENT PERFORMANCE

7.1 INSTRUMENT SCIENTIFIC PERFORMANCE

The detailed description of the instrument performance and of the main requirements is given in the LFI scientific requirements (see [RD2] PL-LFI-PST-SP-011).

All elements here addressed refer to flight performance. If flight environment cannot be reproduced, extrapolations to flight performance are made. Paragraph 9.5 Scientific Performance Verification of the IIDs (see [AD1] and [AD2]) provides more information on this subject. More details on the required verification and test procedures for the various LFI units and deliverable models are described in the LFI Instrument Development Plan document [RD21].

7.1.1 OPTICAL/RADIOMETRIC PARAMETERS

The "optical" portion of the LFI is the array of corrugated feed-horns, which needs to meet the required performance for adequate illumination of the Planck telescope while avoiding systematic effects. Attention is needed for the level of feed-horn side-lobes since this level dominates in some angular ranges the overall side-lobe response of the system.

The nominal optical parameters required for of the LFI feeds at the three frequencies are summarized below:

Feed horns	30 GHz	44 GHz	70 GHz
Aperture [D/ λ]	5.1	5.3	4.2
Bandwidth [%]	20	20	20
Side lobe level [dB]	< -35	< -35	< -35
Edge taper at 22° [dB]	-30	-30	-17
Cross polarization [dB]	<-25	<-25	<-25
Insertion loss [dB] (*)	0.1	0.1	0.1
Return loss [dB]	-25	-25	-25
		8.3 (LFI24)	
Phase center location [mm] (**)	12.39	29.3 (LFI 25,26)	2.36

Table 7.1-1 Required optical parameters

(*) The insertion loss is at operational temperature (~20K)

(**) The phase centre is measured from the aperture.

7.1.1.1 BEAM MAPS

Co-polar and cross-polar beams of the feed horns are measured at least for the E, H and +/- 45deg azimuthal planes with the dynamic range of 70 dB and for the angular regions that are most



determining for the feed-telescope far field pattern (zenith angle ranging from -90° to $+90^\circ$). The knowledge of the pattern position angles (with respect to the mechanical frame) are better than ± 0.25 degrees. Measurements are made at least at five frequencies within the bandwidth ($F_0 \cdot 0.9$, $F_0 \cdot 0.95$, F_0 , $1.05 \cdot F_0$, $1.1 \cdot F_0$, where F_0 = centre frequency)

7.1.1.2 FOCAL PLANE

The focal plane geometry (i.e. relative locations and angles of each horn) and its deformation /stability on cool-down are in line with the following top level LFI alignment requirements

- Z – displacement:

Absolute value of the displacement along Z – axis of the phase centre needs to be less than $\lambda/2$.

- X and Y displacement:

Displacement along X and Y need to be in agreement with the LFI pointing requirement since a shift along X and Y is reflected on a shift in the main beam direction on the sky. The plate scale of the Planck telescope is ~ 2 arcmin/mm,

A pointing shifting of 1 arcmin reflects in a maximum shift of 0.5 mm.

- Tilting of the horns:

The horn tilting requirement are defined in such a way that the straylight degrades less than 10%. By analysis, this requirement reflects in a maximum horn tilt of ~ 0.5 degrees.

- Position and orientation of the horns are known with an uncertainty better than 5%,

Tests at instrument and at system level have been carried out to verify that cross-talk effects between different feeds of the LFI and the HFI are below significance level.

7.1.1.3 FEED-OMT UNIT

The parameters given in the above table refer to the feed-horns only, and do not include the effect of OMTs. The required radiometric parameters for the feed-OMT unit are as follows:

	30 GHz	44 GHz	70 GHz
Bandwidth [%]	20	20	20
Insertion loss [dB] (*)	0.25	0.25	0.25
Return loss [dB]	-17	-17	-17
Cross polarization [dB]	-25	-25	-25

(*) The insertion loss is at operational temperature (~ 20 K)

These specifications are to be considered as upper limits over the whole 20% bandwidth. The isolation between the two ports of the OMT must be better than -25 dB. The design OMT return loss has been set to -20 dB over the whole 20% of bandwidth.



7.1.1.4 4 K LOADS

The deviation of the 4 K source from a black body is minimized. Its reflectivity is below -20 dB (99 % black body).

7.1.1.5 COUPLER

The hybrid coupler (magic-tee) combines the signals from the sky and cold load with a fixed phase offset of either 90 deg or 180 deg between them. It has a 20% bandwidth, low loss, and amplitude balance needed at the output to ensure adequate signal isolation.

7.1.1.6 WAVEGUIDES

The wave-guide-section satisfies the following main requirements:

- Small parasitic heat loads on the 20 K FEU
- Compatibility with launch vibration loads
- Adequate clearance for integration for LFI/HFI
- Low phase dispersion
- The following insertion loss and return loss

	30 GHz	44 GHz	70 GHz
Waveguide type			WR12
Return loss [dB] (*)	-20	-20	-20
Insertion loss [dB] (*)	2.5	3.0	5.0

7.1.2 SPECTRAL RESPONSE

The nominal bandwidth for all the LFI channels is 20 % of the centre frequency (*). The bandpass is measured:

with a 0.05 GHz spectral sampling from 26.5 to 40.0 GHz for RCA@30GHz,
with a 0.05 GHz spectral sampling from 33.0 to 50.0 GHz for RCA@44GHz,
with a 0.005 GHz spectral sampling from 57.5 to 82.5 GHz for RCA@70GHz,
showing bandwidth values compatible with requirements. Measurements have been supported also by ADS simulations showing good agreement.

(*) Bandwidth is defined in terms of noise effective BW.

7.1.3 SENSITIVITY

In the following table, overall radiometer sensitivity levels and relevant parameters are given which have been verified by test and analysis to ensure proper performance of LFI amplifiers:



Centre Frequency	30 GHz	44 GHz	70 GHz
Detector Operating Temperature (K) (1)	20	20	20
Relative Bandwidth ($\Delta\nu/\nu$)	0.27	[0.11 – 0.18]	[0.14 – 0.21]
Number of feed horns	2	3	6
Number of radiometers	4	6	12
Number of detectors	8	12	24
Angular Resolution (FWHM, arcmin) (1)	30	24	13
T_{noise} (K) at 20 K (2)	[10 – 14]	[13 – 17]	[27 – 36]
Nominal Mission(3) (1s sensitivities, per pixel (4))			
Average Sensitivity per pixel (μK)(5)	6.0	7.5	12.9
Radiometer noise temp. [K]	10.7	16.6	29.2
Bandwidth [GHz] (*)	6	8.8	14
FE noise temp. [K]	8.6	14.1	25.7
FE gain [dB]	30	30	30
BE noise temp. [K]	350	350	450
BEM output for 20K input at feed horn [V]	0.2-0.8	0.2-0.8	0.2-0.8
DC gain [dB]	20	20	20
FEM power diss. Per freq. [mW]	59.7	127.6	162.6

Table 7.1-2 Sensitivity levels

Note:

- (1) Goal values
- (2) Values measured during LFI RCA tests – These values don't include the sky temperature
- (3) Two full sky coverage
- (4) A pixel is a square whose side is the Full Width at Half Maximum (FWHM) extent of the beam
- (5) Values in antenna temperature
- (*) Effective bandwidth

Isolation between the channels of an RCA is below 13 dB. The sensitivity dispersion between detectors is better than +/-15 %.

Mismatch between pairs of FEM amplifiers, phase switches and wave-guide pairs are minimized.

7.1.4 STABILITY

There are three main sources of instability to the LFI radiometers:

a) Intrinsic instability of the amplifiers and diodes.

The LFI radiometer is designed to minimise the effect of amplifiers gain instability as well as fluctuations in the detector diodes.



The requirement on the knee frequency of the $1/f$ component of a whole radiometer is to be less than 0.050 Hz. The measured values indicate a better performance, with knee frequencies generally below 0.025 Hz, which ensures that residual effects will be successfully removed by destriping algorithms.

b) Temperature-driven changes in performance

Radiometers components change their performance with changes in their physical temperature. Gain variations are below $-0.05 \text{ dB} / ^\circ\text{C}$. System noise variations are below $0.6 \text{ K}/^\circ\text{C}$. The required stability of the 4 K reference loads leads to a value at the interface between the HFI box and the 4K reference loads of $0.01 \text{ mK}/(\text{Hz})^{1/2}$ for frequencies greater than or equal to 0.01 Hz and of $0.1 \text{ mK}/(\text{Hz})^{1/2}$ for frequencies less than 0.01 Hz. The thermal stability of the FEMs leads to a maximum acceptable temperature fluctuation of 100mK peak-to-peak over a full cooler cycle period at the interface between the sorption cooler cold end and the LFI mail frame. This, in the frequency domain, translates into the following mask:

- $\delta T < 10 \text{ mK}/(\text{Hz})^{1/2}$ for $f > 1 \text{ Hz}$,
- $\delta T < 1 \text{ mK}/(\text{Hz})^{1/2}$ for $10^{-2} \text{ Hz} < f < 1 \text{ Hz}$,
- $\delta T < 2 \text{ mK}/(\text{Hz})^{1/2}$ for $1.7 \cdot 10^{-3} \text{ Hz} < f < 10^{-2} \text{ Hz}$,
- $\delta T < 8 \text{ mK}/(\text{Hz})^{1/2}$ for $10^{-3} \text{ Hz} < f < 1.7 \cdot 10^{-3} \text{ Hz}$,
- $\delta T < 1 \text{ mK}/(\text{Hz})^{1/2}$ for $f < 10^{-3} \text{ Hz}$

c) In addition, power supply variations can induce changes in the HEMT performance leading to instability of the signals.

The power stability is 0.1 mV/h for the drain and gate of each amplification stage.

The overall instrument stability, noise spectrum, $1/f$ knee frequency, offset drifts, gain temperature coefficients, is at unit and instrument level.

EMC tests including measurement of conducted susceptibility, radiated susceptibility, radiated emission have been performed or adequate analysis is provided.

7.1.5 READ OUT ELECTRONICS

The $1/f$ noise additionally introduced by the read-out electronics is below TBD.

7.1.6 DATA COMPRESSION

Tests assure that the data compression algorithm compresses the data to the required level without loss of information. The average compression rate measured during the tests is a factor of 2.43.



7.1.7 MODES OF OPERATION

The temperature at which the LFI is operated is not known with high accuracy. The characteristics of the LFI are determined at a number of interface temperatures within the predicted range.

The sensitivity of LFI to tuning parameters (bias voltages, etc) has also been determined, including non-nominal levels of temperature and power fluctuations.

7.1.8 RESPONSE TO ENERGETIC PARTICLES

The effects of energetic particles have been investigated by exposing the detector assemblies to relevant levels of radiation as expected to be encountered in orbit. Radiation tests have been combined with accurate computer modelling to investigate the effects of a realistic particle spectrum as it is encountered at L2.

7.1.9 RF EMISSIONS

The level of RF Emissions has been verified to be within the requirements.

7.2 INSTRUMENT TECHNICAL PERFORMANCE

The LFI instrument technical performance have been already described and discussed in Paragraphs 6.1.7 (Thermal Interfaces), 6.1.8 (Optical Interfaces) and 6.1.9 (Power). Below there is a more detailed report on the thermal dissipation on the Planck Payload Module.

7.2.1 CONSTRAINTS FOR POWER CONSUMPTION

7.2.1.1 THERMAL DISSIPATION ON PLANCK PAYLOAD MODULE

The maximum thermal dissipations supported by the spacecraft at the different interface level of the Planck Payload module are defined in the table below.

Guaranteed temperatures range on shield (in operating mode)

<i>Required temperatures: (K)</i>	<i>3rd V-Groove</i>	<i>2nd V-Groove</i>	<i>1st V-groove</i>
Min	45	100	150
Max	60	120	170

Temperature to be used for instrument heat load estimation (boundary)

<i>Design temperatures: (K)</i>	<i>3rd V-Groove</i>	<i>2nd V-Groove</i>	<i>1st V-Groove</i>
LFI	52	106	166



HFI	50	110	165
SCS	52	108	158

Heat Load Allocation on 3rd V-Groove estimated for above temperatures.

<i>Heat Loads (mW)</i>	<i>3rd V-Groove</i>	<i>2nd V-Groove</i>	<i>1st V-Groove</i>	<i>Design margin margin (**)</i>
HFI	620	20	50	20%
LFI	710	560	5370	20%
SCS	1175	447	566	10%
Total	2505	1027	5986	

(**) Margin used by Alcatel on instrument heat loads to estimate prediction error)

Table 7.2-1 Maximum thermal dissipation on the Planck Payload Module

These Heat losses allocations are Maximum Values acceptable by the Planck Payload. This mean that the instrument estimated dissipations or losses include 20% of design margin before reaching these values.
With these allocations, the calculated temperature at the sorption cooler interface is 52K $\pm$ 7K.

7.2.1.2 THERMAL DISSIPATION ON FPU

The FEM power consumption is evaluated, keeping into account the contribute of the LNAs (gates and drain lines consumption) and phase switches. For the 30 and 44GHz RCAs a 25 K Ω resistance has been assumed for each gate stage; for the 70GHz RCAs, 40.6 K Ω and 126.2 K Ω have been evaluated for the gate1 and gate2 stages respectively.

The calculus of the FEM and BEM power consumption follows, detailed for each RCA:

RCA#	FEM power dissipation [mW]	BEM power dissipation [mW]
18	26.34	680
19	25.50	639.69
20	29.36	615.52
21	30.43	548
22	24.41	587
23	22.76	725
24	45.26	1560
25	40.22	1540
26	42.17	1535
27	28.11	2515
28	31.61	2515
Tot	346.17	13460.21

The evaluation of the FEMs total power consumption shows that power dissipation at the FPU is within the required value:

P_{tot} measured [mW]	P_{tot} requirement [mW]
346.17	349.0



8 INSTRUMENT OPERATIONS MODES

8.1 SUMMARY OF NOMINAL AND BACK-UP MODES

The definition of operating modes is essential both to estimate the telemetry budgets and understand the organisation of the telemetry.

Note that for "operating mode" we intend a status that can be hold indefinitely. So we exclude from "mode" definition any transient (e.g.: the DPU RAM test is a task performed passing from "off mode" to "stand-by mode"). Moreover the operating mode is intended as a LFI internal situation, not affected by the boundary conditions (e.g. failure in some subsystems). In a given operating mode only a certain set of TM & TC packets are allowed and only a defined set of SW functions run, regardless the boundary conditions of LFI.

These operating modes can be used also by the spacecraft for progressive fall-back in the case of necessity.

UNIT & TELEMETRY			MODES				
UNIT	MOD.	TLM	OFF	STAND-BY	DAE SET_UP	NORMAL SCIENCE	EXTENDED SCIENCE
FEU			OFF	OFF	OFF	ON	ON
	Fem		OFF	OFF	OFF	ON (Ni)	ON (Ni)
BEU			OFF	OFF	OFF	ON	ON
	Bem		OFF	OFF	OFF	ON (Ni)	ON (Ni)
DAE			OFF	OFF	ON	ON	ON
		H/K	OFF	OFF	ON/OFF	ON	ON
		SCIENCE	OFF	OFF	ON/OFF	ON (Ni)	ON (Ni)
REBA			OFF	ON	ON	ON	ON
	DPU		OFF	ON	ON	ON	ON
	SPU		OFF	ON	ON/OFF	ON	ON
		TLM H/K	OFF	ON	ON	ON	ON
		TLM SCIENCE	OFF	OFF	ON/OFF	ON (Nk)	ON (Nk)

Table 8.1-1 Operating modes

Notes:

- The FEU and BEU are ON when one or more RCA (FEM + BEM) are ON
- Temperature sensor data from the BEU is however available when the DAE is ON.



- “Ni” represents the number of FEMs and BEMs that are ON and lies in the range 1 to 11. Each FEM/BEM combination forms a Radiometer Chain Assembly and contains two radiometers.
 - “Nk” represents the number of radiometers whose data are being processed by the REBA to produce Science telemetry packets to be sent to the ground and lies in the range 1 to 22. It should be noted that Nk can be less than 2Ni.
 - ON/OFF in DAE SET_UP Mode means that the following TM are available
 - 1) REBA housekeeping telemetry is always present.
 - 2) Until communication is established between the REBA and the DAE BEU Box, no DAE housekeeping telemetry is available.
 - 3) For diagnostic purposes it is possible to enable and produce science telemetry in DAE SET-UP Mode with the FEM's and BEM's switched off to access noise in the acquisition chains.
- It should be noted that in no mode of operation of LFI is foreseen to operate both the REBA nominal and REBA redundant simultaneously, as the REBA redundant is in cold redundancy. This also applies to the DAE power box.

Figure 8-1 reports the scheme of the nominal transitions for LFI modes.

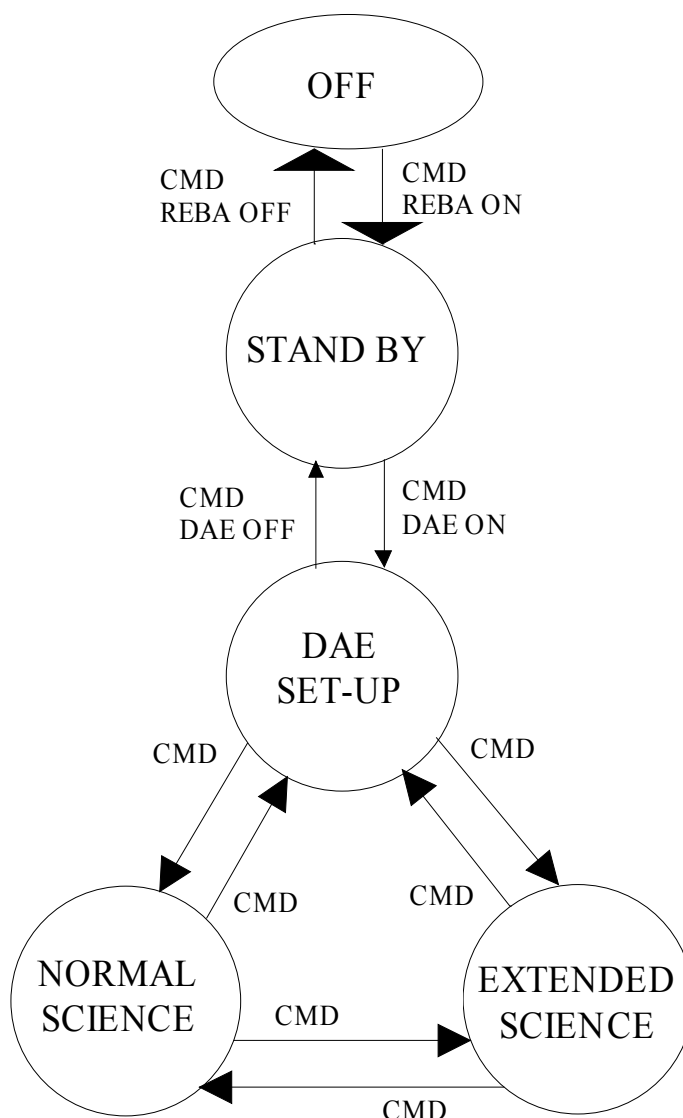


Figure 8-1 LFI Operating Modes and theirs nominal transitions

- 1. OFF MODE:** During this operating mode the instrument is completely off for example during the launch.
- 2. STAND-BY:** During this mode only the REBA can be operated. It is the first interface to the instrument whenever the LFI is switched on. When the instrument is in this mode the RAA must be OFF because no data can be received and no control is possible on the radiometer chains.
- 3. DAE SET-UP:** During this mode the REBA and the DAE are ON, but no radiometer chains are active. Nevertheless science data can be generated and contain only the background noise of the instrument.



4. **NORMAL SCIENCE:** During this mode the RAA is seen by the REBA as a set of 44 independent instruments. This means that each instrument can be operated, by the same SW, in different modes (refer to the activation table) without affecting the LFI modes. Science data from the DAE are continuously acquired by the REBA that decides, on the basis of the activation table, which packets (either science or diagnostic) have to be produced. The whole set of HK is continuously acquired and sent to ground. This mode is the nominal for the LFI observation operations.
5. **EXTENDED SCIENCE:** This mode is similar to the previous except that for the total amount of telemetry sent to the ground. In fact this mode shall be used when, in particular cases, (e.g. calibration...) a larger telemetry rate is needed and made available by an agreement with HFI and the CDMS.

The procedures corresponding to the transitions between the various modes described above are detailed in chapter 13.2.1 for the nominal operations.

In both Normal and Extended Science modes the configuration of the data processing and packet generation is defined as described in Par. 15.1.3. This gives the possibility of operating in all the diagnostic conditions foreseen in [AD2].

Apart from the autonomous fall-backs discussed later in this section all transitions are performed by command. These transitions would normally be performed by commands from the ground in visibility, but the instrument also fully supports timetagged commands stored in the CDMS for use if necessary. The instrument is designed to process all commands that it receives and at minimum reply with a command acceptance telemetry packet. The effect of commands received by the instrument can be monitored through the instrument housekeeping and science telemetry packets.

The instrument cannot autonomously switch on or switch off its units, specifically the REBA and the RAA. Thus full reconfiguration of the instrument requires co-ordination with commands through the CDMS that address the instrument power interfaces in the PCS. As housekeeping telemetry from the instrument is only available directly from the REBA it is important to ensure that RAA is only powered on when the REBA has been powered on - and under normal conditions been fully checked out through verification performed on the ground.

When the REBA is switched on both the DPU and the SPU processors are powered and start to run their respective self-tests in parallel using their respective PROM SW. When the DPU has completed this task it is ready to transmit DPU housekeeping packets. It should be noted that at this stage no housekeeping is available from the SPU. Each successive step in the REBA switch on procedure is performed by command and with verification from the ground and allows the following principal activities to be performed.

- patching of the DPU ASW resident in DPU EEPROM
- patching of the SPU ASW resident in the DPU EEPROM
- download of the DPU ASW to DPU RAM
- run the DPU ASW in DPU RAM
- set the OBT in the REBA
- establish communication between the DPU and SPU under control of the DPU



- transfer the SPU ASW from the DPU to the SPU RAM
- run the SPU ASW in SPU RAM

The switch on procedure of the REBA is described in Par. 13.2.2.

After full ground verification of the successful completion of the REBA switch on procedure the switch on of the RAA can commence by powering on the DAE Power Box. The DAE Power box comes on with secondary power being applied automatically only to the DAE BEU Box and not to the FEM's and BEM's of the RCA's. At this stage communication with the DAE is not yet established, as the DAE communication interfaces do not have been initialised by the REBA which controls all communication with the DAE. However the fact that the DAE is powered on is still verifiable in the REBA housekeeping.

With the DAE BEU Box powered on the DAE Set-Up procedure can be commenced.

The principal activities to be performed by command with verification from the ground are the following :

- establish communication with the DAE through it's digital interfaces
- establish communication with the DAE through it's digital interfaces
- start collection and production of DAE housekeeping telemetry
- adjust bias settings to be applied to the FEM's at FEM switch on

At completion of DAE Set-Up Normal Science Mode, or if agreement has been made Extended Science Mode can be initiated, after the parameter table in the SPU has been uploaded from the ground giving the necessary information for the SPU ASW to reduce and prepare the radiometer science telemetry packets, by powering on atleast one RCA chain FEM/BEM combination and enabling the production of science telemetry packets. In normal operations either single RCA's is switched on in a controlled sequence with verification of the result prior to continuing, or groups of RCA's are switched on together.

With the RAA functioning in Normal Science or Extended Science Mode, as baseline a continuous monitoring of the radiometers is performed by analysis of their housekeeping and science data on the ground after receipt at the DPC allowing periodic updating of the radiometer settings.

Fall-back transitions are foreseen for emergency situation and are depicted in Figure 8-2.

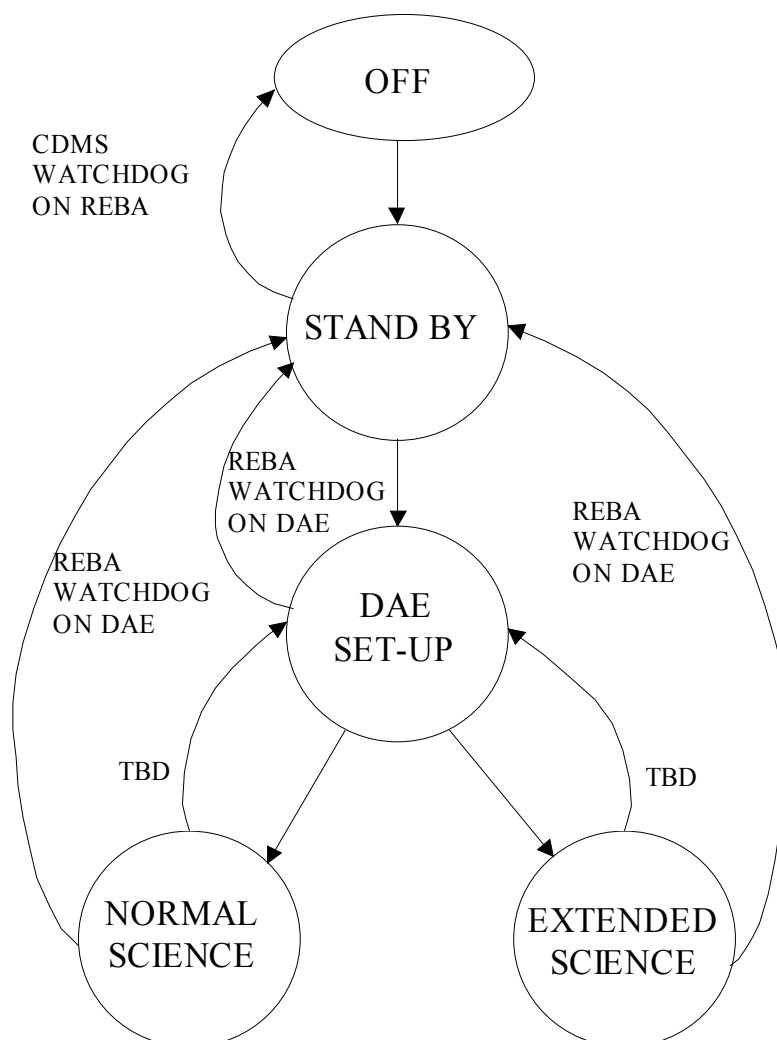


Figure 8-2 LFI fall-back transitions for emergency status

The REBA performs a watch-dog activity on the functioning of the Radiometer Array Assembly including the radiometer chains. These watch-dog functions are the following.

- Control and modify the overall scientific telemetry packet production of the instrument to avoid exceeding the daily allocation to LFI
- Monitor the SPU CPU load : if it get close to 100%, LFI signal it to ground with an alarm to be processed offline. The Instrument doesn't hang even if the CPU load is kept to 100% for a long time
- Monitor the temperature of the FPU and if it exceeds a programmable temperature turn off all the radiometer chain assemblies transitioning to DAE Set-up Mode
- Monitor the data link connection between the REBA and the RAA and, in case of need, request the CDMS to power down the RAA.

All these watchdog functions are individually enabled and disabled by command from the ground.



As the only data communication with the instrument is through the CDMS Mils Std 1553 bus and the instrument cannot be monitored by the ground when outside the visibility period, a watchdog function is necessary in the CDMS to ensure safe operation of the instrument.

In the case that communication is lost with the REBA for more than TBD seconds then the CDMS should ensure that power is removed from both operating power lines to the instrument.

In the case that the CDMS finds that the REBA is producing housekeeping with its PROM based start-up software (indicating that the REBA has gone through a reset) but the RAA is powered on, the CDMS must ensure that power is removed from the PCS line that powers the RAA, as the REBA is no longer in a state to control the functions of the RAA.

These CDMS watch-dog functions shall be enabled and disabled by command from the ground.

8.2 DESCRIPTION OF INSTRUMENT OPERATIONS MODE

8.2.1 NORMAL SCIENCE MODE

This is the normal mode of operation of the LFI with the REBA on, DAE and FEM's and BEM's on and the instrument producing scientific and housekeeping data. It should be noted that in this mode single FEM/BEM combinations can be configured separately or in groups not requiring a transition back to DAE Set-Up Mode for configuration changes. This allows continued scientific data acquisition while radiometer calibration adjustments are made in parallel.

Diagnostic activity is necessary on a limited number of radiometers while the instrument is performing the sky survey in its Normal Operations Mode without stopping the sky survey with the majority of the radiometers.

These are particularly useful during the Satellite Commissioning and Performance Verification phase for instrument health check out, but can be applied during the nominal observing program without disturbing the thermal balance of the FPU because they act only on the processing of digitised science data.

Five types of diagnostic scenarios possibilities are foreseen for a number of radiometer chains among the others for the analysis of potential instrumental effects such as thermal drifts or modulations or whenever a failure investigation is requested or to validate the various stages of the data compression schemes for each radiometer chain.

Diagnostic scenarios send to the ground subsets of the data streams corresponding to partial on-board processing:

- 1) Send data for a sub-set of channels without “lossless” compression (factor about 3-4 potential increase in telemetry rate per radiometer)
- 2) Send data as per the default processing, but without switching (no increase in telemetry rate per radiometer)



8.2.2 EXTENDED SCIENCE MODE

In Extended Science Mode all the facilities of the Normal Science Mode are present in LFI, but by agreement co-ordinated on the ground and then by command to the instrument and the CDMS, the telemetry allocation to LFI for science telemetry has been increased above the nominal baseline value being used during the mission.

8.2.3 DAE SET-UP MODE

In DAE Set-Up Mode the DAE has been switched on by ground command to the CDMS, but no BEM's or FEM's in the RAA are switched on.

In this mode communication between REBA and DAE is established under ground command and all settings of FEM/BEM parameters can be loaded into the REBA prior to moving to Normal Science or Extended Science Modes by command from the ground.

8.2.4 STANDBY MODE

After initial power on of the REBA from the PCS the instrument is in the Standby Mode. During this mode the start-up procedure for the REBA is performed. It is in this mode that the On board Time is transmitted from the CDMU to the REBA and is kept synchronous using the distributed OBC. The housekeeping telemetry is present in this mode even if it is a sub-set of the total HK amount.

8.2.5 LAUNCH/OFF MODE

In this mode all of the instrument units are powered off.

The LFI is in the “off” mode only during launch and for contingency situations and/or to allow diagnostics of HFI or of the spacecraft subsystems.

8.2.6 DIAGNOSTIC MODES

Diagnostic modes beyond the scenarios given in Section 8.2.1 which are available in Normal Science and Extended Science Modes, and the Test Mode of Section 8.2.8 are not foreseen.

8.2.7 DEGRADED STATES

Three main degraded states can be foreseen:

- Degraded State 1: In case one (or more) LFI detectors need to be switched off. This may be required if a detector fails or if, for unforeseen reasons, the physical temperature in the focal



plane is unacceptably high. In this configuration the LFI is in the Normal/Extended Science Operation Mode, except that the defective or unwanted detector/detectors is/are turned off. The nature of the LFI instrument as an array ensures the redundancy of detectors in the focal plane.

- Degraded State 2: in case the HFI 4K cooler fails, the reference load will be at about 30 K. This will require adjustments in the DAE and SPU. In this configuration the LFI is in the Normal/Extended Science
- Degraded State 3: In case the sorption coolers (the one in use or both operational and spare units) fail. The increased temperature in the focal plane (≈ 80 K) causes the low pressure nitrogen to sublime and provide a thermal path for the power dissipated by the LFI radiometers. In this configuration the LFI array will operate in a passive-cooling mode, at an estimated temperature of about 80 K. A dedicated plan will be developed to establish how many and which detectors should be operative in this configuration to maximise the science return.

8.2.8 “LFI –ONLY” CONDITION

There can be a situation in which the full telemetry rate is available for LFI during the test phase in agreement with HFI. In this condition the LFI should be allowed to use the maximum telemetry packet and bit rate up to the sum allowed to the Planck instruments. This condition is covered by the normal LFI modes (see “Extended Science Mode” in § 13.2.1).

8.2.9 CALIBRATION

In flight calibration is performed routinely by exploiting the ± 3.5 mK signal modulation from the CMB dipole.

Additional calibration and measurements of the LFI beam patterns are obtained inflight using the signal from external planets (or other celestial sources such as galactic HII regions), as they fall in the field of view of the instrument. Jupiter and Saturn, in particular, provide an adequate microwave source for beam calibration.

Calibration and beam measurements are performed with LFI in the Normal Science Operation mode (or eventually, in agreement with HFI, in the Extended Science Operation mode), and thus do not require additional operational modes from those available during routine observations.

8.2.10 TRANSFER PHASE

Details of the transfer trajectory are not yet available. Planck-LFI exploits as much as possible the transfer phase to perform commissioning of the instrument and scientific tests of the far sidelobe response, using the Earth and the Moon as test-sources at various off-axis angles, compatibly with the trajectory and attitude selected for the transfer to L2. To carry out these tests the LFI is fully operating.



8.2.11 FOCAL PLANE UNIT OPERATIONS AT AMBIENT TEMPERATURE

For ground testing, the LFI can be operated at ambient temperature although it will be far (a factor of 10 or more) from reaching the sensitivity performance of the 20 K operations.

8.3 CDMS MONITORING ON LFI

8.3.1 WATCH-DOG FROM CDMS

8.3.1.1 INSTRUMENT FALL-BACK WITH THE SUPPORT OF THE CDMS.

The aim of this function is to support the Instrument fall-back to go to a safe condition when the communications between the REBA and the RAA prevent the monitoring and control of the RAA. In particular this action is triggered when the command and HK connection between REBA and RAA fails.

The following flowchart describes the conceptual algorithm implemented.

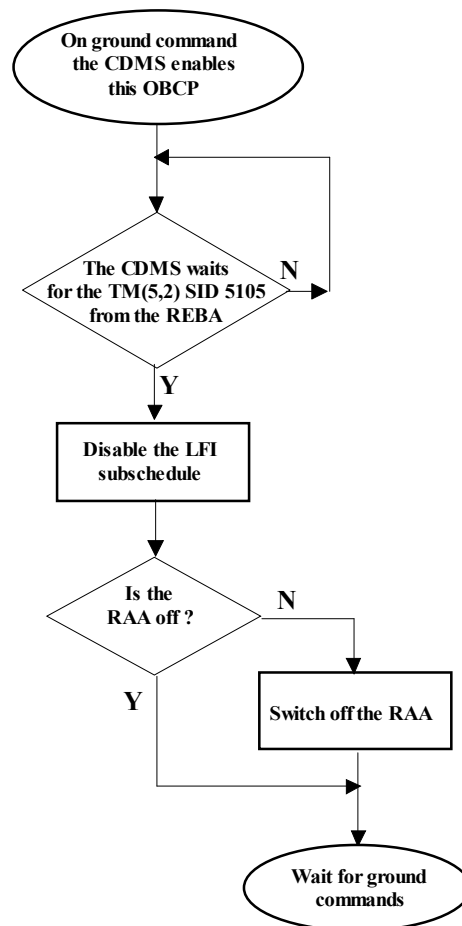




Figure 8-3 External FDIR on loss of DAE HK

8.3.1.2 CDMS WATCHDOG ON REBA COMMUNICATIONS

The aim of this function is to monitor the operations of LFI observing the TM packet production. In particular this action is triggered when the LFI stays for a few seconds (5 TBC) without producing any TM. This would be an indication that a non-commanded reset happened in the REBA due to a failure condition.

Once this condition is detected the CDMS should also check whether the REBA restarted its operations from the Startup SW execution.

In any case the RAA should be switched off to keep it as safe as possible, but no actions is taken on the power supply of the REBA because the troubleshooting of the problem is demanded to the ground operator.

The following flowchart describes the conceptual algorithm implemented.

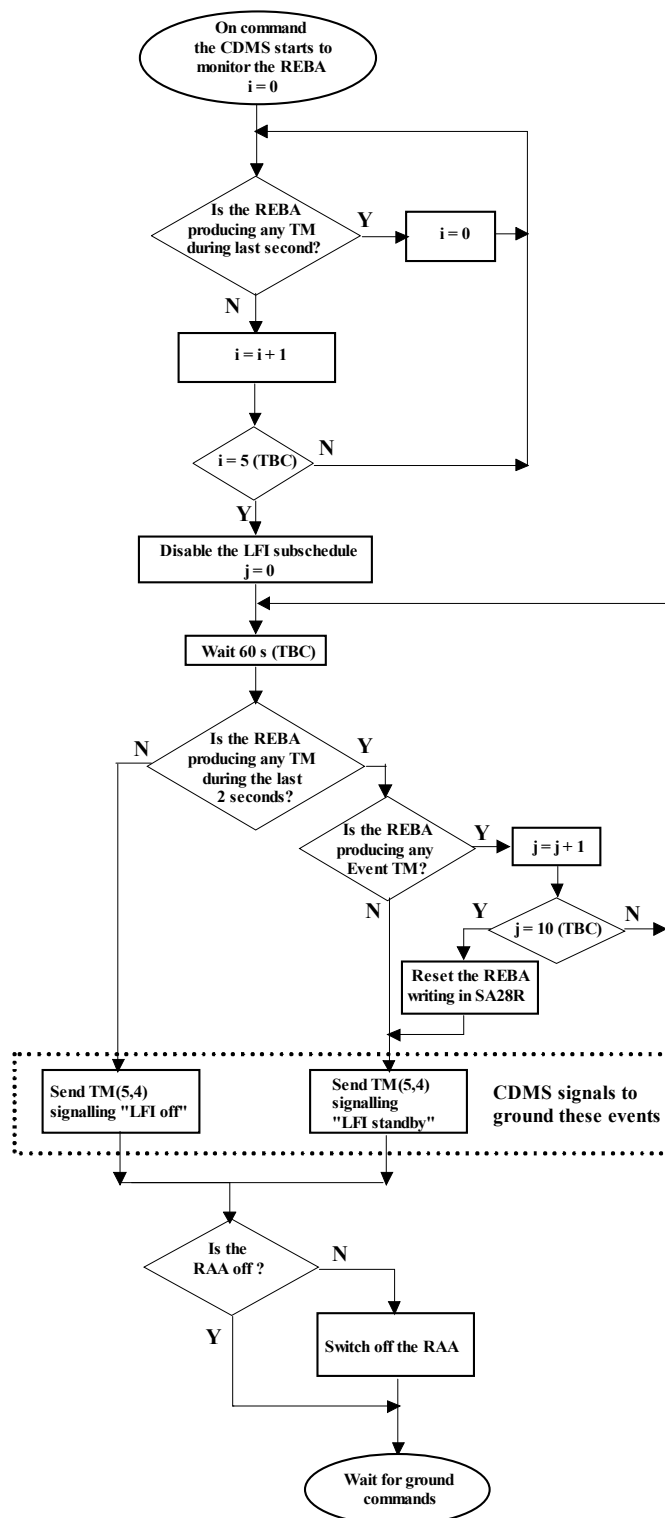


Figure 8-4 External FDIR on loss of TM from LFI



9 INSTRUMENT FAILURES

9.1 FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS

9.1.1 INSTRUMENT FAULT MANAGEMENT AND REDUNDANCY PROVISIONS

The Planck LFI redundancy philosophy is shown in the Reliability Block Diagram (Figure 9-1).

There are eleven LFI Radiometers Chain Assembly (RCA) subdivided as follows

Frequency	Number of RCA
70 GHz	6
44 GHz	3
30 GHz	2

For each frequency the loss of one acquisition chain is acceptable for the system; therefore the reliability block diagram shows the following redundancy:

Frequency	Redundancy provided
70 GHz	5 out of 6
44 GHz	2 out of 3
30 GHz	1 out of 2

In the reliability block diagram (Figure 9-1) it is present the DAE block, divided in two functional sub-blocks.

The first one, named FEE I/F, it's provided with a 8 out of 11 redundancy and the second one, named Management electronics, are divided in two identical blocks in Hot redundancy.

The reliability block diagram shows also two blocks (REBA and SCS) in cold redundancy and crostrapped. This means that the redundant chain (showed in the right side of the figure) is normally in off condition and it is activated in case of primary chain failure.

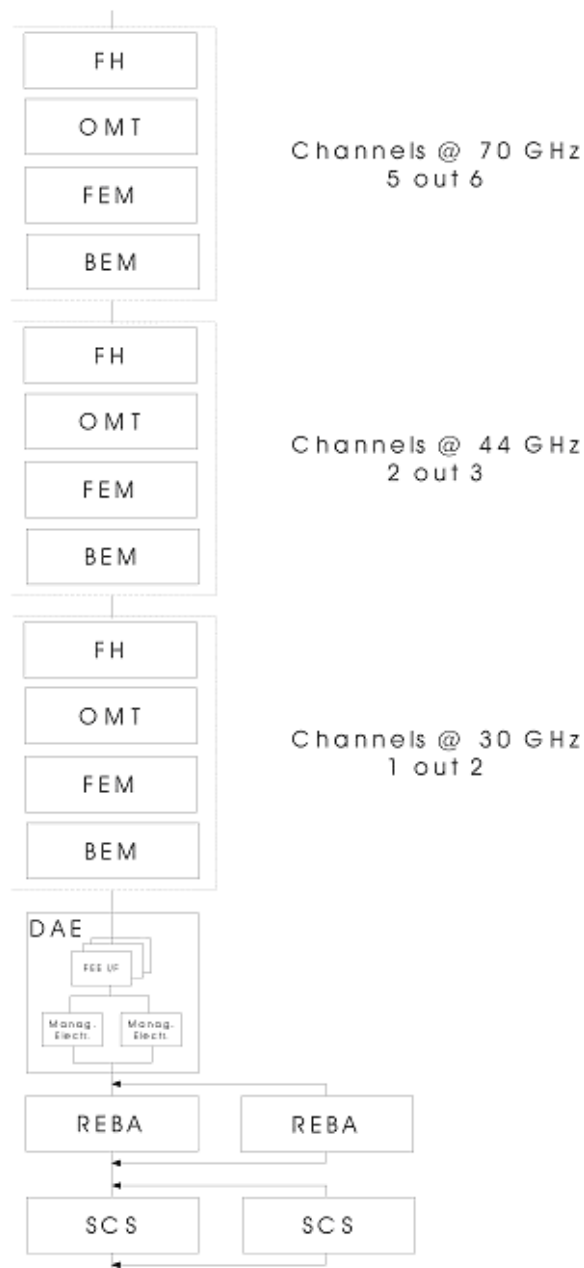


Figure 9-1 Planck LFI Reliability Block Diagram

9.1.1.1 RELIABILITY CONSIDERATIONS ON POWER AND DATA PHILOSOPHY

The Figure 9-2 shows the Planck LFI power distribution.

As shown in the above mentioned figures the power for DAE digital devices, power for DAE analogue devices, powers for FEM and powers for BEM are derived from different secondary



voltage stages of the DC/DC converter. All grounding lines are kept separated up to a star connection point.

A dedicated external bar is provided in order to allow the connection between the secondary ground to chassis ground.

For each block the functional failures modes applicable (compliant with AD7), has been considered. The analysis is performed assuming as failure mode of each item under analysis the complete loss of the function and the incorrect function.

The following criteria have been assumed:

- i) The analysis has been performed assuming the LFI in nominal operational mode. If a different failure effect or observable symptoms can be identified with respect to the different operating mode, this has been highlighted in the FMECA tables.
- ii) According to the assumption described in paragraph 9.1.1 the failure that has as consequence the loss of one acquisition channel (for each range) has been considered acceptable.
- iii) in the FMECA tables, column Observable Symptoms, the sentence “*Evidence of the failure could be detected from the related acquired data*” is used to indicate the possibility to identify the failure by means the LFI full sky observation (made with contributions of the signals coming from the radiometers). More detailed information about any other possible observable symptoms (if any) shall be provided in the next issue of the document.

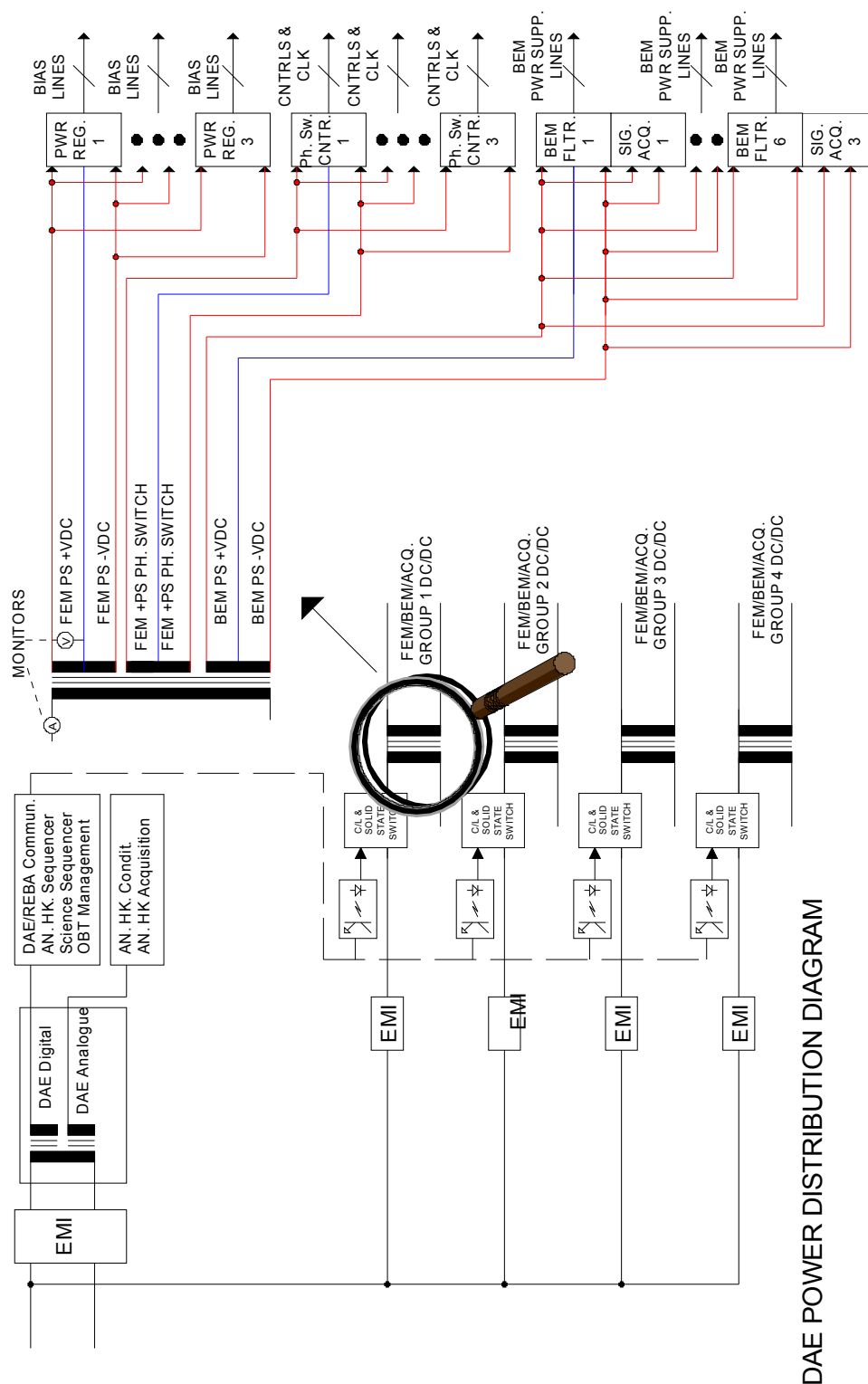


Figure 9-2 Planck LFI power distribution



9.1.2 INSTRUMENT FAILURES IDENTIFICATION

In performing the analysis the SW functionality has been considered and the following criteria has been adopted:

Definition of SW failure (ANSI/IEEE std 729)

“the termination of the ability of a functional unit to perform its required function”.

A failure may be produced when a fault (error) is encountered.

According to the above definition the analysis considers as applicable failure mode the “failed function” that means the complete loss of all the task foreseen or, where applicable, the “incorrect function” that means the loss of a part of the foreseen task.

The SW in the Planck LFI system are located in the following subsystems:

- DPU (DPU-LLS, DPU-HSL and SPU-HLS)
- SPU (SPU-LLS)

Considering that exist the possibility to patch the software, this recovery action is considered as the possible compensation method.

9.1.2.1 ANALYSIS RESULTS AND CONCLUSIONS

The analysis point out several system failure modes which cause a loss or degradation of one RCA (with severity class 2), without possible recovery actions. This condition has been considered acceptable following the consideration reported in paragraph 9.1.1.

The FMECA analysis has determined that there are some functions the failure of which have the consequence of criticality 1, i.e. failures that causes complete and permanent functional failure of the instrument.

For all these failure conditions there is an adequate recovery action based on the presence of the redundant section.

Moreover, also the software functions considered in this analysis have been classified with consequence of criticality 1. This specific point consider that the software failure may be produced when a fault (error) is encountered.

For all these failure conditions the identified recovery action is based on the possibility to patch the software elements that present the fault.

This potential criticality cannot be eliminated considering the redundant section (that contain the same SW) but performing an adequate activity of control during all the SW life cycle according to the specific SW documentation.



9.2 FAILURE DETECTION ISOLATION AND RECOVERY CAPABILITIES

9.2.1 FAILURE MODES

This chapter include a high level description of the possible functional failures and the indication of the applicable FDIR.

Notice that low level FDIR like the 1553 specific FDIR is not discussed in this paragraph.

N	Failure effect	Failure description	Applicable FDIR
1	Low science data quality	One or more items of one or more RCA are failed and the produced data doesn't carry the expected information.	GND
2	Bad compression ratio	The science signal is degraded for a short time period	Internal
3	High science TM data flow	Incorrect tuning of the data processing parameters or drift of the optimal parameters	Internal, GND
4	High FPU temperature	Failure in one or more sensors	Internal
5	High FPU temperature	Failure on the cooler or the thermal isolation of the FPU or the active elements of the FPU.	Internal
6	Loss of Science data from DAE	1355 link errors	Internal
7	Loss of Science data from DAE	Handshake signal errors	GND
8	Loss of commands to DAE	1355 link errors	Internal
9	Loss of HK data from DAE	1355 link errors	Internal, External
10	Loss of Synchronisation between REBA and DAE	1Hz Synch line error	GND
11	Loss of communications between SPU and DPU	1355 link errors	Internal, GND
12	Loss of communications between DAU and DPU	REBA internal failure	GND
13	Loss of HK polling from the S/C	1553 link failure either on LFI or S/C side	Internal
14	Loss of TM production from LFI	1553 link failure either on LFI or S/C side	External
15	Loss of commanding from the S/C	1553 link failure either on LFI or S/C side	External

It is important that it is made clear that all FDIRs can be enabled and disabled from the ground so that the instrument remains manageable under all conditions. Thus there has to be for each a baseline state at instrument switch-on inside the instrument and for the external in the CDMS.



9.2.2 EXTERNAL AUTOMATIC FDIR

External automatic FDIR are those procedures required to be executed by the S/C on LFI when something non-nominal is happening.

These procedures can be triggered by a satellite monitoring activity or by LFI itself that require services to the S/C.

9.2.2.1 LOSS OF HK DATA FROM DAE

The aim of this function is to support the Instrument fall-back to go to a safe condition when the communications between the REBA and the RAA prevent the monitoring of the RAA.

This action is triggered by an Event TM packet issued by the REBA.

The flowchart in Figure 8-3 describes the conceptual algorithm to be implemented.

9.2.2.2 LOSS OF TM PRODUCTION FROM LFI

The aim of this function is to monitor the operations of LFI observing the TM packet production. This action is triggered when the LFI stays for a few seconds (5 TBC) without producing any TM. This would be an indication that an unexpected reset happened in the REBA due to a failure condition. The CDMS should also detect whether the REBA restarted its operations from the Startup SW execution. In any case the RAA should be switched off to keep it as safe as possible, but no actions will be taken on the power supply of the REBA because the troubleshooting of the problem is demanded to the ground operator.

The flowchart in Figure 8-4 describes the conceptual algorithm to be implemented.

9.2.3 INTERNAL AUTOMATIC FDIR

Internal automatic FDIR are covered by the features of the instrument and the autonomous functions triggered by a monitoring activity of the ASW.

9.2.3.1 BAD COMPRESSION RATIO

In case the compression ratio of any of the packet results to be lower than 1, the ASW automatically raise a flag in the HK and send to ground the TM packet without compression.

For example if a stream of data is sent to processing type 5 but its statistics gives a compression factor lower than 1 the SW automatically switch that packet only to processing type 2.

9.2.3.2 HIGH SCIENCE TM DATA FLOW

Because of the sharing of the Mass memory volume between LFI and HFI, it is necessary within LFI to provide a service for controlling the filling of the allocated memory. This system is available even out of visibility, in order to avoid that a persistent failure of LFI data compression could propagate to the satellite SSMM.

This is also aimed to allow the continuous sending of HK packets for the instrument monitoring and to take into account the possibility of lack of visibility for a maximum of 2 days.



This data flow control function is implemented in the REBA SW as an on-board autonomous function.

Every TBD minutes (set by TC between 1 minutes to 6 hours, default is 1 minute, see Table 13.2-44, step 13 and 16) the REBA monitoring function will make a prevision of the daily amount of science TM produced, based on the number of science TM packets delivered since last ground contact.

If the foreseen amount exceeds the limit (TBD, programmable via TC, see Par. 13.2.17, Table 13.2-50, for Normal Science Mode this is 48 kbps) this autonomous function will inhibit the production of some science data packets.

The order of the channels to be inhibited is organised in steps as reported below in the Table 9.2-1 . At each step a maximum of 16 channels could be inhibited.

Moreover if the predicted TM rate, generated by the monitoring function, is lower than the limits and some steps of the Table 9.2-1 have been passed, the autonomous function will go back of one step removing the inhibit from the channels listed in the last step.

The prediction of the science TM packets could also depend on the time elapsed from the last ground contact therefore a "restart algorithm" TC (LC084320) shall be sent to the REBA as soon as the mass memory in the satellite is downloaded to ground.

In case of missing visibility for one day (foreseen in the mission) the science production should be guaranteed the same way. The only difference is that in case the restart is missing, the REBA shall extend the allowed total TM rate to take into account the second day without contact.

The step table for this autonomous function is summarised in the following table whose content has to be defined by TC (see Table 13.2-44, step 15 to 17).

	Channels identifiers															
Step 1	Stop the calibration channel data generation															
Step 2																
Step 3																
Step 4																
Step 5																
Step 6																
Step 7																
Step 8																
Step 9																
Step 10																
Step 11																
Step 12																

Table 9.2-1 Order of the channels to be inhibited for the control of the TM amount (to be filled)

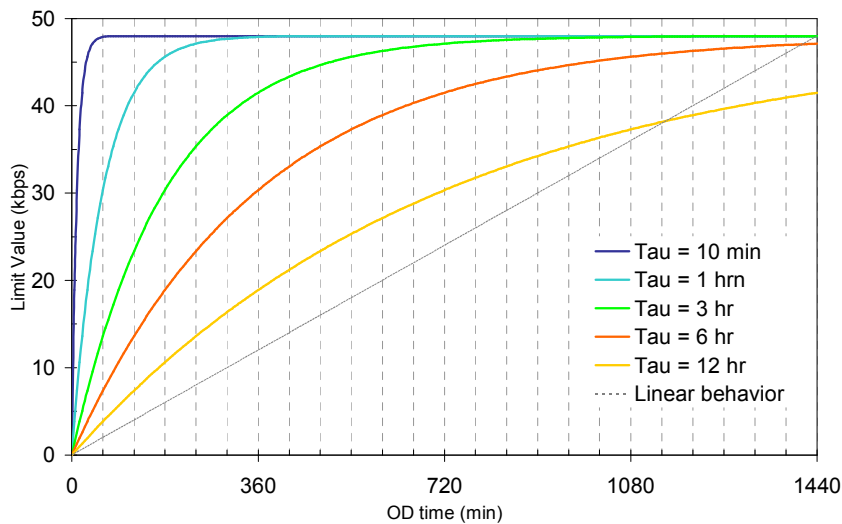


After 48 hours without ground contact (that is without receiving the restarting command) the monitoring and the corresponding autonomous function will automatically stop.

The algorithm to predict the daily amount of science TM is an exponential function with a time constant parameter τ (tau) which is set by TC (see Table 13.2-44, step 12 and 16, default is 360 s):

$$Limit\_value(t) = TM\_rate\_expected \left(1 - e^{-\frac{t}{\tau}} \right)$$

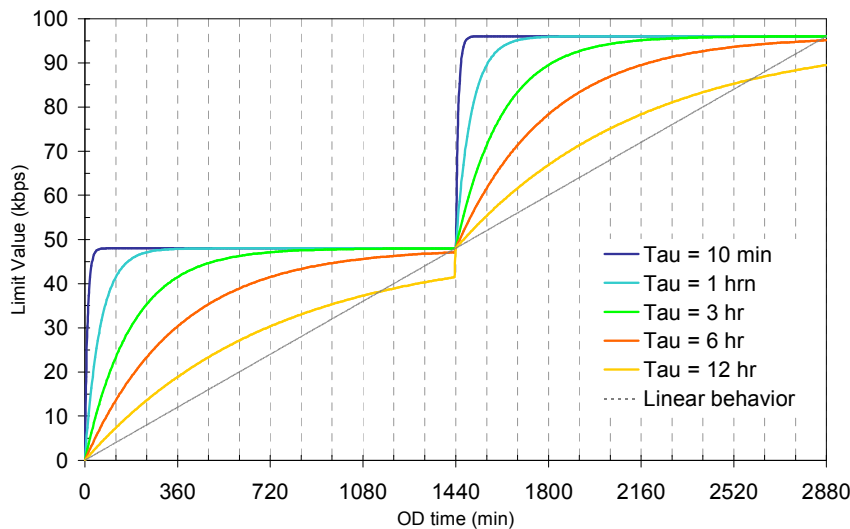
The τ parameter changes the shape of the function and makes it closer or not to a linear behaviour. A few examples are produced in the figure below:



The function is able to cope with a missed DTCP:

$$Limit\_value(t) = TM\_RATE\_EXPECTED + TM\_RATE\_EXPECTED \left(1 - e^{-\frac{t-24h}{\tau}} \right)$$

In this case the function reproduces the following behaviour:





9.2.3.3 HIGH FPU TEMPERATURE

If the FPU temperature read by the temperature sensors rises unexpectedly, this can be addressable to two causes: a failure of the sensors or an actual increase of the FPU temperature.

Both the cases are analysed hereafter.

9.2.3.3.1 Failure in thermal isolation or in any of the active parts

The ASW monitors the temperature of the FPU

When 4 out of the 7 temperature sensors of the focal plane exceed their own threshold values for more than 10 consecutive seconds, the ASW autonomous function sends to the DAE the command to switch off the RCA DC/DC converters.

The threshold for all the temperature sensors is a programmable parameter.

This autonomous function will possibly stop the temperature increase or at least mitigate its effect avoiding the propagation of the failure.

9.2.3.3.2 Failure of one Temperature sensor

If one of the FPU temperature sensors fails giving a high temperature reading the failure is tolerated since the monitoring function described above takes decisions considering 4 out of 7 sensors.

This avoids unmotivated switch off of the FPU until the third sensor failure and at the same time guarantees that the FPU temperature monitoring is correct until the third sensor failure that gives very low temperature readings.

9.2.3.4 1355 ERRORS

The 1355 links among various items of LFI carry the most critical communications thus need to be kept under control.

When the REBA monitor on the 1355 communications signals a "link error" it calls this autonomous function. This will try to re-establish the interrupted connection. If this fails the REBA will send an event message TM(5,4) if the broken link is the DPU-SPU or the SPU to DAE. In case the broken link is the DPU-DAE then the REBA will send an event message TM(5,2) to the CDMS to ask for a switch off of the DAE primary power line.

This because if something goes wrong with the DPU-DAE link that affects the communications, the RAA remains without a possibility to send HK or receive commands. If this happens out of visibility it is safer for the instrument switch the RAA off and try a restart of LFI at the next passage.

Other links are less critical from the safety point of view and LFI can leave the possibility to ground to troubleshoot the problem.

9.2.3.4.1 Loss of Science data from DAE

In case of failure (transient or permanent) of the 1355 link between SPU and DAE the science data will be lost.

The REBA ASW tries to reconnect the link a number of times, if the link remains broken the ASW decides that the link is permanently down and send an Event TM to require the ground intervention. Notice that in this case the settings of the active items on the FPU are not affected to keep the thermal stability.



9.2.3.4.2 Loss of commands to DAE

If only the commands to the DAE are lost, that is one direction of the DPU to DAE link, the REBA ASW tries to reconnect the link as before. Again if the link remains broken the ASW decides that it is permanently down and send an Event TM to require the ground intervention.

Notice that also in this case the settings of the active items on the FPU are not affected to keep the thermal stability.

9.2.3.4.3 Loss of HK data from DAE

If the HK from the DAE are lost the REBA ASW tries to reconnect the link as before. Again if the link remains broken the ASW decides that it is permanently down and send an Event TM to the S/C to require the RAA switch off. The S/C will therefore remove the primary power supply from the relevant line.

Notice that in this case the FPU thermal stability is strongly affected by the reduction of the power dissipated by the FPU active items.

This choice is justify by the impossibility to have information from the FPU sensors thus the instrument is put into in the safest condition.

9.2.3.4.4 Loss of communication between DPU and SPU

In case of failure (transient or permanent) of the 1355 link between SPU and DPU the science data will be lost.

The REBA ASW (DPU part) tries to reconnect the link a number of times, if the links remains broken the ASW decides that the link is permanently down and send an Event TM to require the ground intervention.

Notice that also in this case the settings of the active items on the FPU are not affected to keep the thermal stability.

9.2.3.5 LOSS OF HK POLLING FROM THE S/C

The features of the LFI software cover the condition in which the S/C doesn't fetch the HK packets from LFI for any reason.

In fact LFI is protected against the overfilling of the TM queues discarding the oldest TM packets and keeping in queue the newest.

9.2.4 GROUND ASSISTED FDIR

This kind of FDIR includes all those corrective actions to be exploited on ground starting from the information available from the TM.

Notice that when these FDIR are triggered the instrument is already in a safe condition. Any FDIR required to keep the instrument safe shall be either an internal or external FDIR.

9.2.4.1 LOW SCIENCE DATA QUALITY

This effect could be due to a failure in one of the RCAs and the corresponding recovery action shall be evaluated case by case.



9.2.4.2 HIGH SCIENCE TM DATA FLOW

If this effect is addressable to a wrong setup of the RCAs or the acquisition and processing the recovery action shall be to perform an optimisation of the parameters according to the procedures used during the commissioning phase.

9.2.4.3 LOSS OF SCIENCE DATA FROM DAE

The loss of science data from DAE due to a failure in the handshake procedure can be detected from the HK TM.

If this failure is permanent one possible recovery action could be try to switch to the redundant REBA.

9.2.4.4 LOSS OF SYNCHRONISATION BETWEEN THE DAE AND THE REBA

The loss of synchronisation between the DAE and the REBA can be detected through the suitable services available among the REBA commands.

If this failure is permanent one possible recovery action could be try to switch to the redundant REBA, or if the time drift is enough stabile it could worth to correct the science data timing on ground.

9.2.4.5 LOSS OF COMMUNICATION BETWEEN THE DAU AND THE DPU

The loss of communication between the REBA DAU and the REBA DPU can be detected from the HK TM.

If this failure is permanent one possible recovery action could be try to switch to the redundant REBA.

9.2.4.6 LOSS OF TIME SYNCHRONISATION

TBW



10 INSTRUMENT ON-BOARD SOFTWARE

The REBA software is the on board software of LFI. It is installed in the two computing subunits of REBA: the DPU, responsible of the control and monitoring of the instrument and the interface with the spacecraft and; the SPU, responsible of the data reduction and compression.

The REBA software can be classified (see Figure 10-1) into: REBA Start-up Software (SUSW), installed in the PROM memories, which is the bootstrap code to switch on both the subunits. The Application Software (ASW), which performs the nominal operations of the REBA and the REBA Low Level Software Drivers (LLSWDRV) which are functions provided to the ASW to access the hardware capabilities.

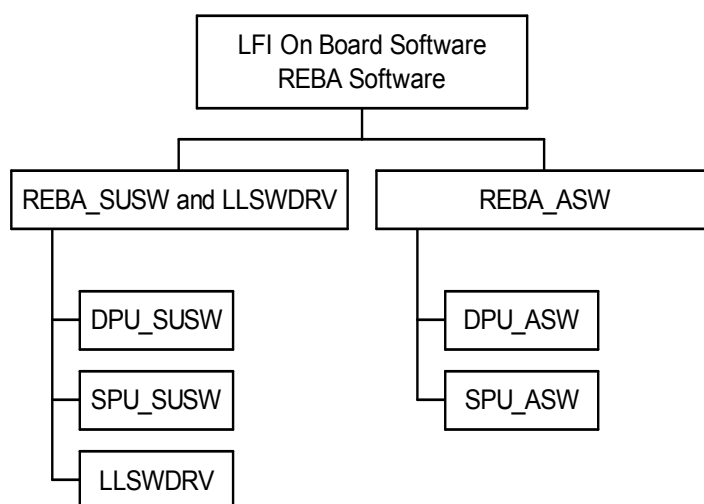


Figure 10-1 REBA Software, high level product tree

10.1 FUNCTIONAL DESCRIPTION

The software product is the REBA Application Software (REBA_ASW). The REBA_ASW can be split into the SPU_ASW and DPU_ASW, depending if we refer to software running in a specific computing subunit of the REBA, SPU or DPU. So, in the rest of the document we refer to REBA_ASW in general, but when some specific reference to a subunit is needed we use the term SPU_ASW or DPU_ASW.

The REBA_ASW performs the following main functions:

SPU_ASW:

- reduction and compression of the scientific data

DPU_ASW:

- control and monitoring of the instrument
- interface with the spacecraft to transfer data and receive commands to/from ground
- communication with the SPU_SUSW during the start-up procedure to load the SPU_ASW



The SPU_SUSW and DPU_SUSW, located in the PROM memories of SPU and DPU, respectively, are in charge of the booting of the subunits. Both are described in RD16, so they are out of the scope of this document

10.1.1 START UP

The REBA switch-on procedure is described in Par. 8.1. The procedure in this section only refer to REBA_ASW (SPU_ASW and DPU_ASW), that is, details on initialisation of SPU_SUSW and DPU_SUSW are described in [RD16].

The DPU_ASW, under CDMS command, reads from EEPROM the SPU_ASW and transfers it to the SPU_SUSW, which loads it into the SPU RAM.

Note: the DPU_ASW is read from the EEPROM and loaded to DPU RAM by the DPU_SUSW.

The SPU_ASW is started by the SPU_SUSW at reception of a command from the DPU_ASW. The DPU_ASW is started by the DPU_SUSW at reception of a TC from the CDMS.

The SPU_ASW and DPU_ASW performs an initialisation procedure that consists on the configuration of the external interfaces as well as the configuration of both DSPs.

After initialisation, the DPU_ASW starts to send to the CDMS a HK packet periodically. After initialisation, the REBA_ASW waits indefinitely for a TC from the CDMS.

The REBA_ASW perform the switch-on procedure of the LFI instrument in a step by step way, that is, by the execution of TCs received one after one from the CDMS. So, the REBA_ASW does not perform automatically any action to operate the instrument.

The baseline of the LFI Switch on procedure is described in Par. 13.2.2

Note: the power on of DAE and REBA is performed directly by the CDMS.

10.1.2 SHUTDOWN

The shutdown of the LFI instrument is performed in a step-by step procedure by the execution of TCs received one after one from the CDMS. So, the REBA_ASW does not perform automatically any action to switch-off the instrument.

The REBA ASW withstands an emergency shutdown where the power is suddenly switched off. After this event the REBA SW could be restarted following the switch-on procedure and does not show any malfunction or degradation of the performances.

Note: the power off of DAE and REBA is performed directly by the CDMS.



10.1.3 TIMING AND SYNCHRONISATION

The REBA_ASW is synchronised with the OBT of the spacecraft according to the service 9 of PS-ICD.

Note: details of the implementation procedure are described in annex C1 of LFI On-Board SW URD [RD11].

The REBA_ASW verifies the REBA OBT according to the service 9 of PS-ICD.

Note: details of the implementation procedure are described in annex C2 of LFI On-Board SW URD [RD11].

The REBA_ASW shall be able to synchronise automatically REBA each second using the low level protocol time received in subframe 33 (SA8R). This feature is normally inactive, it can be activated or deactivated by ground command

The REBA_ASW is able to synchronise the DAE with the OBT according to the procedure described in annex C3 of LFI On-Board SW URD [RD11].

The REBA_ASW is able to verify the synchronisation of DAE according to the procedure described in annex C4 of LFI On-Board SW URD [RD11].

The REBA_ASW stamps all TM packets with a field time corresponding to the acquisition of the data it contains. Time format is according to PS-ICD.

The REBA_ASW notifies the validity of the OBT (whether it is synchronised or not), reported in every TM packet, at least in one periodical HK packet continuously delivered.

10.1.4 DATA REDUCTION AND COMPRESSION

Science data received from DAE are reduced and lossless compressed by the SPU_ASW and fit into the TM packet sizes (1 kbyte).

The SPU_ASW validates the science data received from DAE according to the following procedure:

1. Check checksum field of each data packet (using SMCS hardware facility).
2. Check each frame marker.
3. Check OBT of each data frame.

In the case of the data inconsistency, the SPU_ASW sends an event report.

The baseline data reduction procedure for each detector consists of:



- division into two data streams of the samples coming from the sky and those coming from the reference load
- time averaging of the two data streams
- two linear combinations between the sky and the reference data scaled with two different gain modulation factor "r" to adapt the statistical properties of the data to the capabilities of the compressor
- second quantisation of the data stream to reduce the samples in a numerical format suitable for the compressor
- lossless compression

Note 1:

- The REBA is able to use the default values for the different parameters used in the processing. The REBA is able to modify the values of the processing parameters, provided by a TC from the ground.
- Gain modulation factors may be different for each of the 22 detectors.

Note 2:

- The number of consecutive samples to be averaged in time ($n = (m_d \times m_{1/f})/2$) can be changed by a TC.
- The number of consecutive differences to be averaged (n) may be set for each frequency each of the 11 radiometers.

Before compression, the REBA_ASW performs a quantisation of the data. The quantisation factor and its offset may be modified by TC.

SPU_ASW is able to compress the science data with a lossless compression algorithm in order to transmit the science data to the S/C data bus with the allocated telemetry.

The SPU_ASW implements the 16-bits Adaptive Arithmetic Compression of order 0 as the lossless compression algorithm, according to the specification given in relevant documents.

REBA_ASW implements corrective actions in case that the statistics of the science data received is not the expected and hence, the reduction factor is less than the expected.

Each output science data packet is self-content, in the sense that the decompression of any packet only shall depend on that packet.

Each output science data packet shall contain sky and reference data (or combination of them) from only one detector

Each output science data packet has a "Tertiary header" which identifies the origin of the data.



The REBA_ASW is able to perform the reduction and compression process of the acquired science data according to the following different levels of processing:

- raw data (sky and load),
- averaged (sky and load),
- differenced,

All processing types can be compressed or uncompressed.

The REBA_ASW is able to apply 2 different processing types simultaneously.

The processing types as well as the detectors processed in each type are modifiable by TC.

The REBA_ASW implements a calibration function that processes averaged data with no compression in the 22 detectors successively. This function changes the detector which is processed automatically time to time (22 in 24 hours). These data are processed and sent simultaneously as the second processing type.

This calibration function is started/stopped by TC.

The baseline processing is time averaged sky-reference linear combined data, compressed in one processing type and calibration data (only time averaged not compressed) in the second type.

10.1.5 TELEMETRY

The REBA_ASW sends to the CDMS the following TM packets:

- TC verification reports: TM(1, x)
- HK and diagnostic packets: TM(3, x)
- event reports packets: TM(5, x)
- memory management reports: TM(6, x)
- Function status reports TM(8,6)
- time reports: TM(9, 9)
- enabled packets transmission reports: TM(14, 4)
- link connection reports: TM(17,2)
- science TM packets: TM(21, x)

After initialisation, HK packets are sent periodically at any time.

Two different HK packets of "Essential HK" are also delivered. They are a copy of the REBA HK and the DAE fast HK packets to be delivered every 32s with the difference of having a different APID according to [RD10].

There are foreseen some diagnostic HK packets that are sent only when requested by TC.

All TM packets are formatted following the rules of Herschel/Planck Packet structure ICD (PS-ICD).

REBA_ASW are able to manage the maximum TM rate allowed by the 1553 bus nominal protocol.



Note: REBA_ASW does not implement the burst mode.

The REBA ASW implements at least two TM packets queues and managing the priority among them. This is to guarantee that the HK packets are always delivered, even in case of the TM queue filled with scientific packets.

Science queue is 88 packets (maximum length packet), the General queue is 395 packets capable to allocate the max number of dump packets produced by a single TC dump command.

10.1.6 TELECOMMANDS

The REBA_ASW processes all LFI TCs received from the CDMS.

The REBA_ASW validates the TCs received by sending TM verification reports to the CDMS in the following way:

- Acceptance validation: it checks that the Data field header and the Packet Error Control field are correct according to the PS-ICD definition. This checking includes that the TC has type and subtype fields according to LFI TCs list. Within 2 seconds after reception, it sends a TM acceptance report packet success or failure, TM(1,1) or TM(1,2).
- Start execution: before starting the execution of the TC,
 - the REBA_ASW checks that the specific TC is allowed in the current state of the system.
 - the REBA_ASW checks that the parameters of the TC in the Application Data field are correct.
 - if one of the two checking are not correct the REBA_ASW sends a TM execution report failure packet TM(1,8).
- Completion validation execution: after execution of the TC, the REBA_ASW sends a TM execution report success or failure, TM(1,7) or TM(1,8).

The maximum TC rate is 2 TC packets per second.

Note: for testing and integration purposes, that is, in ground operations, the goal should be to allow the maximum TC rate of the 1553 bus protocol.

The REBA_ASW manages a queue of 16 TCs in such a way that a TC is not executed until the previous TC in the queue finalises its execution.

In case the TCs queue is full the REBA_ASW rejects the TC by sending an acceptance report failure TM(1,2).

The REBA_ASW manages some high priority TCs that are executed just after acceptance validation so they are not sent to the execution queue. These TCs are:

- Reset the SPU HW.
- Reset SMCS chips (SPU, DPU and DAE).
- Clear TC execution queue.



10.1.7 MONITORING AND AUTONOMY FUNCTIONS

The REBA_ASW checks periodically the following parameters:

- Science TM rate produced on board in order to control the filling of the spacecraft mass memory.
- CPU load of the SPU.
- Focal Plane temperature sensors.
- The communication links between REBA and DAE.

In case of deviations from nominal values, the REBA_ASW activates autonomy functions that put the instrument in a safe state or recover from non-nominal situations.

Autonomy functions allows to

- Re-enable, in some cases, previously disabled science processing
- Switch-off the Front End Unit by sending Disable RCA DC/DC commands to the DAE.
- Try to resume the communication between REBA and DAE or ask the CDMS to switch off the RAA

The DPU_ASW reports the activation of any autonomous function by sending to the CDMS an event report.

The REBA monitors some LFI HK parameters in order to manage to some extent the safety of the instrument.

10.1.8 INSTRUMENT OPERATIONAL MODES

The REBA_ASW includes in the HK data the LFI operational mode according to the criteria reported in Par. 8, Table 8.1-1.

The REBA_ASW always maintains in the HK data the last “known” LFI mode.

10.1.9 TESTING

The REBA_ASW implements an “are-you alive” function to test the end to end connection between ground and the instrument. This function is implemented by the service 17 of PS-ICD.



10.1.10 MEMORY MANAGEMENT

Functionally distinct memory areas are assigned to the following categories:

- code,
- fixed constants,
- variable parameters

The DPU_ASW is able to load program segments to the Program RAM of the SPU when the SPU_SUSW is running on the SPU.

The DPU_ASW is able to load program segments to the EEPROM.

Note: the load of program segments to the Program RAM of the DPU is performed by the DPU_SUSW.

The REBA_ASW is able to dump and check any memory area.

Changes and readouts of on-board data or software parameters are implemented via dedicated TCs and not via multi-purpose software load.

10.1.11 COMMUNICATIONS

Requirements of the external interfaces are described in this section, that is, communications with DAE, DAU, CDMS and the SPU_SUSW.

10.1.11.1 DAE COMMUNICATIONS

The REBA_ASW provides configuration and control of the remote DAE SMCS chips 1 and 2 (“control by link” mode). REBA DPU controls DAE SMCS chip 1, and REBA SPU controls DAE SMCS chip 2. (See DAE - REBA electrical interfaces in section 6.2.1.1.3.

REBA configures both DAE SMCS chips according the configuration described in the software specification document.

GPIO ports of DAE SMCS chips are configured as reported in the software specification document. Rest of registers are not changed after the configuration procedure.

REBA SPU receives from DAE the science data through the IEEE 1355 link 3 of the SPU SMCS chip. Data are received each 7.3 ms, alternatively from one of the two DAE buffers.

Science data are transferred from DAE to REBA SPU in the form of packets. The detailed description of the data structure is presented in the annex D of LFI On-Board SW URD [RD11] .

REBA SPU starts a packet data transfer when receives a signal “Data ready”.



REBA SPU maintains internally DAE buffer status to know which buffer (ping or pong) has to be transferred. Before the data transfer is started REBA reads the corresponding DAE semaphore (ping or pong) to insure data consistency. (DAE ping semaphore shall be read from the GPIO_DATA_1: bit 0, DAE pong semaphore is read from the GPIO_DATA_1: bit 1.)

REBA SPU provides a support for the DAE arbitration logic (handshake logic via ping/pong semaphores). REBA SPU resets semaphores whenever it has completed the data transfer. Reset procedure consists in:

- Writing a sequence 0-1 (rising edge) in the GPIO_DATA_0: bit 0, when data transference through the link 3 is completed (DAE ping buffer is transferred).
- Writing a sequence 0-1 (rising edge) in the GPIO_DATA_0: bit 1, when data transference through the link 2 is completed (DAE pong buffer is transferred).

The REBA SPU – DAE timing interface is presented by a diagram in the annex D2 of LFI On-Board SW URD [RD11].

REBA SPU transfers science data from the DAE DPRAM according to the memory maps provided into lower level documents.

REBA DPU receives LFI HK data informing of the health of the instrument from the DAE through the IEEE 1355 link 3 of the DPU SMCS chip. There are two types of LFI HK data to be received from DAE: DAE sensors and status HK data (received each 1 s) and DAE configuration HK data (received each 64 s). Each HK data word is 16 bits.

1. DAE sensors and status HK data consists of:

- Status of the current limiter of each single DC/DC Converter devoted to power a group of FEM/BEM/Signal conditioning chains (4 memory-mapped registers).
- Converted value of temperature sensors (20 memory mapped registers).
- Converted value of current and voltage sensors (10 memory mapped registers).
- Converted value of the 44 drain currents.
- “Science Data Overridden” condition (1 memory-mapped register).
- DAE status (GPIO_DATA_2 register of the DAE SMCS chip 1).

These registers shall be accessed by REBA in read only mode.

2. DAE configuration HK data consists of:

- Adjustable bias voltages for each channel of the FEMs (3 values per each of the 44 channels, total: 132 memory mapped registers).
- Adjustable current levels for phase switches (2 values per each of the 44 channels, total: 88 memory mapped registers).
- Adjustable gains for each signal conditioning channel (44 memory-mapped registers).
- Adjustable offsets for each signal conditioning channel (44 memory-mapped registers).
- Enable/Disable the power output of each single DC/DC Converter devoted to power a group of FEM/BEM/Signal conditioning chains (4 memory-mapped registers).



REBA transfers the HK information from the DAE DPRAM according to the memory maps provided into [RD17_1] and [RD17_2].

REBA provides the following commands to DAE:

- 1) Start/Stop Science Sequencer.
- 2) Start/Stop HK Sequencer.
- 3) DAE Master reset
- 4) Set DAE configuration:
 - Set adjustable voltages for each channel of the FEMs.
 - Set adjustable currents for phase switches control levels.
 - Set adjustable gain for each signal conditioning channel.
 - Set adjustable offset for each signal-conditioning channel.
 - Enable/Disable the power output of each single DC/DC Converter devoted to power a group of FEM/BEM/Signal conditioning chains.
 - Set the activation/deactivation of the phase switch of each radiometer
- 5) Reset remote DAE SMCS chip 1. Reset remote DAE SMCS chip 2.

Commands of groups 1 to 3 are implemented by writing by REBA to the DAE SMCS chip 1, GPIO output port.

Commands of group 4 are implemented by writing by REBA to DAE registers mapped to DPRAM memory.

Commands of group 5 are implemented through the two specially dedicated SMCS reset lines.

All commands are sent by the REBA DPU.

10.1.11.2 DAU COMMUNICATIONS

REBA DPU receives REBA HK data informing of the health of the REBA from the DAU through a communication FIFO interface. Each HK data word in the FIFO is 9 bits.

The HK data coming from DAU FIFO consist of 13 channels as reported in the software specification document.

The DAU status register (bit 0) is read to get the REBA synchronisation status (0=Synchronised/1=Free running).

The REBA DPU commands DAU HK data each 1 s using low level SW drivers functions.

10.1.11.3 CDMS COMMUNICATIONS

The DPU communicates with the CDMS through a MIL-STD-1553B link according to the structure and rules of the high and low level protocols defined in PS-ICD.

The REBA_ASU implements the TCs and TM packet services detailed in [AD5]

10.1.11.4 SPU-SUSW

The DPU_ASU communicates with the SPU_SUSW through the IEEE 1355 link 1 of the DPU SMCS chip.



10.1.12 HARDWARE INTERFACES

The REBA_ASW is implemented in the REBA hardware.

10.1.13 SOFTWARE INTERFACES

The REBA HLSW operates under the Virtuoso operating system.
The base language of programming is C. Nevertheless critical in performance tasks are programmed in assembler.

10.2 PHYSICAL DESCRIPTION OF INSTRUMENT ON-BOARD SOFTWARE

10.2.1 OPERATIONAL ENVIRONMENT

To describe the environment where the REBA_ASW operates, several aspects must be taken into account because they constrain the software implementation and development. These aspects are the REBA hardware, the external interfaces and the different operational configurations during the development.

10.2.1.1 REBA HARDWARE

There are two REBA boxes, one nominal and one redundant. The redundancy concept is cold, which means that both boxes do not operate at the same time; the operation of each unit shall be done by the spacecraft switching-on the corresponding unit. The REBA_ASW is the same in each REBA box, so no software function is needed to operate one or the other REBA box.

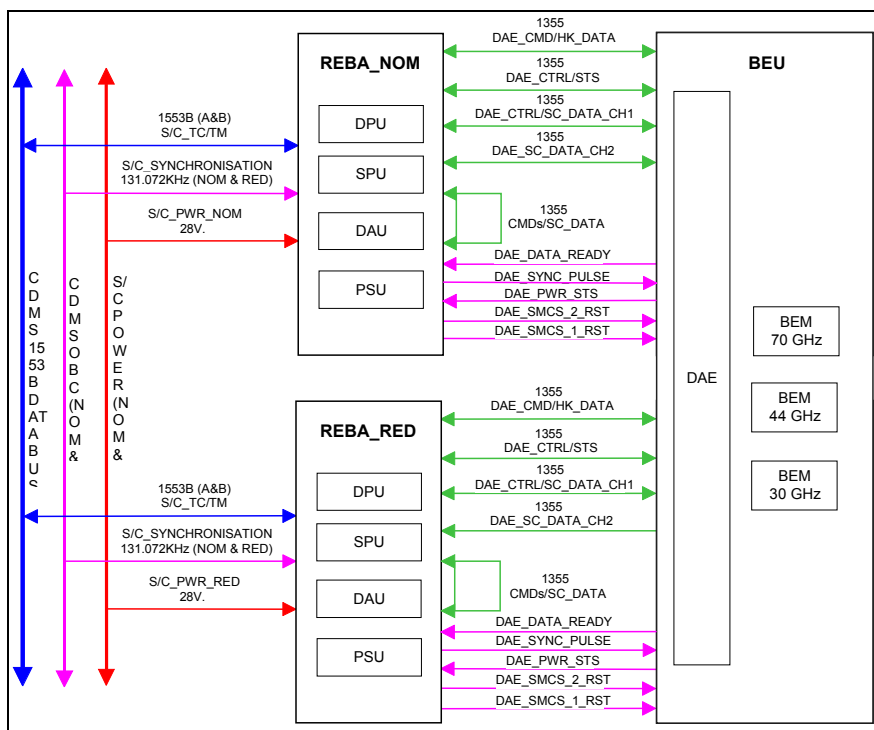


Figure 10-2 Interface Functional Diagram of the REBA, nominal and redundant.

Each REBA consists of the following subunits:

- the Power Supply Unit (PSU) which feeds the REBA unit. It consists of a DC/DC converter that converts the primary power received from the spacecraft PDU to the secondary regulated voltages required only by the REBA and provides galvanic isolation towards the spacecraft side of the interface. The PSU DC/DC converter also receives the On-Board Clock (OBC) from the CDMS that is used to increment the internal On Board Time register. There is no software interface with the REBA_ASW.
- the Data Acquisition Unit (DAU) performs the analogue to digital conversion of the analogue housekeeping data of the REBA itself (temperatures and voltages). The REBA_ASW collects from the DAU the HK data through a FIFO memory.
- the Signal Processing Unit (SPU) is a computing subunit (see details in next paragraphs) and implements part of the REBA_ASW, the SPU_ASW. It receives the science data from the DAE through a IEEE 1355 link implemented in a SMCS chip. A second IEEE 1355 link is used to control by link the remote DAE SMCS chip. The third IEEE 1355 link communicates with the DPU. The SPU is in charge of the reduction and compression of the science data.
- the Digital Processing Unit (DPU) is a computing subunit (see details in next paragraphs) and implements part of the REBA_ASW, the DPU_ASW. It contains another SMCS chip with 3 IEEE 1355 links that communicate with the SPU, and the DAE. A MIL-STD 1553B link is used to communicate with the CDMS. The DPU is in charge of the control and monitoring of the instrument as well as the communication with the spacecraft (CDMS).



The functional block diagram of Figure 10-2 shows the different parts of one section of REBA. A complete specification of REBA can be found in [RD18].

10.2.1.1.1 SPU Hardware

The SPU hardware of LFI consists of one CPU, which main characteristics are:

- TSC21020E processor based architecture running up to 18 MHz.
- PROM Memory for Bootstrap Program Storage. (32 KW x 48 bits) (192 KB)
- SRAM Memory for Program Storage up to 512 KW x 48 bits (3 MB), protected by EDAC.
- SRAM Memory for Data Storage up to 512 KW x 32 bits (2 MB), protected by EDAC.
- Expansion Bus of 32 bit mapped at the Data Memory Bus address space. An SRAM Memory Data Expansion Module with 512KW x 32 bits (2 MB), protected by EDAC, is connected to the CPU.
- Three IEEE-1355 DS High Speed Serial Communication links, implemented by the SMCS332 chip and including an 8Kx32 bits (32 KB) Dual Port Ram buffer.
- Programmable Watchdog Timer

Two of the IEEE-1355 links are used by the SPU_ASW to communicate with the DAE (scientific data) and to control by link the DAE SMCS chip; the third one communicates with the DPU (commands and TM).

A “Data Ready” electrical signal is connected between DAE and the SPU, this signal produces an interruption in the SPU when the DAE is ready to transfer data.

The SPU_ASW is stored in the EEPROM located in the DPU board (see later description). It is transferred to the SPU by the DPU_ASW.

10.2.1.1.2 DPU Hardware

The DPU hardware of LFI consists of one CPU, whose main characteristics are:

- TSC21020E processor based architecture running up to 18 MHz.
- PROM Memory for Bootstrap Program Storage. (32 KW x 48 bits) (192KB)
- SRAM Memory for Program Storage up to 512 KW x 48 bits (3 MB), protected by EDAC
- SRAM Memory for Data Storage up to 512 KW x 32 bits (2 MB), protected by EDAC
- Three IEEE-1355 DS High Speed Serial Communication links, implemented by the SMCS332 chip and including an 8Kx32 bits (32 KB) Dual Port Ram buffer.
- One MIL-STD-1553B Data Bus Interface (redundant A+B) including a 8Kx16 bits (16KB) Dual Port Ram Buffer.
- Programmable Watchdog Timer
- One S/C OBT interface (131.072 KHz clock signal).
- One Back End Unit Timing interface (1 Hz signal).
- An EEPROM (1.5 MB), protected by EDAC, for on-board storage of the SPU_ASW and DPU_ASW.

One IEEE 1355 link is used by the DPU_ASW to communicate with the DAE to control by link the SMCS chip of DAE. The second one is used to communicate with the DAE to transfer commands and HK and the third one is used by DPU_ASW to communicate with the SPU (commands and TM).

Two Reset electrical lines are provided by the DPU to reset each of the two SMCS chips of DAE. The DPU_ASW is stored in the EEPROM.



10.2.1.2 REBA_ASW EXTERNAL INTERFACES

The context diagram in Figure 10-3 shows the REBA_ASW interfaces with other subsystems. The REBA_ASW, formed by the SPU_ASW and DPU_ASW, is stored in the EEPROM of the DPU. During the start-up procedure both applications must be loaded to the corresponding RAM. The SPU_ASW is read by the DPU_ASW from the EEPROM and transferred to the SPU_SUSW that loads it into the SPU RAM and gives it the control. The load of the DPU_ASW is performed by the DPU_SUSW, so it is not included in the diagram (see [RD16]).

Once the REBA_ASW has been started (both DPU_ASW and SPU_ASW) the external entities the REBA_ASW communicates are the DAE, the CDMS and the DAU. Details of the different parts of the diagram are given hereafter:

External entities:

- SPU_SUSW: it performs the start-up procedure of the SPU.
- DAE: Data Acquisition Electronics. It performs the A/D conversion of the scientific data as well as its own housekeeping. It has no processor, so the REBA_ASW has to command the SMCS332 circuits via control links to transfer the data.
- DAU: Data Acquisition Unit: It performs the A/D conversion of the REBA housekeeping. It is part of the REBA hardware. The REBA_ASW commands it to acquire the REBA HK channels.
- CDMS: Command and Data Management Subsystem. This is the only software interface with the spacecraft and, hence, with ground.

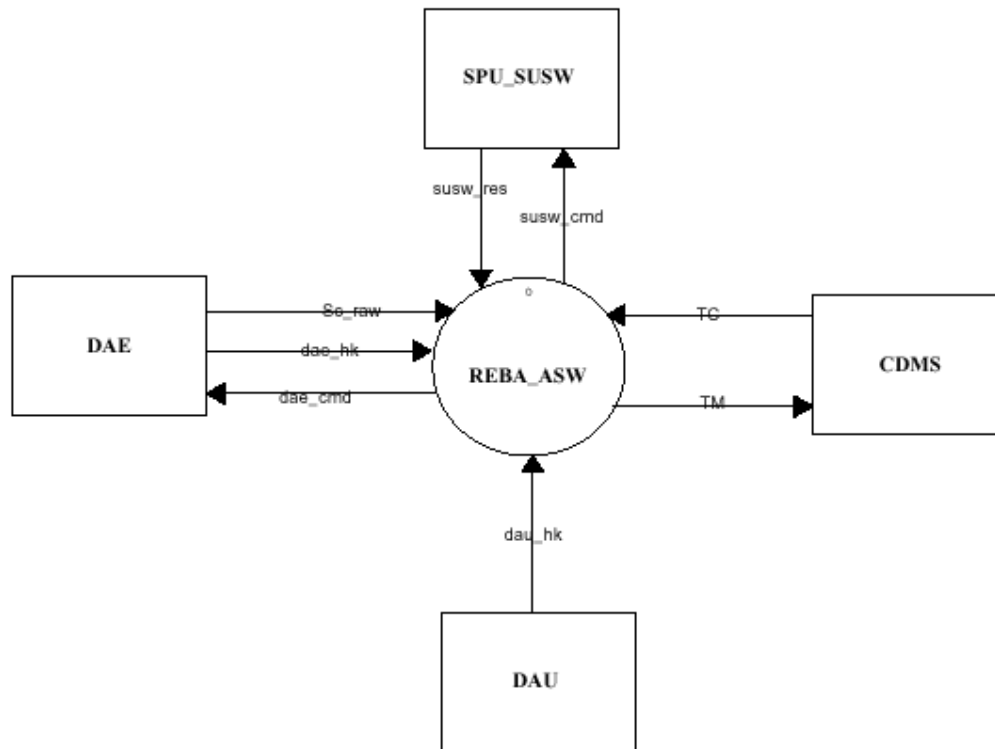


Figure 10-3 Context diagram of the REBA_ASW

Data flows:

- spuswsw_cmd: represents the commands which are sent from the DPU_ASW to the SPU_SUSW to manage the load and start-up of the SPU_ASW. These commands are Load, Dump, Check, Test and Start function, they are defined in [RD16].
- spuswsw_res: represents the responses to the previous commands. It consists of Reports and Acknowledges as defined in [RD16].
- dae_cmd: represents commands to the instrument which are executed by DAE and give functionality to the instrument. It also includes specific commands to control by link the remote SMCS chips of DAE.
- raw_Sc: represents the raw data coming from the DAE. The data are received in form of packets from DAE through IEEE 1355 link of the SPU SMCS chip. Data are sent alternatively from 2 DAE buffers. Details are given in Par. 10.1.
- dae_hk & status: represents the LFI HK data and DAE status received through IEEE 1355 links of the DPU SMCS chip. Some status received in the IEEE link of the SPU SMCS, is used for a handshake in the transfer of the scientific data buffers. Details are given in Par. 10.1.
- dau_cmd: it represents the command to start the acquisition of the dau_hk.
- dau_hk: represents the HK of the REBA itself. Details are given in Par. 10.1.



- TC: are the TC packets received from the ground or the spacecraft through the CDMS. Structure and protocols are defined in PS-ICD. More details in Par. 10.1.
- TM: consists of the science packets, HK packets and event reports as well as the answers to the TCs. Structure and protocols are defined in PS-ICD. More details in Par. 10.1.

10.3 MEMORY ADDRESSING INFORMATION

Table 10.3-1 reports the memory addressing information.

Memory Device Detail	Size	Address Bus	Data Bus	Mem ID	SAU	TC Patch	TC Dump	Dump TM
LFI DPU PROM	32kw x 48 bit	24 bits	48 bits	00h	6 bytes		6,5	6,6
LFI DPU PRAM	512kw x 48 bit	24 bits	48 bits	01h	6 bytes	6,2	6,5	6,6
LFI DPU DRAM	512kw x 32 bit	32 bits	32 or 40 bits	11h	4 bytes	6,2	6,5	6,6
LFI DPU EEPROM	256kw x 48 bit	32 bits	32 or 40 bits	03h	6 bytes	6,2	6,5	6,6
LFI SPU PROM	32kw x 48 bit	24 bits	48 bits	80h	6 bytes		6,5	6,6
LFI SPU PRAM	512kw x 48 bit	24 bits	48 bits	81h	6 bytes	6,2	6,5	6,6
LFI SPU DRAM	512kw x 32 bit	32 bits	32 or 40 bits	91h	4 bytes	6,2	6,5	6,6
LFI SPU EXT DRAM	512kw x 32 bit	32 bits	32 or 40 bits	92h	4 bytes	6,2	6,5	6,6
LFI DAE SMCS1 DPRAM 1	0x0000 to 0x0FFF non contiguous 0x1000 to 0x1075 contiguous	32 bits	16 bits	F4h	2 bytes	6,2	6,5	6,6
LFI DAE Ping Pong DPRAM 2	2 x 2280words x 16 bit	32 bits	16 bits	F6h	2 bytes		6,5	6,6
LFI DPU SMCS DPRAM	8kw x 32 bit	32 bits	32 bits	14h	4 bytes			
LFI SPU SMCS DPRAM	8kw x 32 bit	32 bits	32 bits	94h	4 bytes			
LFI DPU 1553 DPRAM	8kw x 16 bit	32 bits	16 bits	15h	2 bytes			

Table 10.3-1 Memory addressing information

See par. 11.1.9 for a description of memories ID.



10.3.1 MEMORY ALLOCATIONS

The details of the memories allocations are given in the following paragraphs. Note that 1553 DPRAM and DPU and SPU SMCS DPRAM are not allowed to be dumped or checked and thus no additional information is required and reported here.

Note that Memory ID, Start Address and Length are all 2 bytes size. Memory Id is requiring a single byte, instead the size (and thus the Starting Address) up to three bytes. For this reason the second byte of the Memory Id is used by the Starting Address.

10.3.1.1 REBA DPU PROM

The overall addressing range of this memory is 0000 0000 to 0000 7FFF. Note that for the ASW the range is reduced to 0000 0000 to 0000 0017.

Here after memory allocations are reported.

Slot	Starting	Length
Code Instructions	0000 0000	3E67
Constants	0000 7000	70FF

10.3.1.2 REBA DPU PRAM

This memory is used by the ASW, indeed the last four slots of the ASW (see par. 10.3.1.4) are copied here.

The overall addressing range of this memory is 0080 0000 to 0081 FFFF. Note that for the ASW the range is reduced to 0000 0018 to 0001 FFFF.

The starting address where each slot is copied on the DRAM is described in the following table.

Slot	Starting	Length
DPU3	0000 0000	0000 0100
DPU4	0000 0100	0000 000F
DPU5	0000 0200	0000 0081
DPU6	0000 1000	0000 9D86

The reserved Program RAM area for DPU_SUSW is detailed below

PM Address (hex)	Description
87.0000 – 87.FFFF	General purpose Program RAM for DPU_SUSW

10.3.1.3 REBA DPU DRAM

This memory is used by the ASW indeed the first two slots of the ASW (see par. 10.3.1.4) are copied here.

The overall addressing range of this memory is 0000 0000 to 0001 FFFF.

The starting address where each slot is copied on the DRAM is described in the following table.



Slot	Starting	Length
DPU1	0003 0000	0000 1032
DPU2	0003 FC00	0000 0008

The reserved Data RAM area for DPU_SUSW is detailed below

DM Address (hex)	Description
0000.0000	Reset Source
0000.0001	Hardware initialization tests result
0000.0002	PROM Initialization checksum – Computed value
0000.0003	PROM Initialization checksum – Expected value
0000.0004	Error detection during command loop execution
0000.0005	EDAC double failure last wrong address – Program Memory
0000.0006	EDAC double failure last wrong address – Data Memory
0000.0007	DSP Interrupt pending register value (when unexpected int. detected)
0000.0008	PMPSC Interrupt pending register value (when unexpected int. detected)
0000.0009	DMPSC Interrupt pending register value (when unexpected int. detected)
0000.000A	ACE-1553 Interrupt pending register value (when unexpected int. detected)
0000.000B	Last SEF Address in PM
0000.000C	Last SEF Address in DM
0000.000D	Number of times DSP unexpected interrupts have been detected
0000.000E	Number of times PMPSC unexpected interrupts have been detected
0000.000F	Number of times DMPSC unexpected interrupts have been detected
0000.0010	Number of times ACE-1553 unexpected interrupts have been detected
0000.0011	Not used
0000.0012	Not used
0000.0013	Value of VOFFSET_TM channel (acquired once for initialization tests)
0000.0014	Value of VGAIN_TM channel (acquired once for initialization tests)
0000.0015	Value of VCC_VOL_TM channel (acquired once for initialization tests)
0000.0016	Value of 15VP_VOL_TM channel (acquired once for initialization tests)
0000.0017	Value of 15VN_VOL_TM channel (acquired once for initialization tests)
0000.0018	Value of 15VN_1553_VOL_TM channel (acquired once for initialization tests)
0000.0019	Not used
0000.001A	Not used
0000.001B	Unit Status Error Word. All writings are ORed. For integration purposes only
0000.001C	Unit Status Housekeeping word, except counter. All writings are ORed. For integration purposes only
0000.001D	Housekeeping Error Word. All writings are ORed. For integration purposes only
0000.001E – 0000.FFFF	General purpose Data RAM for DPU_SUSW

0000.0000h: Reset Source word

Bit (0 is LSB)	Description	Coding
5 – 31	Not used	
4	SW reset	0=Not detected, 1=detected
3	EDAC DEF reset (Data mem.)	0=Not detected, 1=detected
2	EDAC DEF reset (Program mem.)	0=Not detected, 1=detected
1	Watchdog reset	0=Not detected, 1=detected
0	Power up reset or 1553 reset	0=Not detected, 1=detected

0000.0001h: Hardware initialization tests result word



Bit (0 is LSB)	Description	Coding
26- 31	Not used	
25	15VN_1553_VOL_TM channel test	0 = Failed
24	15VN_VOL_TM channel test	0 = Failed
23	15VP_VOL_TM channel test	0 = Failed
22	VCC_VOL_TM channel test	0 = Failed
21	VGAIN_TM channel test	0 = Failed
20	VOFFSET_TM channel test	0 = Failed
19	Not used	
18	1553 DPRAM Address-Data test	0 = Failed
17	SMCS DPRAM Address-Data test	0 = Failed
16	Program RAM Address-Data test	0 = Failed
15	Data RAM Address-Data test	0 = Failed
14	1553 DPRAM pattern A test	0 = Failed
13	SMCS DPRAM pattern A test	0 = Failed
12	Program RAM pattern A test	0 = Failed
11	Data RAM pattern A test	0 = Failed
10	1553 DPRAM pattern 5 test	0 = Failed
9	SMCS DPRAM pattern 5 test	0 = Failed
8	Program RAM pattern 5 test	0 = Failed
7	Data RAM pattern 5 test	0 = Failed
6	EDAC double error test – Program Memory	0 = Failed
5	EDAC double error test – Data Memory	0 = Failed
4	EDAC single error test – Program Memory	0 = Failed
3	EDAC single error test – Data Memory	0 = Failed
2	EDAC no fail test - Program Memory	0 = Failed
1	EDAC no fail test - Data Memory	0 = Failed
0	PROM Checksum test	0 = Failed

0000.0002h: PROM Initialization checksum - Computed value

Bit (0 is LSB)	Description
16 – 31	Not used
0 – 15	PROM Computed checksum

0000.0003h: PROM Initialization checksum - Expected value

Bit (0 is LSB)	Description
16 – 31	Not used
0 – 15	PROM Expected checksum

0000.0004h: Error detection during command loop execution word

Bit (0 is LSB)	Description	Coding
7 – 31	Not used	
6	Inconsistency error	1 = detected
5	Unexpected 1553 Interrupt. The unexpected interrupts are: 0x6FBC (IPR value). This error can also be reported when valid interrupts are detected but some inconsistency appears when handling the interrupt.	1 = detected
4	Unexpected DMPSC Interrupt. The unexpected interrupts are: 0x7FFF (IPR value)	1 = detected
3	Unexpected PMPSC Interrupt. The unexpected interrupts are: 0x7FE7 (IPR value)	1 = detected
2	Unexpected DSP interrupt The unexpected interrupts are: 0xFFFFBFCF (IPR value)	1 = detected
1	EDAC double failure in Data memory	1 = detected
0	EDAC double failure in Program memory	1 = detected



0000.0005h: EDAC double failure last wrong address – Program memory

Bit (0 is LSB)	Description
24 – 31	Not used
0 – 23	EDAC double failure last wrong address in Program memory (absolute address value) Note: previous failing addresses will be overwritten.

0000.0006h: EDAC double failure last wrong address – Data memory

Bit (0 is LSB)	Description
0 - 31	EDAC double failure last wrong address in Data memory (absolute address value) Note: previous failing addresses will be overwritten.

0000.0007h: DSP Interrupt pending register value in case of unexpected DSP Interrupt

Bit (0 is LSB)	Description
0 - 31	DSP irptl register value

0000.0008h: PMPSC Interrupt pending register value in case of unexpected PMPSC Interrupt

Bit (0 is LSB)	Description
15 – 31	Not used
0 - 14	PMPSC intp register value

0000.0009h: DMPSC Interrupt pending register value in case of unexpected DMPSC Interrupt

Bit (0 is LSB)	Description
15 – 31	Not used
0 - 14	DMPSC intp register value

0000.000Ah: ACE-1553 Interrupt pending register value in case of unexpected Interrupt

Bit (0 is LSB)	Description
16 – 31	Not used
0 - 15	ACE-1553 intp register value Note: Previous values will be overwritten.

Note about the reporting of IPRs:

When DPU_SUSW detects an unexpected interrupt from DSP, ACE-1553, PMPSC or DMPSC, DPU_SUSW reports the value of the relevant Interrupt Pending Register by ORing the current value of the IPR with the value already contained in the appropriate position of the report area. With this method of IPR reporting no unexpected interrupt is ever lost. DPU_SUSW clears the IPR report memory position only during the HW reset initialization (it will not be cleared in case of Warm reset). The master APSW may clear this report area position if necessary by loading zeros.

At start-up (DPU-SUSW), the dumped area: the address 0 contains 0x00000001, the address 1 contains 0x03F7FFFF, the addresses 2 and 3 have the same value and check that the addresses 5,6,11, 12, 19 and 1A are 0.

10.3.1.4 REBA EEPROM

The REBA EEPROM is where the ASW is stored in the LFI instrument. In the switch on procedure of the instrument the ASW is copied in the RAM memories of the REBA where it is run. In addition the EEPROM is the place where the DAE default configuration is saved.



The overall addressing range of this memory is 0088 0000 to 008B FFFF. Note that for the ASW the range is reduced to 0008 0000 to 000B FFFF.

Note that on the REBA redundant unit, there is a damaged area with EDAC problems in FM-R (page from 0x22E80 to 0x22EFF).

DPU ASW memory allocation:

Slot	Starting	Length	CRC
DPU1	0000 0000	0000 1032	E619
DPU2	0000 1032	0000 0008	057D
DPU3	0000 103A	0000 0100	2314
DPU4	0000 113A	0000 000F	5D51
DPU5	0000 1149	0000 0081	C377
DPU6	0000 11CA	0000 9D86	FE0E

SPU ASW memory allocation:

Slot	Starting	Length	CRC
SPU1	0001 0000	0000 06FA	9893
SPU2	0001 06FA	0000 0008	768F
SPU3	0001 0702	0000 0100	1BB4
SPU4	0001 0802	0000 000F	898E
SPU5	0001 0811	0000 0081	6C63
SPU6	0001 0892	0000 643C	B813

DAE default configuration:

Content	Starting	Stop	CRC
DAE default configuration	0003 FF50	0003 FFFF	N/A

10.3.1.5 REBA SPU PROM

The overall addressing range of this memory is 0000 0000 to 0000 7FFF. Note that for the ASW the range is reduced to 0000 0000 to 0000 0017.

Here after memory allocations are reported.

Slot	Starting	Length
Code Instructions	0000	2B04
Constants	7000	70FF

10.3.1.6 REBA SPU PRAM

This memory is used by the ASW, indeed the last four slots of the SPU ASW (see par. 10.3.1.4) are copied here.

The overall addressing range of this memory is 0080 0000 to 0081 FFFF. Note that for the ASW the range is reduced to 0000 0018 to 0001 FFFF.

The starting address where each slot is copied on the PRAM is described in the following table.

Slot	Starting	Length



SPU3	0000 0000	0000 0100
SPU4	0000 0100	0000 000F
SPU5	0000 0200	0000 0081
SPU6	0000 1000	0000 643C

The reserved Program RAM area for SPU_SUSW is detailed below

PM Address (hex)	Description
87.0000 – 87.FFFF	General purpose Program RAM for SPU_SUSW

10.3.1.7 REBA SPU DRAM

This memory is used by the ASW indeed the first two slots of the SPU ASW (see par. 10.3.1.4) are copied here.

The overall addressing range of this memory is 0000 0000 to 0001 FFFF.

The starting address where each slot is copied on the DRAM is described in the following table.

Slot	Starting	Length
SPU1	0003 0000	0000 06FA
SPU2	0007 FC00	0000 0008

The reserved Data RAM area for SPU_SUSW is detailed below

DM Address (hex)	Description
0000.0000	Reset Source
0000.0001	Hardware tests result
0000.0002	PROM Initialization checksum – Computed value
0000.0003	PROM Initialization checksum – Expected value
0000.0004	Error detection during command loop execution
0000.0005	EDAC double failure last wrong address – Program Memory
0000.0006	EDAC double failure last wrong address – Data Memory
0000.0007	DSP Interrupt pending register value (when unexpected int. detected)
0000.0008	PMPSC Interrupt pending register value (when unexpected int. detected)
0000.0009	DMPSC Interrupt pending register value (when unexpected int. detected)
0000.000A	SMCS Interrupt pending register value (when unexpected int. detected)
0000.000B	Last SEF Address in PM
0000.000C	Last SEF Address in DM
0000.000D	Number of times DSP unexpected interrupts have been detected
0000.000E	Number of times PMPSC unexpected interrupts have been detected
0000.000F	Number of times DMPSC unexpected interrupts have been detected
0000.0010	Number of times SMCS unexpected interrupts have been detected
0000.0011 – 0000.FFFF	General purpose Data RAM for SPU_SUSW

0000.0000h: Reset Source word



Bit (0 is LSB)	Description	Coding
5 - 31	Not used	
4	SW reset	0=Not detected, 1=detected
3	EDAC DEF reset (Data mem.)	0=Not detected, 1=detected
2	EDAC DEF reset (Program mem.)	0=Not detected, 1=detected
1	Watchdog reset	0=Not detected, 1=detected
0	Power up reset	0=Not detected, 1=detected

0000.0001h: Hardware tests result word

Bit (0 is LSB)	Description	Coding
19- 31	Not used	
18	Extended Data RAM Address-Data test	0 = Failed
17	SMCS DPRAM Address-Data test	0 = Failed
16	Program RAM Address-Data test	0 = Failed
15	Data RAM Address-Data test	0 = Failed
14	Extended Data RAM pattern A test	0 = Failed
13	SMCS DPRAM pattern A test	0 = Failed
12	Program RAM pattern A test	0 = Failed
11	Data RAM pattern A test	0 = Failed
10	Extended Data RAM pattern 5 test	0 = Failed
9	SMCS DPRAM pattern 5 test	0 = Failed
8	Program RAM pattern 5 test	0 = Failed
7	Data RAM pattern 5 test	0 = Failed
6	EDAC double error test – Program Memory	0 = Failed
5	EDAC double error test – Data Memory	0 = Failed
4	EDAC single error test – Program Memory	0 = Failed
3	EDAC single error test – Data Memory	0 = Failed
2	EDAC no fail test – Program Memory	0 = Failed
1	EDAC no fail test - Data Memory	0 = Failed
0	PROM Checksum test	0 = Failed

0000.0002h: PROM Initialization checksum - Computed value

Bit (0 is LSB)	Description
16 - 31	Not used
0 - 15	PROM Computed checksum

0000.0003h: PROM Initialization checksum - Expected value

Bit (0 is LSB)	Description
16 - 31	Not used
0 - 15	PROM Expected checksum

0000.0004h: Error detection during command loop execution word



Bit (0 is LSB)	Description	Coding
7 – 31	Not used	
6	Inconsistency error	1 = detected
5	Unexpected SMCS Interrupt. The unexpected interrupts are: 0xFFFFFC22 (IPR value)	1 = detected
4	Unexpected DMPSC Interrupt. The unexpected interrupts are: 0x7FFF (IPR value)	1 = detected
3	Unexpected PMPSC Interrupt. The unexpected interrupts are: 0x7FFF (IPR value)	1 = detected
2	Unexpected DSP interrupt. The unexpected interrupts are: 0xFFFFFFFF (IPR value)	1 = detected
1	EDAC double failure in Data memory	1 = failure detected
0	EDAC double failure in Program memory	1 = failure detected

0000.0005h: EDAC double failure last wrong address – Program memory

Bit (0 is LSB)	Description
24 - 31	Not used
0 - 23	EDAC double failure last wrong address in Program memory (absolute address value) Note: previous failing addresses will be overwritten.

0000.0006h: EDAC double failure last wrong address – Data memory

Bit (0 is LSB)	Description
0 - 31	EDAC double failure last wrong address in Data memory (absolute address value) Note: previous failing addresses will be overwritten.

0000.0007h: DSP Interrupt pending register value in case of unexpected DSP Interrupt

Bit (0 is LSB)	Description
0 - 31	DSP irptl register value

0000.0008h: PMPSC Interrupt pending register value in case of unexpected PMPSC Interrupt

Bit (0 is LSB)	Description
15 – 31	Not used
0 - 14	PMPSC intp register value

0000.0009h: DMPSC Interrupt pending register value in case of unexpected DMPSC Interrupt

Bit (0 is LSB)	Description
15 – 31	Not used
0 - 14	DMPSC intp register value

0000.000Ah: SMCS Interrupt pending register value in case of unexpected SMCS Interrupt

Bit (0 is LSB)	Description
0 - 31	SMCS intp register value Note: Previous values will be overwritten.

Note about the reporting of IPRs:

When SPU_SUSW detects an unexpected interrupt from DSP, SMCS, PMPSC or DMPSC, SPU_SUSW reports the value of the relevant Interrupt Pending Register by ORing the current value of the IPR with the value already contained in the appropriate position of the report area. With this method of IPR reporting no unexpected interrupt is ever lost. SPU_SUSW clears the IPR report



memory position only during the HW reset initialization (it will not be cleared in case of Warm reset). The master APSW may clear this report area position if necessary by loading zeros.

At start-up (SPU-SUSW), the dumped area: the address 0 contains 0x00000001, the address 1 contains 0x0007FFFF, the addresses 2 and 3 have the same value and check that the addresses 5,6,11 and 12 are 0.

10.3.1.8 REBA SPU EXT DRAM

The overall addressing range of this memory is 8000 0000 to 8007 FFFF.

10.3.1.9 DAE MEMORIES

There is no mean to perform any patch in DAE memory because there is no EEPROM but at the same time during Commissioning there will be some activities of dumping in order to check the access to these memories.

During normal flight operation in case of a contingency there could be the possibility to dump the whole content of the PING/PONG DAE DPRAM2 that is where scientific data are stored just before they are sent to REBA.

The REBA SPU transfers science data from the DAE as a packet. Each packet contains 60 data frames. Each frame contains 48 16-bit words. All the details are given in par. 10.4.3.2.

SMCS1 DPRAM1

The overall addressing range of this memory is 0000 0000 to 0000 8000.

Memory allocation:

REBA Use of the value	Value	DPRAM Addresses
Slow HK and DAE configuration	FEM VG 1 detector Id 0 to 43	0200 to 022B
	FEM VG 2 detector Id 0 to 43	0240 to 026B
	FEM Drain Voltage detector Id 0 to 43	0280 to 02AB
	Phase Switch I1 detector Id 0 to 43	0000 to 002B
	Phase Switch I2 detector Id 0 to 43	0040 to 006B
	RCA gain detector Id 0 to 43	0400 to 042B
	RCA offset detector Id 0 to 43	0440 to 046B
	(*) FEM Drain current 0 to 27	1000 to 101B
	(*) FEM Drain current 28 to 43	1020 to 102F
	(**) Phase Switch A-C en/dis Horn Id 0 to 10	0080 0082
		0084 0086
		0088 008A
		008C 008E
		0090 0092
		0094 0096
		0098 009A
		009C 009E
		00A0 00A2
		00A4 00A6
		00A8 00AA
	Phase Switch B-D en/dis Horn Id 0 to 10	0081 0083
		0085 0087



		0089	008B
		008D	008F
		0091	0093
		0095	0097
		0099	009B
		009D	009F
		00A1	00A3
		00A5	00A7
		00A9	00AB
	Phase Switch A-C Direct Polarised Horn Id 0 to 10	00C0	00C2
		00C4	00C6
		00C8	00CA
		00CC	00CE
		00D0	00D2
		00D4	00D6
		00D8	00DA
		00DC	00DE
		00E0	00E2
		00E4	00E6
		00E8	00EA
	Phase Switch B-D Direct Polarised Horn Id 0 to 10	00C1	00C3
		00C5	00C7
		00C9	00CB
		00CD	00CF
		00D1	00D3
		00D5	00D7
		00D9	00DB
		00DD	00DF
		00E1	00E3
		00E5	00E7
		00E9	00EB
	DC/DC converters enable/disable (DC Id 1 to 4)	0600 to 0603	
Fast HK: Power box HK sensors (including 1 reserved word)	Main DC/DC Temp	1040 to 104F	
	Main DC/DC Vout 1		
	Reserved		
	Main DC/DC Primary C.		
	Science DC/DC 1 Temp		
	Science DC/DC 1 Vout		
	Science DC/DC 1 Current		
	Science DC/DC 2 Temp		
	Science DC/DC 2 Vout		
	Science DC/DC 2 Current		
	Science DC/DC 3 Temp		
	Science DC/DC 3 Vout		
	Science DC/DC 3 Current		
	Science DC/DC 4 Temp		
	Science DC/DC 4 Vout		
	Science DC/DC 4 Current		
Fast HK: Left Group Temp. Sensors	FPA Temp 1	1050 to 1055	
	FPA Temp 2		
	FPA Temp 3		
	FPA Temp 4		



	FPA Temp 5	1058 to 105D
	FPA Temp 6	
	Left BEM Temp 1	
	Left BEM Temp 2	
	Left FEM Temp 1	
	Left FEM Temp 2	
	Left DAQ Temp 1	
	Left DAQ Temp 2	
Fast HK: Right Group Temp. Sensors	FPA Temp 7	1060 to 1065
	FPA Temp 8	
	FPA Temp 9	
	FPA Temp 10	
	FPA Temp 11	
	FPA Temp 12	
	Right BEM Temp 1	1068 to 106D
	Right BEM Temp 2	
	Right FEM Temp 1	
	Right FEM Temp 2	
	Right DAQ Temp 1	
	Right DAQ Temp 2	
Fast HK: Science DC/DC status	Science DC/DC status	1070 (***)
Fast HK: DAE data overridden flags	Ping Buff. Overridden Flag	1071
	Pong Buff. Overridden Flag	1072
TC DAE OBt synchronisation	OBt PRESET value LS word	0800
	OBt PRESET value MS word	0801
TC DAE OBt verification	OBt MS word	1073
	OBt IS word	1074
	OBt LS word	1075

Note (*): FEM Drain Current values are only Slow HK, that is, they are not used as configuration setting in any TC. DAE default configuration shall leave these values to spare for consistency with Slow HK format..

Note (**): each of the fields Phase Switch A-C (B-D) en/dis Horn Id 0 to 10 and Phase Switch A-C (B-D) Direct Polarised Horn Id 0 to 10 are linked to 2 addresses. Each address is indicated in both columns in the table. Note that address in second column is the first + 2.

This organisation of data is linked to the architecture of the DAE and implies that when DPUS_ASW writes to one of the two addresses both addresses shall be automatically written. On the other hand DPU_ASW can either read one or the other of the two; they are connected to the same physical location thus they give the same result.

Ping Pong DPRAM2 (read-only)

The overall addressing range of this memory is 0000 0000 to 0000 8000.

Memory allocation:

Buffer	Size	DPRAM Addresses	
Science Ping Buffer	2880	0000	to 0B3F
Science Pong Buffer	2880	1000	to 1B3F



10.4 INSTRUMENT ON-BOARD SOFTWARE OPERATIONS

10.4.1 SWITCH-ON PROCEDURE

Refer to Paragraph 13.2 for a detailed description. In particular: see Paragraph 13.2.2 “REBA ASW INIT”, Table 13.2-19 Summary of the REBA ASW Init procedure and Table 13.2-20 REBA ASW Init.

10.4.2 SYNCHRONISATION PROCEDURE

10.4.2.1 REBA OBT SYNCHRONISATION

At reception of the TC(9,4) from the CDMS, DPU_ASW performs the synchronisation procedure described in PS-ICD, based on the time received in TC(9,5), being effective this time at the first subframe of the next second cycle.

The implementation procedure is the following:

- Time of TC(9,5) is kept.
- Clear on synchronise option is used, so the Time Tag Register shall be set to 0 after the reception of Synchronise without data mode command of first subframe.
- After reception of the interruption of Synchronise without data, the time kept shall be modified to take into account the 20 us of the length of the 1553 message and the duration of the management of the interruption.
- The signal to copy the modified time to the OBT device is triggered by the software.

10.4.2.2 REBA OBT VERIFICATION

At reception of the TC(9,7) from the CDMS, DPU_ASW performs the verification procedure described in PS-ICD, based on the verification signal received at the first subframe of the next second cycle.

The implementation procedure is the following:

- Clear on synchronise option is used, so the Time Tag Register shall be set to 0 after the reception of Synchronise without data mode command of first subframe.
- After reception of the interruption of Synchronise without data, a signal to latch the OBT is triggered by the software.
- The time is modified to take into account the 20 us of the length of the 1553 message and the duration of the management of the interruption.
- The DPU_ASW sends a time verification report TM(9,9) to the CDMS.



10.4.2.3 DAE OBT SYNCHRONISATION

The OBT synchronisation of DAE is performed by the DPU_ASW at reception of a TC. DAE is synchronised with the 1 Hz clock generated by REBA. The DPU_ASW executes the following steps:

- 1) DPU_ASW enables IRQ0/1Hz interrupt to be produced in the following multiple of second of the REBA OBT Counter, that is, in the next change of the bit 17 of OBT register.
- 2) When IRQ0/1Hz interrupt occurs:
 - a) DPU_ASW reads the REBA OBT Counter and adds to it 1 s. (This is because DAE is synchronised in the next cycle of the 1 Hz clock.)
 - b) DPU_ASW writes the OBT value into the DAE pre-set 32-bit register (COMI port address is 0x800-0x801).
 - c) DPU_ASW enables the DAE synchronisation through a dedicated command line: GPIO_DATA_0(bit 3) of the DAE chip 1.
- 3) DPU_ASW disables IRQ0/1Hz interrupt.

DAE is synchronised at the next rising edge of the 1 Hz clock cycle and is clocked with the time previously sent.

10.4.2.4 DAE OBT VERIFICATION

The verification of the DAE OBT synchronisation is performed by REBA in a similar way than the synchronisation. At reception of a TC, the DPU_ASW executes the following steps:

- 1) DPU_ASW enables IRQ0/1Hz interrupt to be produced in the following multiple of second of the REBA OBT Counter, that is, in the next change of the bit 17.
- 2) When IRQ_2 IRQ0/1Hz interrupt occurs:
 - a) DPU_ASW reads the REBA OBT Counter and adds to it 1 s. (This is because DAE shall output OBT in the next cycle of the 1 Hz clock.)
 - b) DPU_ASW enables the DAE verification through a dedicated command line: GPIO_DATA_0(bit 4) of the DAE chip 1.
(DAE latches its time at the next 1 Hz cycle and writes it into the memory mapped DAE OBT register.)
- 3) DPU_ASW transfers the DAE OBT register (COMI port address is 0x900-0x902) and checks the DAE OBT with the time result of the step 2.a.

10.4.3 DAE SCIENCE DATA INTERFACE

10.4.3.1 TIMING FLOW DIAGRAM OF THE DAE - REBA SPU INTERFACE

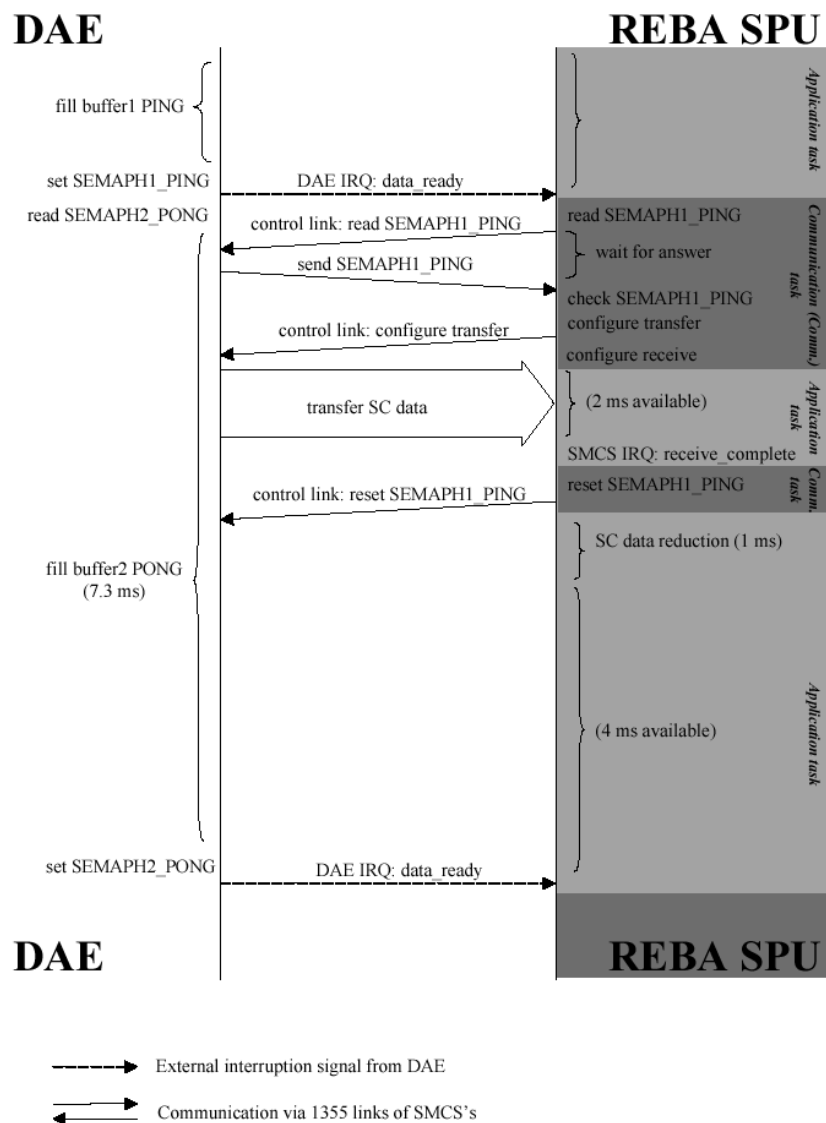


Figure 10-4 DAE to REBA scientific data flow

10.4.3.2 STRUCTURE OF THE DAE - REBA SCIENCE PACKETS

Each buffer is able to store up to 60 consecutive frames, each one having the following format:

16 bits
Frame marker
DAE OBTC MSW
DAE OBTC IW
DAE OBTC LSW



Converted science Datum 1 st of group 0
.....
Converted science Datum 24 th of group 0
Converted science Datum 1 st of group 1
.....
Converted science Datum 20 th of group 1

Note: the total number of words to be written into each buffer is 2880.

In the table below the sequence in which the frames have to be stored is shown.

	Ping Buffer	Pong Buffer	
Even Frame-Marker = 0x0000	Frame 0 group 0	Frame 60 group 0	Even Frame-Marker = 0x0000
	Frame 0 group 1	Frame 60 group 1	
Odd Frame – Marker = 0x0001	Frame 1 group 0	Frame 61 group 0	Odd Frame – Marker = 0x0001
	Frame 1 group 1	Frame 61 group 1	
			
Odd Frame – Marker = 0x0001	Frame 59 group 1	Frame 119 group 1	Odd Frame – Marker = 0x0001

Note: even frames (the ones containing all samples taken on falling edge of phase switches clock) data hall have a frame marker = 0x0000 while odd frames (the ones containing all samples taken on rising edge of phase switches clock) have a frame marker = 0x0001.

The data are stored always in the same order (e.g. ch. 0 of Feed-horn 27 belonging to 30 GHz group are always written in the same memory locations of the buffers (ping or pong)).

group 0 (LEFT)					group 1 (RIGHT)				
Dat. #	FQ.	Horn ID. FH #	Radiom eter #	Detecto r #	Dat. #	FRE Q.	Horn ID. FH #	Radiom eter #	Detecto r #
0	30	27	0	0	0	30	28	0	0
1	30	27	0	1	1	30	28	0	1
2	30	27	1	0	2	30	28	1	0
3	30	27	1	1	3	30	28	1	1
4	44	24	0	0	4	70	20	0	0
5	44	24	0	1	5	70	20	0	1
6	44	24	1	0	6	70	20	1	0
7	44	24	1	1	7	70	20	1	1
8	70	21	0	0	8	70	19	0	0
9	70	21	0	1	9	70	19	0	1
10	70	21	1	0	10	70	19	1	0
11	70	21	1	1	11	70	19	1	1
12	70	22	0	0	12	70	18	0	0
13	70	22	0	1	13	70	18	0	1
14	70	22	1	0	14	70	18	1	0
15	70	22	1	1	15	70	18	1	1



16	70	23	0	0
17	70	23	0	1
18	70	23	1	0
19	70	23	1	1
20	44	25	0	0
21	44	25	0	1
22	44	25	1	0
23	44	25	1	1

16	44	26	0	0
17	44	26	0	1
18	44	26	1	0
19	44	26	1	1



11 SUMMARY OF INSTRUMENT HK TELEMETRY DATA

11.1 SUMMARY OF HK AND DIAGNOSTIC TELEMETRY PACKETS

11.1.1 TELEMETRY PACKET STRUCTURE

The structure of the telemetry packets is the following as reported in [RD10].

SOURCE PACKET HEADER (48 bits)						PACKET DATA FIELD (VARIABLE)			
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH	DATA FIELD HEADER	SOURCE DATA	PACKET ERROR CONTROL
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count				
3	1	1	11	2	14				
16 bits				16 bits		16 bits	80 bits	up to 503 x 16 bits	16 bits

Table 11.1-1 TM structure

Source Packet Header

Packet ID

- *Version Number*: The Version Number must be set to '000_{BIN}' for all telemetry issued on-board.
- *Type*: For Telemetry Source Packets, the type must be set to zero.
- *Data Field Header Flag*: This indicates the presence or absence of a Data Field Header and must be set to 1 except for Time Packets and for Idle Packets where it is set to 0.
- *Application Process ID (APID)*: The Application Process ID uniquely identifies the **on-board source** of the packet.

For LFI, according to [RD10], the selected APIDs are the following:

Description	APID
Telecommands	0x600
TM packets for TC acceptance non periodic TM packets Essential HK packets	0x600
TM type 3 packets (HK & diagnostic telemetry)	0x602



TM type 21 packets (Science telemetry including calibration)	0x604

Table 11.1-2 Available APIDs for LFI

Packet Sequence Control

- *Segmentation [Grouping] Flags*: These two bits shall be set to ‘11’_{BIN}, indicating “no segmentation”.
- *Source Sequence Count*: A separate source sequence count shall be maintained for each Application Process ID and shall be incremented by 1 whenever the source (APID) releases a packet. Therefore the counter corresponds to the order of release of packets by the source and enables the ground to detect missing packets.

According to the CCSDS Recommendation for Packet Telemetry (CCSDS 102.0-B-5, Blue Book), The *Source Sequence Count* shall be continuous, modulo 16384, and a re-setting of the *Source Sequence Count* before reaching 16383 shall not take place unless it is unavoidable (section 3.1.3.2 of the Blue Book).

For LFI there is an exception to the previous recommendation. At power on, LFI delivers TM packets ordered by SSC as required by specifications but as soon as ASW is started, all the Source Sequence Counters (different for each APID) are reset and restarted from zero. This non conformance was reported in ASP-NC-3634 and discussed accordingly. It has been decided that this is a minor issue since ASW should be started only once during flight operations and has been agreed to leave it as it is.

Packet Length

The Packet Length field specifies the number of octets contained within the Packet Data Field, including the Data Field Header. The number is an unsigned integer “C” where $C = (\text{Number of octets in Packet Data Field}) - 1$.

For Herschel / Planck the maximum length of a Telemetry Source Packet Data Field is **1018 octets**, i.e. the maximum value for C is 1017.

It should be noted that the actual length of the entire Telemetry Source Packet, including the Source Packet Header, is 6 octets longer. Therefore the **maximum TM Packet length is 1024 octets**.

The Packet Length is an integer number of 16 bit words, as a result C is always an odd number (of octets).

Packet Data Field

Data Field Header

The content of the Data Field Header depends on the nature of the Telemetry, however all data field headers have the same basic structure, as follows:



Spare	TM Packet PUS Version Number	Spare	Packet Type	Packet Subtype	Spare	Time
Bitstring (1bit)	Enumerated (3 bits)	Bitstring (4bit)	Enumerated (8 bits)	Enumerated (8 bits)	Bitstring (8bit)	(48 bits)

Table 11.1-3 Data field header structure

- *Spare*: To maintain symmetry with the Telecommand packet Data Field Header, this bit is reserved and shall be set to zero
- *TM Source Packet PUS Version Number*: ONLY ONE PUS VERSION NUMBER IS PERMITTED: VERSION 0 (VALUE = 0).
- *Spare*: Spare bits are placed in order to make up an integral octet. These spare bits shall be set to zero.
- *Packet Type*: This indicates the Service to which this telemetry source packet relates.
- *Packet Subtype*: Together with the Packet Type, the Subtype uniquely identifies the nature of the Service constituted by this telemetry source packet. The definition of Packet Type and Subtype is unique across all Application Processes
- *Spare*: Spare bits are introduced in order to make up an integral octet. These spare bits shall be set to zero.
- *Time*: This field represents the on-board reference time of the packet, referenced to TAI, expressed in CUC. The 4 MS bytes (Coarse Time) represent the count of integer seconds. The LS bytes (Fine Time) represent the fractions of seconds down to the level of 2^{-16} s. The relationship of the time information to packet data generation or packet completion shall be fixed and defined per packet type/subtype of each application.

Source Data (Variable)

The telemetry source data constitutes the data element of the TM Packet

Packet Error Control (PEC)

The Packet Error Control field shall transport an error detection code that can be used by the ground to verify the integrity of the complete telemetry source packet. The presence of the PEC and its type is fixed for the complete mission for all Applications.

See appendix 4 of [RD10] for further details.

11.1.2 HOUSEKEEPING TELEMETRY

It is considered HK telemetry all the TM packets that report at any level the status of the instrument, both for nominal functioning and for diagnostic purposes.

The services included in HK telemetry are:



TM-Packet Type/Sub.	TM Packet Name
TM(1,1)	Telecommand Acceptance Report-Success
TM(1,2)	Telecommand Acceptance Report-Failure
TM(1,7)	Telecommand Execution Report –Completed
TM(1,8)	Telecommand Execution Report – Failure
TM(3,25)	Housekeeping Parameter Report
TM(3,26)	Diagnostic Parameter Report
TM(5,1)	Event Report
TM(5,2)	Exception Report
TM(5,4)	Error/Alarm Report
TM(6,6)	Memory Dump, Absolute Addresses
TM(6,10)	Memory Check Report, Absolute Addresses
TM(8,6)	Function Status Report
TM(9,9)	Time Verification Report
TM(14,4)	Enabled Telemetry Packets Report
TM(17,2)	Connection Test Report

Table 11.1-4 List of HK telemetry services

Among these packets some of them are produced by the instrument in a predictable way, other are produced only under particular conditions.

11.1.2.1 PREDICTABLE HK

These packets are those of service (3,25) that report continuously the parameters of the instrument (see [AN3] for the details of the packets).

The amount of data delivered by these packets is summarised in the Table 11.1-5. Notice that the number of HK parameters indicates the number of atomic information regardless their dimensions.

One particular case of HK packets are the so-called Essential HK. These packets are intended to be delivered to ground during the operations of the instrument even when the satellite TM capability is limited by the use of the Low Gain Antenna.

Essential HK feature is the following:

- 1) REBA starts to send the REBA Essential HK packets as soon as the ASW is initialised. No Essential HK is foreseen to be produced by the SUSW.
- 2) REBA starts to send the DAE essential packets as soon as DAE fast nominal is produced, that is, at reception of the TC “Start DAE HK acquisition”.
- 3) Once the REBA starts to deliver the Essential HK packets it continuously sends the both normal and essential packets. That is, it is the satellite that sends to ground only the essential in case of TM capability limited.



- 4) Since the Essential HK are identified by the APID and the service 14 does not foresee to enable/disable transmission of packets based on APID if the transmission of one nominal is disable, the corresponding essential is also disabled.

These packets are redundant with respect to the nominal HK stream, but it is guaranteed that they respect the available essential telemetry of 330bps per instrument.

In order to minimise the impact on the already developed SW and data structure the LFI "Essential HK" are a plain copy of the REBA and the DAE HK packets that in certain cases are delivered twice to the CDMS.

In order to meet the telemetry budget limitations these Essential HK packets are generated in average only once every 8 normal HK packets.

The satellite and the ground segment recognise the "Essential HK" using their APID that is the 600h whereas the normal HK has the APID 602h and this is the only difference between normal HK and essential HK.

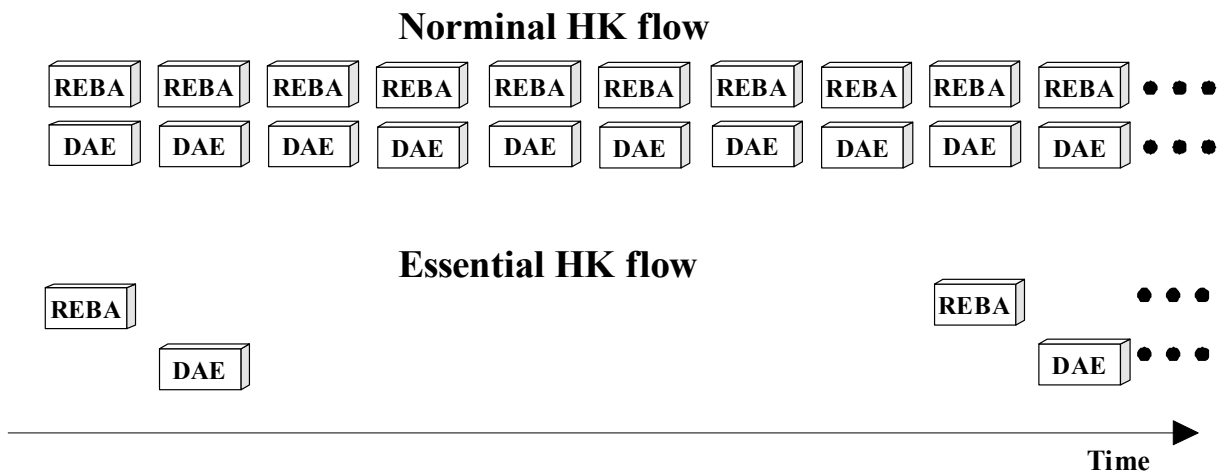


Figure 11-1 Essential HK concept

The REBA and DAE Essential HK packets are sent independently, that is, once each 8 packets of the corresponding nominal. Note that, depending on the reception of the TC to start DAE HK acquisition, both essential (REBA and DAE) could be produced at the same time. Even in this case, we respect the limit of 330bps.

This concept of essential HK is applied only to the HK packets generated by the ASW because these could be used to check the functioning of the instrument during the observation in any condition. The absence of essential HK when the instrument is "On" can be detected in the frame of the FDIR to check whether an instrument reset has occurred.

In fact since SUSW doesn't generate "Essential HK", the absence of these HK could be detected by the CDMS. In this way the CDMS can understand that while LFI was, let's say, in "Normal science" an unexpected reset has occurred in the REBA. After that the SUSW has been automatically started, therefore it can respond to the CDMS, but the HK packet flow is somehow different from the



expected and the CDMS can trigger the start of a recovery action (e.g. switch off the RAA that remains without control).

	DAE slow	DAE fast	REBA HK	Essential 1	Essential 2	Total
Polling Period (s/pkt)	64	4	4	32	32	
Number of HK parameters (1/pkt)	356	304	1388	304	1388	3740
HK data volume (byte/pkt)	716	394	602	394	602	
HK data generation (byte/s)	11.19	98.50	150.50	12.31	18.81	291.31
Packet overhead (byte/pkt)	18	18	18	18	18	
HK gross data rate (kbit/s)	91.75	824.00	1240.00	103.00	155.00	2413.75
Packet frequency (pkt/s)	0.015625	0.25	0.25	0.03125	0.03125	0.578

Table 11.1-5 Predictable HK production

11.1.2.2 NON PREDICTABLE HK

These TM packets are grouped under a generic name of HK even if they could be a type different from 3. Some hypotheses can be done for the use of all these packets:

- Type (1,x): these packets are generated by LFI in response to a Telecommand packet. Their maximum frequency of occurrence is related to the frequency of the TCs therefore 2 per second for the acceptance (TM(1,1) and TM(1,2)) and 2 per second for the execution report (TM(1,7) and TM(1,8)).
- Type (3,26): these packets are required by a TC(14,x) used for activating the production of diagnostic HK packets containing parameters usually not transmitted to ground (see Par. 11.1.8 and [AN7] for details).
- Type (5,x): these packets are generated autonomously by the instrument in case of asynchronous events to be reported to the S/C and to ground. The production of these packets is hopefully limited during normal operation because they would signal anomaly behaviours.
- Type (6,x): these packets are mainly produced, on TC request, during the first part of the mission, probably in absence of scientific data production, even if their production is allowed also during the observation. The aim of this service is the management (load and dump) of memory areas in order to check the correct functioning of the instrument.
- Type (8,6): these packets are produced, on TC request, by ground. This service is available for troubleshooting purpose to check in an independent way the correct functioning of the ASW.
- Type (9,9): this time verification packet is requested by the CDMS using a TC, in order to check the consistency of the time used to stamp the scientific data. It is likely produced during the visibility periods along the entire mission.
- Type (14,4): this packet, when required by TC, reports the list of TM packets enabled to be generated.



- Type (17,2): this packet is produced as response to the command of checking the connection between the CDMS and LFI.

TM-Packet Type/Sub.	Linked to TC	Normally produced during		Period
		Commissioning	Observation	
TM(1,1)	Yes	X	X	> 0.5s
TM(1,2)	Yes	X	X	
TM(1,7)	Yes	X	X	> 0.5s
TM(1,8)	Yes	X	X	
TM(3,26)	Yes	X		
TM(5,1)	No	X	X	Very rare
TM(5,2)	No	X	X	
TM(5,3)	No	X	X	
TM(6,6)	Yes	X		> 0.5s
TM(6,10)	Yes	X		> 0.5s
TM(8,6)	Yes	X	X	Very rare
TM(9,9)	Yes	X	X	< 1 per day
TM(14,4)	Yes	X		
TM(17,2)	Yes	X	X	Very rare

Table 11.1-6 Non predictable HK production



11.1.3 TC ACCEPTANCE REPORT SUCCESS – TM(1,1)

The general format for the “Source Packet Header” of this packet is the following:

Source Packet Header						
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
‘000’	‘0’	‘1’	‘110 0000 0000’ 0x600	‘11’		‘0000 0000 0000 1111’

The value of the “Source Sequence Count” field is provided by a counter packet by packet.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 0001’	‘0000 0001’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

Source Data		
DATA	SIZE	COMMENTS
TC packet ID	2 bytes	
Packet sequence control	2 bytes	

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN2] for definition of LFI specific monitoring and definition parameters as described in [AD6].



11.1.4 TC ACCEPTANCE REPORT FAILURE – TM(1,2)

The “Source Packet Header” is the same as for TM(1,1) except for the value of the “Packet Length” field that is 0x15 to 0x1D.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 0001’	‘0000 0010’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

Source Data		
DATA	SIZE	COMMENTS
TC packet ID	2 bytes	
Packet sequence control	2 bytes	
Error code	2 bytes	See table below for error code definition.
Parameters	4/12 bytes	All TC NACKs (except TC “DAE OBT verification”) have 1 parameter of 4 bytes. TC NACK of “DAE OBT verification” has 2 parameters of 6 bytes. See table below for parameter description.

The packet is terminated by 16 bits CRC field.

Definition of error condition parameters

Error code (Hex)	Description	Parameters (PTC,PFC) <range>	Param. size
0000	Illegal APID	- 0000h (MSB) -Received Packet ID field (2,16)	4bytes
0001	Incomplete or invalid length or total packet size doesn’t match the message size returned by the transfer layer	- 0000h (MSB) -Received length field (3,12)	4bytes
0002	Incorrect checksum	- 0000h (MSB) -Received checksum field (2,16)	4bytes
0003	Illegal packet type	- 0000 00h (MSB)	4bytes



		-Received packet type (2,8)	
0004	Illegal packet sub-type	- 0000 00h (MSB) -Received packet sub-type (2,8)	4bytes
0005	Illegal or inconsistent application data (used only by DPU SUSW, not used by DPU ASW)	-0000 0000h	4bytes
0010	TC rejected: Command queue overflow	-0000 0000h	4bytes
0012	DPU Invalid memory ID	- 0000 00h (MSB) -Received memory ID (2,8)	4bytes
0013	DPU Invalid address field	- 00h (MSB) -Received address (2,8) + (2,16)	4bytes
0014	DPU Invalid data length in SAUs	- 0000h (MSB) -Received data length (3,12)	4bytes
0015	DPU Invalid checksum (checksum received does not correspond to the Data Field in Load)	- 0000h (MSB) -Received checksum (2,16)	4bytes
0017	DPU Invalid activity ID field	- 0000 00h (MSB) -Received activity ID (2,8)	4bytes
0018	DPU Invalid SID field for Service 8	- 0000h (MSB) -Received SID (2,8)	4bytes
0019	DPU Invalid function ID field	- 0000 00h (MSB) -Received function ID (2,8)	4bytes
001A	Invalid parameter N in service 14,1	- 0000h (MSB) -Received N (3,12)	4bytes
001B	DPU Invalid checksum after re-reads memory area in Load command	- 0000h (MSB) -Calculated checksum (2,16)	4bytes
001C	Illegal packet type for Service 14	- 0000 00h (MSB) -Received packet type (2,8)	4bytes
001D	Illegal packet sub-type for Service 14	- 0000 00h (MSB) -Received packet sub-type (2,8)	4bytes
001E	DPU Invalid SID field for Service 14	-Received Type (2,8) -Received subtype (2,8) -Received SID (2,16)	4bytes
001F	Type-subtype-SID already enabled (for Service 14)	-Received Type (2,8) -Received subtype (2,8) -Received SID (2,16)	4bytes
0020	Type-subtype-SID already disabled (for Service 14)	-Received Type (2,8) -Received subtype (2,8) -Received SID (2,16)	4bytes
0022	Invalid TM rate parameter (for “Set expected	- 0000 00h (MSB)	4bytes



	TM rate parameter")	-Received TM rate (3,12)	
0023	Invalid Tau value (for "Start CF monitoring" and "Set Tau")	-Received Tau value (5,1)	4bytes
0024	Invalid CF threshold value	-Received value (5,1)	4bytes
0025	Function ID already "stopped"	- 0000 00h (MSB) -Received function ID (2,8)	4bytes
0026	Function ID already "running"	- 0000 00h (MSB) -Received function ID (2,8)	4bytes
0027	REBA OBT synchronisation/verification error	- 0000h (MSB) Error type: (2,16) - 91h sema. Timeout - 92h sync TC sequence error - 93h autosync enabled	4bytes
0028	DPU-SPU not connected (Details on each link status shall be available in the LFI HK)	-0000 0000h	4bytes
0029	DPU-SPU communication error	- 0000h (MSB) Error type: (2,16) - 01h SPU access timeout - 02h SPU conn. timeout - 05h TX timeout - 06h ACK timeout - 07h SPU communication status access timeout	4bytes
002A	DPU-DAE not connected (Details on each link status shall be available in the LFI HK)	-0000 0000h	4bytes
002B	DPU-DAE communication error	- 0000h (MSB) Error type: (2,16) - 11h DAE access timeout - 12h DAE link2 conn. timeout - 13h DAE link 3 conn. timeout - 14h DAE communication status timeout - 15h WD TX-C timeout - 16h WD TX-N timeout - 17h RD TX-C timeout - 18h RD RX-N timeout - 19h WG TX-C timeout - 1Ah WG RX-C timeout - 1Bh WG TX-C timeout	4bytes



		- 1Ch RR TX-C timeout - 1Dh RR RX-C timeout 1Eh WR TX-C timeout	
002C	TC synchronisation is in process (for “Enable autosynch”)	-0000 0000h	4bytes
002D	SPU Ack/Nack not valid	- 0000h (MSB) -SPU Ack/Nack (2,16)	4bytes
002E	Invalid size in SPU Dump packet	- 0000h (MSB) -SPU dump size (2,16)	4bytes
002F	DAE HK acquisition stopped (for “start FPT monitoring”)	-0000 0000h	4bytes
0030	SPU runs SUSW (for “Start CPU monitoring” and “Start CF monitoring”)	-0000 0000h	4bytes
0031	Internal data access timeout (for “Get” and “Reset” commands)	- 0000h (MSB) Resource ID: (2,16) - 81h RES_DIAG_BUFF	4bytes
0032	DAE OBT synchronisation/verification is not performed: 1Hz signal timeout	- 0000h (MSB) -“first”/”second” signal (2,16)	4bytes
0033	DAE OBT synchronisation/verification is not performed: DAE communication error	-Step (1-3) (2,16) <1..3> Error type: (2,16) - 11h DAE access timeout - 15h WD TX-C timeout - 16h WD TX-N timeout - 17h RD TX-C timeout - 18h RD RX-N timeout - 19h WG TX-C timeout - 1Ah WG RX-C timeout - 1Bh WG TX-C timeout	4bytes
0034	DAE OBT is not correct in DAE verification	-REBA OBT (9,17) -DAE OBT (9,17)	6bytes 6bytes
0035	Autosync is already enabled (for “Enable autosynch”)	-0000 0000h	4bytes
0036	Autosync is already disabled (for “Disable autosynch”)	-0000 0000h	4bytes
0037	AF is already enabled (for “Enable AF”)	-0000 0000h	4bytes
0038	AF is already disabled (for “Disable AF”)	-0000 0000h	4bytes
003A	Invalid command for SPU running application	-0000 0000h	4bytes
003D	Not enough memory to allocate TM packet	-0000 0000h	4bytes
003E	Invalid checksum for DAE configuration in	-0000 0000h	4bytes



	EEPROM		
003F	DPU LLSWDRV returns error	-driver function ID	4bytes
0040	Error checking functions of SPU or DAE for function status report	-0000 0000h	4bytes
0041	SPU invalid command ID	- 0000h (MSB) -Wrong command ID (2,16)	4bytes
0042	SPU Invalid memory ID	- 0000 00h (MSB) -Received memory ID (2,8)	4bytes
0043	SPU Invalid address field	- 00h (MSB) -Received address (2,8) + (2,16)	4bytes
0044	SPU Invalid Data length in SAUs	- 0000h (MSB) -Received Data Length (3,12)	4bytes
0045	SPU Invalid checksum (checksum received does not correspond to the Data field in Load)	- 0000h (MSB) -Received checksum (2,16)	4bytes
0046			
0047	SPU Invalid activity ID field	- 0000h (MSB) -Received activity ID (2,16)	4bytes
0048	SPU Invalid SID field	- 0000h (MSB) -Received SID (2,16)	4bytes
0049	SPU Invalid Parameter field	-Received invalid parameter in SID	4bytes
004A	SPU could not perform command	-0000 0000h	4bytes
004B	SPU invalid checksum after re-reads memory area in Load command	- 0000h (MSB) -Calculated checksum (2,16)	4bytes
0071	SPU invalid command ID	- 0000h (MSB) -Wrong command ID (2,16)	4bytes
0072	SPU Invalid memory ID	- 0000 00h (MSB) -Received memory ID (2,8)	4bytes
0073	SPU Invalid address field	- 00h (MSB) -Received address (2,8) + (2,16)	4bytes
0074	SPU Invalid Data length in SAUs	- 0000h (MSB) -Received Data Length (3,12)	4bytes
0077	SPU Invalid activity ID field	- 0000h (MSB) -Received activity ID (2,16)	4bytes
0078	SPU Invalid SID field (for “startfunc” commands)	- 0000h (MSB) -Received SID (2,16)	4bytes
007E	Invalid SID (applicable to “Get” commands only)	- 0000h (MSB) -Received SID (2,16)	4bytes



0082	Invalid GMF value	-Received value (5,1)	4bytes
0083	Invalid ReQuant value	-Received value (5,1)	4bytes
0084	Invalid nAverage value (applicable to “Set nAverage” only)	-Radiometer ID (2,16) -Wrong nAverage (3,12)	4bytes
0085	Cannot update nAverage value for a horn under processing (applicable to “Set nAverage” only)	- 0000h (MSB) -Radiometer ID (2,16)	4bytes
0086	Invalid processing type for mode A or B (applicable to ‘Set science processing types’ only)	-Sub-mode (A or B) (2,16) <0..1> -Received sub-mode (2,16) <0..6>	4bytes
0089	Memory allocation failure (applicable to ‘Enable a channels’ and ‘Set science processing types’ only)	-Sub-mode (2,16) <0..1> -Detector ID (2,16)	4bytes
008A	Cannot change science mode configuration while science processing is running (applicable to ‘Set science processing types’ only)	-0000 0000h	4bytes
008B	Science processing is already running (applicable to ‘Start Science processing’ only)	-0000 0000h	4bytes
008C	Science processing is already stopped (applicable to ‘Stop Science processing’ only)	-0000 0000h	4bytes
008D	SPU-DAE connection failure (applicable to ‘get DAE SMCS-2 registers’ and ‘SPU connect to DAE’ only) (Details on each link status shall be available in the REBA HK TM.)	-0000 0000h	4bytes
008E	Calibration channel switching is already running (applicable to “Start Calibration channel switching” only)	-0000 0000h	4bytes
008F	Calibration channel switching is already stopped (applicable to “Stop Calibration channel switching” only)	-0000 0000h	4bytes
0091	Calibration channel switching cannot be started while Science processing is not started (applicable to “Start calibration channel switching” only)	-0000 0000h	4bytes
0092	Calibration switching period is wrong (for “Set switching period” and “Start Calibration channel switching” only)	- 0000h (MSB) -Received switching period (3,12)	4bytes
0093	Science verification is already enabled (for	-0000 0000h	4bytes



	“Enable Science verification”)		
0094	Science verification is already disabled (for “Disable Science verification”)	-0000 0000h	4bytes
0095	Science processing status access time out	-0000 0000h	4bytes
0096	SPU-DAE communication status access timeout	-0000 0000h	4bytes
0097	SPU-DAE access time out	-0000 0000h	4bytes
0098	SPU-DAE is not connected	-0000 0000h	4bytes
0099	Science configuration timeout	-0000 0000h	4bytes
009A	Science detector already enabled	-0000 0000h	4bytes
009B	Science detector already disabled	-0000 0000h	4bytes
009E	Received command length does not correspond to command type	-Received command length (3,12) -Expected command length (3,12)	4bytes
009F	SPU LLSWDRV returns error	-Driver function ID	4bytes
00D0	TC rejected: Command queue overflow (DPU_SUSW)	-0000 0000h	4bytes
00DA	Could not perform command (DPU SUSW)	-0000 0000h	4 bytes
00DB	Invalid checksum after re-reading memory area (DPU_SUSW)	- 0000h (MSB) -Invalid checksum calculated (2,16)	4 bytes

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN3] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.5 TC EXECUTION REPORT COMPLETED – TM(1,7)

The “Source Packet Header” is the same as for TM(1,1).

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 0001’	‘0000 0111’	‘0000 0000’	



The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

The structure of the Source data fields is the same as Par. 11.1.3.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN4] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.6 TC EXECUTION REPORT FAILURE – TM(1,8)

The “Source Packet Header” is the same as for TM(1,1) except for the value of the “Packet Length” field that is 0x15 to 0x1D.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 0001’	‘0000 1000’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

The structure of the Source data fields is the same as Par. 11.1.4.
An example of one TM(1,8) is given in Par. 11.4.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN5] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.7 HK PARAMETER REPORT – TM (3,25)

The general format for the “Source Packet Header” of this packet is the following:

Source Packet Header



PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
'000'	'0'	'1'	'110 0000 0010' 0x602	'11'		

The value of the “Source Sequence Count” field is provided by a counter packet by packet. The value of the “Packet Length” field is related to the different SIDs.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
'0'	'000'	'0000'	'0000 0011'	'0001 1001'	'0000 0000'	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

11.1.7.1 DAE SLOW HK PACKET FORMAT (120101369)

This packet contains the complete set of settings of the RCAs kept in the DAE. It is sent to ground every 64 seconds.

Packet Length: 0x32F.

DATA	SIZE	SCOS Name	COMMENTS (PTC,PFC) <range>
Sequence counter	2 bytes	LM006342	
SID	2 bytes	LM090342	101(decimal) (2,16)
FEM V gate 1	88 bytes	LM001322 [.] LM044322	44 detectors x 2 byte (3,12) <0..255>
FEM V gate 2	88 bytes	LM101322 [.] LM144322	44 detectors x 2 byte (3,12) <0..255>
FEM V drain	88 bytes	LM201322	44 detectors x 2 byte (3,12) <0..255>



DATA	SIZE	SCOS Name	COMMENTS (PTC,PFC) <range>
		[..] LM244322	
Phase switch I1	88 bytes	LM151322 [..] LM194322	44 detectors x 2 byte (3,12) <0..255>
Phase switch I2	88 bytes	LM401322 [..] LM444322	44 detectors x 2 byte (3,12) <0..255>
RCA gain	88 bytes	LM001326 [..] LM044326	44 detectors x 2 byte (2,8) <...>
RCA offset	88 bytes	LM101326 [..] LM144326	44 detectors x 2 byte (3,12) <0..255>
FEM drain currents	88 bytes	LM051322 [..] LM094322	44 detectors x 2 bytes (3,12) <0..255>
Phase Switch A-C en/dis	22 bytes	LM251322 [..] LM261322	11 horns x 2 bytes (2,16) <0..1>
Phase Switch B-D en/dis	22 bytes	LM451322 [..] LM461322	11 horns x 2 bytes (2,16) <0..1>
Phase Switch A-C Polarise 1/2	22 bytes	LM301322 [..] LM311322	11 horns x 2 bytes (2,16) <0..1>
Phase Switch B-D Polarise 1/2	22 bytes	LM321322 [..] LM331322	11 horns x 2 bytes (2,16) <0..1>
DC/DC converter en/dis	8 bytes	LM001332 [..] LM004332	4 DC/DC converters x 2 bytes (2,16) <0..1>
Blanking time	2 bytes	LM100326	
Packet period	2 bytes	LM001320	64(decimal) (3,12)

The packet is terminated by 16 bits CRC field

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN6] for definition of LFI specific monitoring and definition parameters as described in [AD6].



11.1.7.2 DAE FAST HK PACKET FORMAT (120102369)

This packet contains the HK of the DAE. Because they are quite less than 1 kbyte long 4 samples (one each second) of these HK are allocated within a single packet.

Packet Length: 0x195

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM091342	102(decimal) (2,16)
Sample 1	98 bytes		
Sample 2	98 bytes		
Sample 3	98 bytes		
Sample 4	98 bytes		

The packet is terminated by 16 bits CRC field.

Each of the samples contains the following parameters.

DATA	SIZE	Scos name	COMMENTS (PTC,PFC) <range>
Sample OBT	6 bytes	LM101320	OBT corresponding to start of the sample generation (9,17)
Power box HK sensors	32 bytes	LM101332 [.. LM116332	16 I/V/T sensor values x 2 bytes (3,12) <0..16383>
Left group Temp. sensors	22 bytes	LM201332 [.. LM211332	11 Temp.values x 2 bytes (3,12) <0..16383>
Right group Temp sensors	22 bytes	LM301332 [.. LM311332	11 Temp.values x 2 bytes (3,12) <0..16383>
DAE data overridden flag	2 bytes	LM401328 LM402328	1 byte for ping and 1 byte for pong buffers 2 x (2,8) <0..1>
DAE SMCS-1GPIO	4 bytes	LM411328 [.. LM414328	4 x (6,8)
DC/DC current limiter status	8 bytes	LM421332 [.. LM424332	4 DC/DC converters x 2 bytes (2,16) <0..1>
Packet period	2 bytes	LM002320	1(decimal) (3,12)
Total size	98 bytes		

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].



See the addenda [AN6] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.7.2.1 DAE Fast Essential HK (121202369)

These packets are a copy of the DAE Fast HK and delivered together with the others with two exceptions:

- The APID in the Packet Header is 600h
- The period of generation is 32s.

This packet are produced only in DAE Setup, Normal Science and Extended Science modes.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN6] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.7.3 REBA SUSW HK (120201342)

This packet contains the minimum amount of HK data coming from the REBA in “Standby” op-mode. For simplicity they are delivered once per second even if the resulting packet is quite small.

Note: REBA SUSW HK packet format is already fixed (at least for EM) and it really undesirable to change its definition.

Packet Length: 0x2F

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM092342	201(decimal) (2,16)
LFI status-1	2 bytes	LM101342	See NOTE-1 (2,16) <0..3>
DAU channel 1 value	2 bytes	LM121342	(3,12) <0..511>
DAU channel 2 value	2 bytes	LM122342	(3,12) <0..511>
DAU channel 3 value	2 bytes	LM123342	(3,12) <0..511>
DAU channel 4 value	2 bytes	LM124342	(3,12) <0..511>
DAU channel 5 value	2 bytes	LM125342	(3,12) <0..511>
DAU channel 6 value	2 bytes	LM126342	(3,12) <0..511>
DAU channel 7 value	2 bytes	LM127342	(3,12) <0..511>
DAU channel 8 value	2 bytes	LM128342	(3,12) <0..511>
DAU channel 9 value	2 bytes	LM129342	(3,12) <0..511>
DAU channel 10 value	2 bytes	LM130342	(3,12) <0..511>
DAU channel 11 value	2 bytes	LM131342	(3,12) <0..511>
DAU channel 12 value	2 bytes	LM132342	(3,12) <0..511>
DAU channel 13 value	2 bytes	LM133342	(3,12) <0..511>



Software SUSW ID	2 bytes	LM104342	00 01h (2,16)
Software SUSW version	2 bytes	LM105342	See NOTE-2 (2,16)
Error detection code (DPU)	2 bytes	LM107342 LM108342	See NOTE-3 2 x (6,8)

The packet is terminated by 16 bits CRC field.

NOTE-1:

LFI status-1 bit assignment shall be as follows:

- Bit 15 (LSB): DAE power status (1=ON)
- Bit 14 : OBTclock status (1=internal)
- Bits 13-0 (MSB) : reserved. All set to 0.

NOTE-2:

Software version (2 bytes). The MSB (most significant byte) corresponds to the DPU SW version number. The LSB (least significant byte) corresponds to the DPU SW revision number.

NOTE-3:

Error detection code bit assignment shall be as follows (1b = failure is detected):

- Bit 15 (LSB): EDAC double failure in Program memory
- Bit 14 : EDAC double failure in Data memory
- Bit 13 : Unexpected interrupt in DSP
- Bit 12 : Unexpected interrupt in PMPSC
- Bit 11 : Unexpected interrupt in DMPSC
- Bit 10 : Unexpected interrupt in 1553
- Bit 9 : Inconsistency error
- Bits 8-0 (MSB) : reserved. All set to 0.

These flags are cleared in the corresponding memory addresses after the generation of the HK packet that contains them.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN6] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.7.4 REBA HK (PACKET ID 120202369)

This packet contains the data coming from the REBA during the operations except in “Standby” op-mode. Also these are organised as a set of 4 samples (taken one per second)

This packet is under revision for the organisation of the parameters after the first step of coding of the REBA SW. No changes are foreseen in the overall dimensions and production rate.



Packet Length: 0x263

Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
SID (LM093342)	2 bytes	202 (decimal) (2,16)
Sample 1	150 bytes	
Sample 2	150 bytes	
Sample 3	150 bytes	
Sample 4	150 bytes	

The packet is terminated by 16 bits CRC field.

Each of the samples contains the following parameters.

DATA	SIZE	SCOS Name	COMMENTS (PTC,PFC) <range>
Sample OBT	6 bytes	LM102320	OBT corresponding to start of the sample generation (9,17)
LFI status-2	1 bytes	LM201342	
LFI Mode	1 bytes	LM202342	See NOTE-1
DAU channel 1 value	2 bytes	LM211342	(3,12) <0..511>
DAU channel 2 value	2 bytes	LM212342	(3,12) <0..511>
DAU channel 3 value	2 bytes	LM213342	(3,12) <0..511>
DAU channel 4 value	2 bytes	LM214342	(3,12) <0..511>
DAU channel 5 value	2 bytes	LM215342	(3,12) <0..511>
DAU channel 6 value	2 bytes	LM216342	(3,12) <0..511>
DAU channel 7 value	2 bytes	LM217342	(3,12) <0..511>
DAU channel 8 value	2 bytes	LM218342	(3,12) <0..511>
DAU channel 9 value	2 bytes	LM219342	(3,12) <0..511>
DAU channel 10 value	2 bytes	LM220342	(3,12) <0..511>
DAU channel 11 value	2 bytes	LM221342	(3,12) <0..511>
DAU channel 12 value	2 bytes	LM222342	(3,12) <0..511>
DAU channel 13 value	2 bytes	LM223342	(3,12) <0..511>
Software ID	2 bytes	LM206342	See NOTE-2 (2,16)
DPU software version	2 bytes	LM207342	See NOTE-3 (2,16)
DPU CPU load	2 bytes	LM500342	During last 0.9 s period. Integer number in 0-1000 range. One unit corresponds to 0.1% of the CPU load. (3,12) <0..1000>
CDMS communication I	6 bytes	See Tab	
Monitoring I	20 bytes	See Tab	
DPU Tasks Status	4 bytes		
DPU HK acquisition and production	4 bytes		
Spare	4 bytes		0x0000 0000



DATA	SIZE	SCOS Name	COMMENTS (PTC,PFC) <range>
- Spare	4 bytes		
DPU DSP and HW error	4 bytes		
DPU 1355 communication status	8 bytes		
DPU SW Conflicts	4 bytes		
SPU software version	2 bytes	LM556350	See NOTE-3 (2,16)
SPU CPU load	2 bytes	LM557350	During last 0.9 s period. Integer number in 0-1000 range. One unit corresponds to 0.1% of the CPU load. (3,12) <0..1000>
SPU Science processing I	24 bytes		
SPU Tasks Status	4 bytes		
SPU DSP and HW error	4 bytes		
SPU 1355 communication status	8 bytes		
SPU SW Conflicts	4 bytes		
Spare	2 bytes		
Sampling period	2 bytes		1(decimal) (3,12)
Total size	150 bytes		

NOTE-1:

The correct assignment of the LFI Mode-8 bits assignment (LM202342) is as follows:

Bit 7 (least significant bit)	DAE power status = 0 if DAE is on
Bit 6	OBT clock status
Bit 5	0b = Unknown 1b - Known
Bits 4-3 “ LFI mode”	00b= StandBy 01b = DAE_SetUp 10b = Normal Science 11b = Extended Science
Bits 2-0	Reserved. All set to 0.

For the different LFI modes, the value of the parameter turns out to be the following:

LFI Mode	LM202342
Stand By	0000 0101b 5h
DAE Set up	0000 1100b Ch
Normal Science	0001 0100b 14h
Extended Science	0001 1100b 1Ch



NOTE-2:

Software ID (16 bits) is as follows:

00 01h DPU_SUSW, SPU Software ID is unknown (no communication with the SPU)

00 02h DPU_ASW, SPU Software ID is unknown (no communication with the SPU)

01 02h DPU_ASW & SPU_SUSW

02 02h DPU_ASW & SPU_ASW

NOTE-3:

Software version (2 bytes). The MSB (most significant byte) corresponds to the SW version number, and the LSB (least significant byte) corresponds to the SW revision number.

The following table describes the fields that are inside each sample of the LFI HK packet. (+reset) means that this value shall be reset to 0 after it is put in the HK packet.

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
CDMS communication I (6 bytes)	1. Transfer level Errors: (1 byte) (+reset)	Unexpected subframe counter	7	(2,8)	LM501340
		Unexpected TC counter	6		
		TM transfer confirmation error	5		
		Spare	4		
		Format error in incoming message	3		
		Loop back error in outgoing message	2		
		Time out error in transmission	1		
		Handshake error in DPRAM	0		
	2. Application level Errors: (1 byte) (+reset)	General TM queue is full	7	(2,8)	
		Science TM queue is full	6		
		TC queue is full	5		
		No free TM map blocks	4		
		No free TC map blocks	3		
		TC packet size is not valid	2		
		2 ms window time out	1		
		SF time out	0		
	3. Autosync status (1 byte)	Is auto-synchronisation enabled/disabled	7	(2,8)	LM502340
		Spare	6-0		
	4. Spare (1 byte)				
	5. Last TM packet counter confirmed (1 byte)				
	6. Last TC packet counter confirmed (1 byte)				



Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
Monitoring I (20 bytes)	1. Status: (1 byte)	AF_EnblDisblScienceDetector Processing enabled/disabled	7	(1,0)	LM521340
		AF_SwitchOffFEU enabled/disabled	6	(1,0)	LM520340
		AF_Restart_All1355Comm enabled/disabled	5	(1,0)	LM519340
		Spare	4-0		
	2. Status: (1 byte) (+reset)	CPU is monitored (+reset)	7	(1,0)	LM528340
		FPT is monitored (+reset)	6	(1,0)	LM527340
		TM rate is monitored (+reset)	5	(1,0)	LM526340
		Spare	4		
		AF_EnblDisblScienceDetectorProcessing activated	3	(1,0)	LM525340
		AF_SwitchOffFEU activated	2	(1,0)	LM524340
		AF_Restart_All1355Comm activated	1	(1,0)	LM523340
		Spare	0		
	3. Errors: (1 byte) (+reset)	SPU CPU too high	7	(1,0)	LM529340
		FPT too high	6	(1,0)	
		TM rate too high	5	(1,0)	
		Spare	4		
		SPU CPU is not monitored	3	(1,0)	
		FPT is not monitored	2	(1,0)	
		Spare	1		
		Spare	0		
	4. Spare (1 byte)				
	5. SPU CPU out-of limit counter (2 bytes)			(3,12) <0..10>	LM532340
	6. FPT monitoring threshold (2 bytes)			(3,12) <..>	LM533340
	7. TM_Rate Monitoring period in min (2 bytes)			(3,12) <1..360>	LM534340
	8. TM expected (2 bytes)			(3,12) <0..60>	LM535340
	9. Total size of Science TM packets transmitted to the CDMS (4 bytes)	This counter value is in kBytes. Calculated since ASW initialisation or since last counter reset by TC		(3,14) No limits	LM536340



	10. TM Rate Tau value (2 bytes)		(3,12) <..>	LM537340
	11. TM Rate Step (1 byte)		(3,4) <0..1 6>	LM542340
	12. Spare (1 byte)			

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
DPU Tasks Status (4 bytes)	1. Task Status (2 bytes)	SPC_CPU_Monitoring running/stopped	15	(6,8)	LM543340
		FP_Temperature Monitoring running/stopped	14		
		TM_RateMonitoring running/stopped	13		
		Spare	12		
		DAE Control	11		
		DAE HK acquisition	10		
		SPU ASW	9		
		tDpuRevFromSpu	8		
		Scrubbing status	7	(6,8)	
		Spare	6-0		
2. Spare (2 bytes)					

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name	
DPU HK acquisition and production (4 bytes)	1. HK status (2 bytes)	SPU ASW HK acquired	15	(6,8)	LM544340	
		SPU SUSW HK acquired	14			
		REBA HK sent (+reset)	13			
		DAE fast HK sent (+reset)	12			
		DAE slow HK sent (+reset)	11			
		REBA diagnostic HK sent (+reset)	10			
		Science stat (CF) 1 HK sent (+reset)	9			
		Science stat (SPU max memory) 2 HK sent (+reset)	8			
		Science stat (SPU curr memory) 3 HK sent (+reset)	7	(6,8)		
		Science stat (SPU CPU) 4 HK sent (+reset)	6			
		Spare	5-0			
	2. HK Errors I: (2 bytes) (+reset)	SPU ASW HK acquisition error	15	(6,8)		LM546340
		DAU acquisition error (cannot start)	14			
		DAU acquisition time out	13			
		DAE fast acquisition error	12			
		DAE slow acquisition error	11			
	Science stat 1 (CF) acquisition error	10				



		Science stat 2 (SPU max memory) acquisition error	9	(6,8)	
		Science stat 3 (SPU curr memory) acquisition error	8		
		Science stat 4 (SPU CPU) acquisition error	7		
		Compression factor is not set	6		
		SPU HK packet lost (sequence error)	5		
		Spare	4-0		

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
DPU DSP and HW error (4 bytes)	1. DSP STKY register: (2 byte) (+reset)	ALU floating point underflow	15	2 _x (6,8)	LM547340
		ALU floating point overflow	14		
		ALU fixed point overflow	13		
		ALU floating point invalid operation	12		
		Multiplier fixed point overflow	11		
		Multiplier floating point overflow	10		
		Multiplier floating point underflow	9		
		Multiplier floating point invalid operation	8		
		DAG1 circular buffer 7 overflow	7		
		DAG2 circular buffer 15 overflow	6		
		PC stack full	5		
		PC stack empty	4		
		Status stack overflow	3		
		Status stack empty	2		
		Loop stack overflow	1		
		Loop stack empty	0		
	3. Errors (1 byte) (+reset)	EDAC double failure in Program memory	7	(6,8)	LM548340
		EDAC double failure in Data memory	6		
		EDAC single failure in Program memory	5		
		EDAC single failure in Data memory	4		
		WD interrupt	3		
		1553 I/F interrupt	2		
		Spare	1-0		
	4. Spare (1 byte)				

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
DPU 1355 communication	1. SMCS Errors: (2 bytes) (+reset)	Spare	15	(6,8)	LM551340
		SMCS receive buffer overflow (link1)	14		
		Disconnect error (link1)	13		
		Parity error (link1)	12		



status (8 bytes)		SMCS checksum error in reception (link2)	11	(6,8)	
		SMCS receive buffer overflow (link2)	10		
		Disconnect error (link2)	9		
		Parity error (link2)	8		
		SMCS checksum error in reception (link3)	7		
		SMCS receive buffer overflow (link3)	6		
		Disconnect error (link3)	5		
		Parity error (link3)	4		
		SMCS lost interrupt	3		
		Spare	2-0		
	2. Status (2 bytes)	CONNECTED=1/NOT_CONNECTED=0 (link1)	15	(6,8)	LM552340
		Transmit link is running=1 (link1)	14		
		NULL token is received=1 (link1)	13		
		FCT token is received=1 (link1)	12		
		CONNECTED=1/NOT_CONNECTED=0 (link2)	11		
		Transmit link is running=1 (link2)	10		
		NULL token is received=1 (link2)	9		
		FCT token is received=1 (link2)	8		
		DAE SMCS configured=1	7	(6,8)	
		CONNECTED=1/NOT_CONNECTED=0 (link3)	6		
		Transmit link is running=1 (link3)	5		
		NULL token is received=1 (link3)	4		
		FCT token is received=1 (link3)	3		
		DPU-DAE communication status (bit 5 AND bit 9 AND bit 10) (control by link communication)	2		
		DPU-SPU communication status (the same as bit 0)	1		
		Spare	0		
	3. Communication Errors: (2 bytes) (+reset)	SPU packet TX timeout	15	(6,8)	LM553340
		SPU packet RX timeout (ACK/NACK only)	14		
		DAE cmd: execution error DAEC TX timeout	13		
		DAE cmd: execution error DAEC RX timeout	12		
		DAE cmd: execution error DAEN TX timeout	11		
		DAE cmd: execution error DAEN RX timeout	10		
		SPU packet received unexpected	9		



		SPU packet size wrong	8		
		SPU unknown packet	7		
		Spare	6-0		
	4. Spare (2 bytes)				

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
DPU SW conflicts (FIFO and resources) (4 bytes)	1. FIFOs Errors: (2 bytes) (+reset)	FIF_TM_GEN_QUE overflow	15	(6,8)	LM554350
		FIF_TM_SC_QUE overflow	14		
		FIF_TC_QUE overflow	13		
		FIF_FPT_MONIT overflow	12		
		FIF_CPU_MONIT overflow	11		
		FIF_CF_MONIT overflow	10		
		FIF_DPU_RX_SPU overflow	9		
		FIF_DPU_QUE	8		
		FIF_DPU_SPU_HK	7		
		Spare	6-0		
	2. Resources Errors (2 bytes) (+reset)	RES_DPU_SPU_ACCESS	15	(6,8)	LM555350
		RES_DPU_DAE_ACCESS	14		
		RES_DPU_SPU_COMM_STAT	13		
		RES_DPU_DAE_COMM_STAT	12		
		RES_DPU_ERR_QUE	11		
		RES_GEN_TM_QUE	10		
		RES_DIAG_BUFF	9		
		RES_DPU_OBT	8		
		Spare	7-0		

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
SPU Science processing I (24 bytes)	1. Errors: (2 bytes) (+reset)	“Data ready” signal time out	15	(6,8)	LM558350
		Ping/Pong is not expected	14		
		Validation error: wrong checksum	13		
		Validation error: wrong marker	12		
		Validation error: wrong OBT	11		
		Validation error: wrong DAE packet size	10		
		Science circular buffer is full	9		
		Compression failure: factor less than 1	8		
		Cannot read ping/pong flags in DAE GPIO	7		
		Cannot reset ping/pong flag in DAE GPIO	6		
		Cannot transfer Science data: time out	5		
		Spare	4-0		



	2. Calibration detector Id (1 byte)			(2,8) <0..4 >3>	LM559350
	3. Calibration switching period in min (1 byte)			(3,4) <1..>	LM596350
	4. Science mode configuration (20 bytes)	Submode A (2 bytes)		2 x	LM597350
		Submode B (2 bytes)		(2,16) <0..6 >	LM598350
		Spare (2 bytes)			
		Detector mask A0 (1 byte)		(6,8)	LM560350
		Detector mask A1 (1 byte)		(6,8)	LM561350
		Detector mask A2 (1 byte)		(6,8)	LM562350
		Detector mask A3 (1 byte)		(6,8)	LM563350
		Detector mask A4 (1 byte)		(6,8)	LM564350
		Detector mask A5 (1 byte)		(6,8)	LM565350
		Spare (2 bytes)			
		Detector mask B0 (1 byte)		(6,8)	LM570350
		Detector mask B1 (1 byte)		(6,8)	LM571350
		Detector mask B2 (1 byte)		(6,8)	LM572350
		Detector mask B3 (1 byte)		(6,8)	LM573350
		Detector mask B4 (1 byte)		(6,8)	LM574350
		Detector mask B5 (1 byte)		(6,8)	LM575350

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
SPU Tasks status (4 bytes)	1. Task Status (2 bytes)	Science Processing status	15	2 x (6,8)	LM576350
		Science validation status	14		
		Calibration switching status	13		
		Scrubbing status	12		
		Spare	11-0		
	2. Spare (2 bytes)				

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
SPU DSP and HW error (4 bytes)	1. DSP STKY register: (2 byte) (+reset)	ALU floating point underflow	15	2 x (6,8)	LM579350
		ALU floating point overflow	14		
		ALU fixed point overflow	13		
		ALU floating point invalid operation	12		
		Multiplier fixed point overflow	11		
		Multiplier floating point overflow	10		



		Multiplier floating point underflow	9		
		Multiplier floating point invalid operation	8		
		DAG1 circular buffer 7 overflow	7		
		DAG2 circular buffer 15 overflow	6		
		PC stack full	5		
		PC stack empty	4		
		Status stack overflow	3		
		Status stack empty	2		
		Loop stack overflow	1		
		Loop stack empty	0		
	3. Errors (1 byte) (+reset)	EDAC double failure in Program memory	7	(6,8)	LM580350
		EDAC double failure in Data memory	6		
		EDAC single failure in Program memory	5		
		EDAC single failure in Data memory	4		
		WD interrupt	3		
		Spare	2-0		
	4. Spare (1 byte)				

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
SPU 1355 communication status (8 bytes)	1. SMCS Errors: (2 bytes) (+reset)	Spare	15	(6,8)	LM586350
		SMCS receive buffer overflow (link1)	14		
		Spare	13		
		Spare	12		
		SMCS checksum error in reception (link2)	11		
		SMCS receive buffer overflow (link2)	10		
		Disconnect error (link2)	9		
		Parity error (link2)	8		
		SMCS checksum error in reception (link3)	7		
		SMCS receive buffer overflow (link3)	6		
		Disconnect error (link3)	5		
		Parity error (link3)	4		
		SMCS lost interrupt	3		
		Spare	2-0		
	2. Status (2 bytes)	CONNECTED=1/NOT_CONNECTED=0 (link1)	15	(6,8)	LM587350
		Transmit link is running=1 (link1)	14		
		NULL token is received=1 (link1)	13		
		FCT token is received=1 (link1)	12		
		CONNECTED=1/NOT_CONNECTED=0 (link2)	11		
		Transmit link is running=1 (link2)	10		
		NULL token is received=1 (link2)	9		
		FCT token is received=1 (link2)	8		



		DAE SMCS configured=1	7	(6,8)	
		CONNECTED=1/NOT_CONNECTED=0 (link3)	6		
		Transmit link is running=1 (link3)	5		
		NULL token is received=1 (link3)	4		
		FCT token is received=1 (link3)	3		
		SPU-DAE communication status (bit 5 AND bit 9 AND 10) (control by link communication)	2		
		Spare	1-0		
	3. Communication errors (2 bytes) (+reset)	DPU packet TX timeout	15	2 x (6,8)	LM588350
		Spare	14		
		DAE cmd: execution error DAEC TX timeout	13		
		DAE cmd: execution error DAEC RX timeout	12		
		Spare	11		
		DAE cmd: execution error DAEN RX timeout	10		
		Spare	9-0		
	4. Spare (2 bytes)				

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
SPU SW Conflicts (FIFOS and resources) (4 bytes)	1. FIFOs Errors: (+reset) (2 bytes)	FIF_SC_FREE overflow	15	2 x (6,8)	LM591350
		FIF_SC_TX overflow	14		
		FIF_CH_READY overflow	13		
		FIF_SPU_RX_DPU overflow	12		
		FIF_SPU_ERR_QUE overflow	11		
		Spare	10-0		
	2. Resources Errors (+reset) (2 bytes)	RES_SPU_DPU_ACCESS	15	2 x (6,8)	LM592350
		RES_SPU_DAE_ACCESS	14		
		RES_SPU_DAE_COMM_STAT	13		
		RES_SC_CONF	12		
		RES_SC_PROC	11		
		RES_SPU_ERR_QUE	10		
		RES_CLB_CHAN	9		
		Spare	8-0		

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN6] for definition of LFI specific monitoring and definition parameters as described in [AD6].



11.1.7.4.1 REBA Essential HK (121202369)

These packets are a copy of the REBA HK and delivered together with the others with two exceptions:

- The APID in the Packet Header are 600h
- The period of generation is 32s.

This packet is produced in all the Op-Modes but only when the ASW is running.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN6] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8 DIAGNOSTIC PARAMETER REPORT – TM (3,26)

The general format for the “Source Packet Header” of this packet is the following:

Source Packet Header						
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
‘000’	‘0’	‘1’	‘110 0000 0010’ 0x602	‘11’		

The value of the “Source Sequence Count” field is provided by a counter packet by packet. The value of the “Packet Length” field is related to the different SIDs.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 0011’	‘0001 1010’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.



11.1.8.1 REBA DIAGNOSTIC HK (120300369)

This packet contains the data coming from the REBA during the operations except in “Standby” op-mode. Also these are organised as a set of 4 samples (taken one per second)

This packet is under revision for the organisation of the parameters after the first step of coding of the REBA SW. No changes are foreseen in the overall dimensions and production rate.

Packet Length: 0x3E3

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM093342	300 (decimal) (2,16)
Sample 1	250 bytes		
Sample 2	250 bytes		
Sample 3	250 bytes		
Sample 4	250 bytes		

The packet is terminated by 16 bits CRC field.

Each of the samples contains the following parameters.

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
Sample OBT	6 bytes	LM102322	OBT corresponding to start of the sample generation (9,17)
LFI status-2	1 byte	LM201342	
LFI operati_mode	1 byte	LM00A342	
LFI mode	1 byte	LM202342	See NOTE-1 2 x (6,8)
DAU channel 1 value	2 bytes	LM211342	(3,12) <0..511>
DAU channel 2 value	2 bytes	LM212342	(3,12) <0..511>
DAU channel 3 value	2 bytes	LM213342	(3,12) <0..511>
DAU channel 4 value	2 bytes	LM214342	(3,12) <0..511>
DAU channel 5 value	2 bytes	LM215342	(3,12) <0..511>
DAU channel 6 value	2 bytes	LM216342	(3,12) <0..511>
DAU channel 7 value	2 bytes	LM217342	(3,12) <0..511>
DAU channel 8 value	2 bytes	LM218342	(3,12) <0..511>
DAU channel 9 value	2 bytes	LM219342	(3,12) <0..511>
DAU channel 10 value	2 bytes	LM220342	(3,12) <0..511>
DAU channel 11 value	2 bytes	LM221342	(3,12) <0..511>
DAU channel 12 value	2 bytes	LM222342	(3,12) <0..511>
DAU channel 13 value	2 bytes	LM223342	(3,12) <0..511>



Software ID	2 bytes	LM206342	See NOTE-2 (2,16)
DPU software version	2 bytes	LM207342	See NOTE-3 (2,16)
DPU CPU load	2 bytes	LM500340	During last 0.9 s period. Integer number in 0-1000 range. One unit corresponds to 0.1% of the CPU load. (3,12) <0..1000>
CDMS communication I	6 bytes	LM501340 LM502340	See description of REBA HK
Monitoring I	20 bytes		See description of REBA HK
DPU Task Status	4 bytes		See description of REBA HK
HK acquisition and production	4 bytes		See description of REBA HK
Spare	4 bytes		See description of REBA HK
Spare	4 bytes		
DPU DSP and HW error	4 bytes		See description of REBA HK
DPU 1355 communication status	8 bytes		See description of REBA HK
DPU SW conflicts	4 bytes		See description of REBA HK
SPU software version	2 bytes	LM556350	See NOTE-3 (2,16)
SPU CPU load	2 bytes	LM557350	During last 0.9 s period. Integer number in 0-1000 range. One unit corresponds to 0.1% of the CPU load. (3,12) <0..1000>
SPU Science processing I	24 bytes		See description of REBA HK
SPU Tasks Status	4 bytes		See description of REBA HK
SPU DSP and HW error	4 bytes		See description of REBA HK
SPU 1355 communication status	8 bytes		See description of REBA HK
SPU SW Conflicts	4 bytes		See description of REBA HK
Spare	2 bytes		
CDMS communication II	24 bytes		See description in the following table
Monitoring II	12 bytes		See description in the following table
DPU-SPU communication	18 bytes		See description in the following table
DPU SW FIFOs and MAP Status	12 bytes		See description in the following table
SPU-DPU communication	16 bytes		See description in the following table



SPU Science processing II	8 bytes		See description in the following table
SPU FIFOs Status	8 bytes		See description in the following table
Spare	2 bytes		See description in the following table
Sampling period	2 bytes	LM005320	1(decimal)
Total size	250 bytes		

NOTE-1:

LFI status-1 bit assignment shall be as follows:

- Bit 15 (LSB): DAE power status (1=ON)
- Bit 114 : OBTclock status (1=internal)
- Bits 13-0 (MSB) : reserved. All set to 0.

NOTE-2:

Software ID (16 bits) is as follows:

00 01h DPU_SUSW, SPU Software ID is unknown (no communication with the SPU)

00 02h DPU_ASW, SPU Software ID is unknown (no communication with the SPU)

01 02h DPU_ASW & SPU_SUSW

02 02h DPU_ASW & SPU_ASW

NOTE-3:

Software version (2 bytes). The MSB (most significant byte) corresponds to the SW version number, and the LSB (least significant byte) corresponds to the SW revision number.

The following table describes the fields that are inside each sample of the REBA diagnostic packet. (+reset) means that this value is reset to 0 after it is put in the packet.

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
CDMS communication II (24 bytes)	1. Number of Science packets generated (4 bytes)			(3,14)	LM101340
	2. Number of HK packets generated (4 bytes)			(3,14)	LM102340
	3. Number of Event packet generated (4 bytes)			(3,14)	LM103340
	4. Number of other packets generated (4 bytes)	Not HK, not Event and not Science		(3,14)	LM104340
	5. Number of Science TM packets lost (2 bytes)	Since DPU ASW initialisation		(3,12)	LM105340
	6. Number of NOT Science TM packets lost (2 bytes)	Since DPU ASW initialisation		(3,12)	LM106340
	7. Spare (4 bytes)				



Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
Monitoring II (12 bytes)	1. FPT sensors counters (12 bytes)	FPT Sensor 0 (1 byte)		7 x (3,4) <0..10>	LM110340
		FPT Sensor 1 (1 byte)			LM111340
		FPT Sensor 2 (1 byte)			LM112340
		FPT Sensor 3 (1 byte)			LM113340
		FPT Sensor 4 (1 byte)			LM114340
		FPT Sensor 5 (1 byte)			LM115340
		FPT Sensor 6 (1 byte)			LM116340
		FPT Sensor 7 (1 byte)			LM117340
		Spare			
		Spare			
		Spare			
		Spare			

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
DPU-SPU communication (18 bytes)	1. Number of HK packets received (4 bytes)				LM118340
	2. Number of Event packets received (4 bytes)				LM119340
	3. Number of Science packets received (4 bytes)				LM120340
	4. OBT of last received SPU HK packet (6 bytes)				

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
DPU FIFOS and MAP Status (12 bytes)	FIF_TM_GEN_QUE status (1 byte)				
	FIF_TM_SC_QUE status (1 byte)				
	FIF_TC_QUE status (1 byte)				
	FIF_FPT_MONIT status (1 byte)				



Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
	FIF_CPU_MONIT status (1 byte)				
	FIF_CF_MONIT status (1 byte)				
	FIF_DPU_RX_SPU status (1 byte)				
	FIF_DPU_ERR_QUE status (1 byte)				
	FIF_DPU_SPU_HK status (1 byte)				
	TC block map status (1 byte)				
	TM block map status (1 byte)				
	Spare (1 byte)				

Data	16-bit Words	Bit meaning/Comment	Bits	(PTC, PFC)	SCOS Name
SPU-DPU communication (16 bytes)	1. Number of HK packets generated (4 bytes)				LM121340
	2. Number of Event packets generated (4 bytes)				LM122340
	3. Number of Science TM packets produced (4 bytes)	Since the last start/restart of the Science data processing function			LM123340
	4. Total number of Science TM packets produced (4 bytes)	Since the SPU ASW initialisation			

Data	16-bit Words	Bit meaning/Comment	(PTC, PFC)
SPU Science processing II (8 bytes)	1. Number of science data blocks received from DAE (4 bytes)	Since the last start/restart of the Science data processing function	
	2. Total number of science data blocks received from DAE (4 bytes)	Since the SPU ASW initialisation	

Data	16-bit Words	Bit meaning/Comment	(PTC, PFC)
SPU FIFOS Status	1. FIF_CH_READY status (1 byte)		



(8 bytes)	2. FIF_SC_FREE status (1 byte)		
	3. FIF_SC_TX status (1 byte)		
	4. FIF_SPU_RX_DP U status (1 byte)		
	5. FIF_SPU_ERR_Q UE status (1 byte)		
	6. Spare (3 byte)		

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.2 COMPRESSION FACTORS HK PACKET FORMAT (PERIODICAL) (120301350)

Once activated with a TC(14,1), this packet is delivered periodically. It contains information already present into the science data stream, but here they are available into the HK stream and organised in a simpler way to be used in a “quick look analysis”.

Packet Length: 0x3F7

Packet contains compression factors for last produced science compressed TM packets. Compression factor values along with channel and packet identification are stored in a circular buffer each time a science TM packet is produced. Circular buffer has size to store 125 entries. Since these packets are not strictly periodical because they are generated the basis of the compression factor that is statistically distributed the “Packet period” field is not significant therefore it is set to '00 00h'.

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM101350	301(decimal) (2,16)
Compression factors	1000 bytes		125 entries (correspond to 125 last produced compressed science packets). Each entry is 8 bytes:
		LM102350	8 bits - Channel ID (2,8) <0..43>
		LM103350	1 bit - Processing Group (2,1) <A=0, B=1>
			3 bits - Spare
		LM104350	4 bits - Processing type (2,4) <0..6>
		LM105350	2 bits - Phase Switch Status (2,2)



		LM106350	14 bits - Packet counter within given channel ID (3,10)
		LM107350	4 bytes – compression factor (5,1) <1..>
Packet period	2 bytes		00 00h

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.3 SPU MAXIMUM MEMORY OCCUPANCY HK PACKET FORMAT (PERIODICAL) (120302350)

Once activated with a TC(14,1) this packet is produced and delivered periodically.

Packet Length: 0x3F9

This packet contains maximum memory occupancy for last produced science TM packets. Memory occupancy values along with channel and packet identification are stored in a circular buffer each type a science TM packet is produced. Circular buffer has size to store 167 entries. Since these packets are not strictly periodical because they are generated the basis of the compression factor that is statistically distributed the “Packet period” field is not significant therefore it is set to '00 00h'.

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM111350	302(decimal) (2,16)
Maximum memory occupancies	1000 bytes		167 entries (correspond 167 last produced science packets). Each entry is 6 bytes:
		LM112350	8 bits - Channel ID (2,8) <0..43>
		LM113350	1 bit - Processing Group (2,1) <A=0, B=1>
			3 bits - Spare
		LM114350	4 bits - Processing type (2,4) <0..6>
		LM115350	2 bits - Phase Switch Status (2,2)
		LM116350	14 bits - Packet counter within given channel ID (3,10)
		LM117350	2 bytes – memory occupancy (3,12)
Packet period	2 bytes		00 00h

The packet is terminated by 16 bits CRC field.



See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.4 SPU CURRENT MEMORY OCCUPANCY HK PACKET FORMAT (PERIODICAL) (120303350)

Once activated with a TC(14,1) this packet is produced and delivered periodically.

Packet Length: 0x3F9

Packet contains actual memory occupancies for last produced science TM packets. Memory occupancy values along with channel and packet identification are stored in a circular buffer each type a science TM packet is produced. Circular buffer has size to store 167 entries. Since these packets are not strictly periodical because they are generated the basis of the compression factor that is statistically distributed the “Packet period” field is not significant therefore it is set to '00 00h'.

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM121350	303(decimal) (2,16)
Memory occupancies	1002 bytes		167 entries (correspond 167 last produced science packets). Each entry is 6 bytes:
		LM122350	8 bits - Channel ID (2,8) <0..43>
		LM132350	1 bit - Processing Group (2,1) <A=0, B=1>
			3 bits - Spare
		LM124350	4 bits - Processing type (2,4) <0..6>
		LM125350	2 bits - Phase Switch Status (2,2)
		LM126350	14 bits - Packet counter within given channel ID (3,10)
		LM126350	2 bytes – memory occupancy (3,12)
Packet period	2 bytes		00 00h

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.5 SPU CPU CONSUMPTION HK PACKET FORMAT (PERIODICAL) (121304350)

Once activated with a TC(14,1) this packet is produced and delivered periodically.



Packet Length: 0x3F9

Packet contains CPU consumption values (CPU time spent for compression of each compressed science TM packet) for last produced compressed science TM packets. CPU consumption values along with channel and packet identification are stored in a circular buffer each type a compressed science TM packet is produced. Circular buffer has size to store 167 entries. Since these packets are not strictly periodical because they are generated the basis of the compression factor that is statistically distributed the “Packet period” field is not significant therefore it is set to '00 00h'.

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM131350	304(decimal) (2,16)
CPU consumption	1002 bytes		167 entries (correspond 167 last produced science packets). Each entry is 6 bytes:
		LM132530	8 bits - Channel ID (2,8) <0..43>
		LM133350	1 bit - Processing Group (2,1) <A=0, B=1>
			3 bits – Spare
		LM134350	4 bits - Processing type (2,4) <0..6>
		LM135350	2 bits - Phase Switch Status (2,2)
		LM136350	14 bits - Packet counter within given channel ID (3,10)
		LM137350	2 bytes – CPU consumption in ms (3,12)
Packet period	2 bytes		00 00h

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.6 FPT-OUT-OF-LIMIT COUNTERS PACKET FORMAT (NON PERIODICAL) (120938340)

This packet notifies to ground the counters related to each FP temperature sensor for the monitoring of the FPU before switching automatically off the radiometers.

Packet Length: 0x25

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM150350	938(decimal) (2,16)
FP temperature limits	14 bytes	LM151350 [..]	7 sensors x 2 bytes. (3,12) <0..10>



		LM157350	
Spare	10 bytes		5 sensors x 2 bytes.

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.7 CF THRESHOLDS PACKET FORMAT (NON PERIODICAL)

11.1.8.8 AVERAGE CF PACKET FORMAT (NON PERIODICAL)

11.1.8.9 DAE ACTUAL CONFIGURATION PACKET FORMAT (121101369)

This packet contains actual DAE configuration parameters in DAE DPRAM. This packet type can be enabled even if the periodical DAE slow HK is enabled. It is foreseen for test purposes to get configuration immediately and not wait for period of 64 s. It is returned by the execution of the “Get DAE current configuration” TC. Packet format is the same as per Par. 11.1.7.1.

The difference is:

- SID value: 1101 (decimal)
- Packet period field is set to 0.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.10 DAE DEFAULT CONFIGURATION HK PACKET FORMAT (121111369)

The packet contains default DAE configuration parameters in DPU EEPROM. This packet is returned by the execution of the “Get DAE default configuration” TC. Packet format is the same as per Par. 11.1.7.1.

The difference is:

- SID value: 1111 (decimal)
- FEM drain currents and DC/DC converter en/dis: spare because a default value for these parameters does not exist, they must be configured specifically with a “Configure DAE” TC.
- Packet period field is set to 0.



See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.11 COMPRESSION FACTORS HK PACKET FORMAT (NON PERIODICAL) (121301350)

The packet format for this *single* packet is exactly the same as for the corresponding *periodical* packet defined in Par. 11.1.8.2.

The difference is:

- SID value: 1301 (decimal)

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.12 SPU MAXIMUM MEMORY OCCUPANCY PACKET FORMAT (NON PERIODICAL) (121302350)

The packet format for this *single* packet is exactly the same as for the corresponding *periodical* packet defined in Par. 11.1.8.3.

The difference is:

- SID value: 1302 (decimal)

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.13 SPU CURRENT MEMORY OCCUPANCY PACKET FORMAT (NON PERIODICAL) (121303350)

The packet format for this *single* packet is exactly the same as for the corresponding *periodical* packet defined in Par. 11.1.8.4.

The difference is:

- SID value: 1303 (decimal)



See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.14 SPU CPU CONSUMPTION PACKET FORMAT (NON PERIODICAL) (121304350)

The packet format for this *single* packet is exactly the same as for the corresponding *periodical* packet defined in Par. 11.1.8.5.

The difference is:

- SID value: 1304 (decimal)

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.15 DPU HW REGISTERS & EDAC FAILURES PACKET FORMAT (122021340)

This packet is mainly used in case of troubleshooting and for ground testing.

Packet Length: 0x309

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes		2021(decimal)
PM ASIC Register values	124 bytes		31 registers x 4 bytes
DM ASIC Register values	124 bytes		31 registers x 4 bytes
SMCS Register values	480 bytes		120 registers x 4 bytes
ACE Register values	32 bytes		16 registers x 2 bytes
Number of single EDAC failures	2 bytes		(3,12)
Number of double EDAC failures	2 bytes		(3,12)

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].



See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.16 DAE SMCS 1 PACKET FORMAT (122029328)

This packet is mainly used in case of troubleshooting and for ground testing.

Packet Length: 0x1ED

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes		2029(decimal)
SMCS Register values	480 bytes		120 registers x 4 bytes

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.17 DAE SMCS 1 GPIO PACKET FORMAT (122099328)

This packet is mainly used in case of troubleshooting and for ground testing.

Packet Length: 0x11

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM001328	2099(decimal) (2,16)
GPIO 0	1 byte	LM002328	(6,8)
GPIO 1	1 byte	LM003328	(6,8)
GPIO 2	1 byte	LM004328	(6,8)
GPIO 3	1 byte	LM005328	(6,8)

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.18 SPU HW REGISTERS & EDAC FAILURES PACKET FORMAT (122121350)

Packet format is the same as in Par. 11.1.8.15.



The difference is:

- SID value: 2121 (decimal)
- Fields for ACE registers are set to 0.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.19 DAE SMCS 2 PACKET FORMAT (121129328)

Packet format is the same as in Par. 11.1.8.16.

The difference is:

- SID value: 2129 (decimal)

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.20 OFFSETS AND REQUANTS PACKET FORMAT (121303350)

Packet Length: 0x16D

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM200350	2130 (decimal) (2,16)
Offset list	176 bytes	LM201350 [.. LM244350	44 detectors x 4 bytes. 44 x (5,1)
ReQuant list	176 bytes	LM251350 [.. LM294350	44 detectors x 4 bytes. 44 x (5,1) <Positive>

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].



11.1.8.21 GMF AND NAVERAGE PACKET FORMAT (121131350)

This packet notifies to ground the value set into the instrument for the scientific processing. In particular it reports the number of raw samples to be averaged per each bin in the sky for each radiometer and the Gain Modulation Factor for each channel.

Packet Length: 0x199

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes	LM300350	2131(decimal) (2,16)
GMF1 list	176 bytes	LM301350 [..] LM344350	44 detectors x 4 bytes 44 x (5,1) <Positive>
GMF2 list	176 bytes	LM351350 [..] LM394350	44 detectors x 4 bytes 44 x (5,1) <Positive>
NAverage list	44 bytes	LM401350 [..] LM422350	22 radiometers x 2 bytes 44 x (3,12)

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.22 DPU 1355 LINKS ERRORS PACKET FORMAT (120022350)

This packet contains the 1355 link errors detected in the DPU since the DPU_ASW initialisation.

Packet Length: 0x25

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>
SID	2 bytes		2022(decimal)
Number of checksum error in reception link 2	2 bytes		
Number of checksum error in reception link 3	2 bytes		
Number of receive buffer overflow on link 1	2 bytes		
Number of receive buffer overflow on link 2	2 bytes		
Number of receive	2 bytes		



buffer overflow on link 3			
Number of disconnect error link 1	2 bytes		
Number of disconnect error link 2	2 bytes		
Number of disconnect error link 3	2 bytes		
Number of parity error link 1	2 bytes		
Number of parity error link 2	2 bytes		
Number of parity error link 3	2 bytes		
Number of SMCS interrupt lost	2 bytes		

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.23 SPU 1355 LINKS ERRORS PACKET FORMAT (121122350)

This packet contains the 1355 link errors detected in the SPU since the SPU_ASW initialisation.

Packet format is the same as in Par. 11.1.8.22.

The difference is:

- SID value: 2122 (decimal)

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.8.24 TM RATE STEPS TABLE PACKET FORMAT (120704350)

This packet contains the information needed by the Science TM rate monitoring autonomous function indicating the order of detectors whose data shall be discarded for limiting the TM rate.

Packet Length: 0xB3

DATA	SIZE	SCOS name	COMMENTS (PTC,PFC) <range>



SID	2 bytes	LMC00340	704(decimal) (2,16)
Detectors ID step 2	16 bytes	LMC01350 [.] LMC16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 3	16 bytes	LMC01350 [.] LMC16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 4	16 bytes	LMF01350 [.] LMF16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 5	16 bytes	LMG01350 [.] LMG16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 6	16 bytes	LMH01350 [.] LMH16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 7	16 bytes	LMM01350 [.] LMM16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 8	16 bytes	LMP01350 [.] LMP16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 9	16 bytes	LMR01350 [.] LMR16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 10	16 bytes	LMS01350 [.] LMS16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 11	16 bytes	LMT01350 [.] LMT16350	16 x (2,8) <0..43>+<FF=no detector>
Detectors ID step 12	16 bytes	LMU01350 [.] LMU16350	16 x (2,8) <0..43>+<FF=no detector>

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN7] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.9 MEMORY DUMP, ABSOLUTE ADDRESS – TM(6,6) (120066369)

The general format for the “Source Packet Header” of this packet is the following:



Source Packet Header						
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
'000'	'0'	'1'	'110 0000 0000' 0x600	'11'		

The value of the "Source Sequence Count" field is provided by a counter packet by packet. The value of the "Packet Length" field is up to 0x3F9 according to the packets.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
'0'	'000'	'0000'	'0000 0110'	'0000 0110'	'0000 0000'	

The "Time" field contains the value of the OBT register sampled together with the data contained into the packet.

Source Data		
DATA	SIZE	COMMENTS
Memory ID	2 bytes	See description below
Start Address	2 bytes	
Length	2 bytes	In SAUs
Data	N x 2 bytes	
Checksum	2 bytes	

The packet is terminated by 16 bits CRC field.

The memory address is built as follows: the MSB is specified by the LSB of Memory ID field and the 2 LSB are specified in the 2 bytes of the Start Address field. This is because 3 bytes are needed to reference the whole memories.

The MSB of the Memory ID field in the Memory management TC/TM is defined as follows: Memory ID = sssstmmmm (8 bits).



sss	Identifies the subsystem. DPU=000b SPU=100b DAE=111b
t	0b: Program Memory 1b: Data Memory
mmmm	Identifies the block inside the memory type. 0000b: PROM 0001b: RAM 0010b: Extended RAM 0011b: EEPROM 0100b: SMCS DPRAM 0101b: 1553 DPRAM 0110b: SMCS DPRAM-2

Memory ID codes for Program Memory:

Memory ID (bin)	Memory type	SAU	Address (hex) at SUSW	Address (hex) at ASW
sss0 0000	PROM	48	00.0000 00.7FFF	00.0000 00.0017
sss0 0001	RAM	48	80.0000 81.FFFF	00.0018 01.FFFF
sss0 0011	EEPROM (only DPU)	48	88.0000 8B.FFFF	08.0000 0B.FFFF

Memory ID codes for Data Memory:

Memory ID (bin)	Memory type	SAU	Address (hex)
sss1 0001	RAM	32	0000.0000 0001.FFFF
sss1 0010	Extended RAM	32	8000.0000 8007.FFFF
sss1 0100	SMCS DPRAM	32	8018.0000 8018.1FFF
sss1 0101	1553 DPRAM (only DPU)	16	4008.0000 4008.1FFF

Memory ID codes for DAE Memory:

Memory ID (bin)	Memory type	SAU	Address (hex)
111 1 0100	SMCS DPRAM 1	16	0000.0000 0000.8000
111 1 0110	SMCS DPRAM 2	16	0000.0000 0000.8000



A summary of all memory allocations is given in Par. 10.3. Note that Memory ID, Start Address and Length are all 2 bytes size. Memory Id (as defined above) is requiring a single byte, instead the size (and thus the Starting Address) up to three bytes. For this reason the second byte of the Memory Id is used by the Starting Address. See an example below:

LFI DPU DRAM	Mem ID	Starting Address	Length
	11h	0003 0000	0000 1032
Parameter	LM050369	LM051369	LM052369
Value	1103h	0000h	1032

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN11] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.10 MEMORY CHECK REPORT, ABSOLUTE ADDRESS – TM(6,10)

The general format for the “Source Packet Header” of this packet is identical to that of TM(6,6).

The value of the “Source Sequence Count” field is provided by a counter packet by packet. The value of the “Packet Length” field is 0x13.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 0110’	‘0000 1010’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

Source Data		
DATA	SIZE	COMMENTS
Memory ID	2 bytes	See chapter 11.1.9
Start Address	2 bytes	
Length	2 bytes	In SAUs
Checksum	2 bytes	

The packet is terminated by 16 bits CRC field.



See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN12] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.11 FUNCTION STATUS REPORT – TM(8,6)

The general format for the “Source Packet Header” of this packet is identical to that of TM(6,6).

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 1000’	‘0000 0110’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
Function ID	1 byte	See table in chapter 12.1.4 (2,8)
Activity ID	1 byte	(2,8) <00h or FFh> 00h: stopped FFh: running Note: all activities finish after execution of the command, so possible status of functions are running or stopped

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN19] for definition of LFI specific monitoring and definition parameters as described in [AD6].



11.1.12 TIME VERIFICATION REPORT – TM(9,9)

The general format for the “Source Packet Header” of this packet is the following:

Source Packet Header						
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
‘000’	‘0’	‘1’	‘110 0000 0000’ 0x600	‘11’		‘0000 0000 0001 0101’

The value of the “Source Sequence Count” field is provided by a counter packet by packet.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 1001’	‘0000 1001’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
Time	6 bytes	(9,17)

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN13] for definition of LFI specific monitoring and definition parameters as described in [AD6].



11.1.13 ENABLED TELEMETRY PACKETS REPORT – TM(14,4)

The general format for the “Source Packet Header” of this packet is the following:

Source Packet Header						
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
‘000’	‘0’	‘1’	‘110 0000 0000’ 0x600	‘11’		

The value of the “Source Sequence Count” field is provided by a counter packet by packet.
Packet Length: to be determined in accordance to the packet content.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 1110’	‘0000 0100’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
Number of TM packet definitions	2 bytes	(3,12) <1..20>
Type, Sub-type, SID	N x (1+1+2) bytes	- Type (2,8) - Subtype (2,8) - SID (2,16)

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].



See the addenda [AN14] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.1.14 LINK CONNECTION REPORT – TM(17,2)

The general format for the “Source Packet Header” of this packet is the following:

Source Packet Header						
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
‘000’	‘0’	‘1’	‘110 0000 0000’ 0x600	‘11’		‘0000 1011’

The value of the “Source Sequence Count” field is provided by a counter packet by packet.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0001 0001’	‘0000 0010’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

The “Source Data” field is empty.

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN15] for definition of LFI specific monitoring and definition parameters as described in [AD6].



11.2 DEFINITION OF SYNTHETIC PARAMETERS

The LFI derived parameters are defined in details in Annex [AN36]. They can be groups in the following categories:

1. Synthetic Parameters;
2. SCOS Displays:
 - i. Alphanumeric displays;
 - ii. Graphical displays;
 - iii. Scrolling displays.

11.3 DEFINITION OF EVENT REPORTS

11.3.1 EVENT REPORT – TM (5,1)

The general format for the “Source Packet Header” of this packet is the following:

Source Packet Header						
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
‘000’	‘0’	‘1’	‘110 0000 0000’ 0x600	‘11’		

The value of the “Source Sequence Count” field is provided by a counter packet by packet. Packet Length: 0x25 depending on the size of the parameters.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 0101’	‘0000 0001’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.



Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
Event ID	2 bytes	See table below (2,16)
SID	2 bytes	(2,16)
Parameters	8 bytes	See table below
Event Sequence Counter	2 bytes	(3,12)
Parameters	12 bytes	See table below

The packet is terminated by 16 bits CRC field.

The following table reports the asynchronous events that generates a TM(5,1)

Event ID & SID	Event type	Parameters in event report		Description
4001	DSP exception error Reserved to REBA	-DPU/SPU (2 bytes)(2,16) (See NOTE 1) -Error code (2 bytes)(2,16) (See NOTE 3) -Spare (4 bytes) - Spare set to 0 (12 bytes)		Error bits set in LFI HK packet
5002	EDAC single error	-DPU/SPU (2 bytes) (2,16) (See NOTE 1) -PM/DM (2 bytes) (2,16) (See NOTE 2) -Wrong address (4 bytes) (3,14) -Correct value 2 MSB (4 bytes) (3,14) -Correct value 4 LSB (4 bytes) (3,14) - Spare set to 0 (4 bytes)		Error bits set in LFI HK packet
5031	SMCS HW communication error	-DPU/SPU (2 bytes) (2,16) (See NOTE 1) -Error code (2 bytes) (2,16) (See NOTE 4) Link number (2 bytes) (2,16) Command (2 bytes) (2,16) (See NOTE 4) - Spare set to 0 (12 bytes)		Error bits set in LFI HK packet
5104	TM rate exceeds allowed limit	- Parameter Tau (4 bytes) (5,1) - Current Science TM filling (4 bytes) (3,14)		Error bits set in LFI HK packet



		- Checking time in minutes since last reset of Science TM rate monitoring (2 bytes) (3,12) - TM_RATE_EXPECTED parameter (2 bytes) (3,12) - Spare set to 0 (8bytes)		
5106	TM rate returns under limit	- Parameter Tau (4 bytes) (3,14) - Current science TM filling (4 bytes) (3,14) - Checking time in minutes since last reset of Science TM monitoring (2 bytes) (3,12) - TM_RATE_EXP parameter (2 bytes) (3,12) - Spare set to 0 (8 bytes)		
5110	AF report execution	- AF ID (2 bytes) (2,16) (See NOTE 5) - Success/Failure (2 bytes) (2,16) (See NOTE 5) - Spare set to 0 (16 bytes)		
5200	Science validation error data size	- Ping/pong buffer (0/1) (2 bytes) (2,16) <0..1> - Received packet size (2 bytes) (3,12) - Number of DAE packets (4 bytes) (3,14) - Expected packet size (2 bytes) (3,12) - OBT of first received frame (6 bytes) (9,17) - Spare set to 0 (4 bytes)		Error bit set in LFI HK Enabled only for Ground Testing
5201	"Data Ready" signal in SPU time-out error	- Expected ping/pong buffer (0/1) (2 bytes) (2,16) <0..1> - Number of DAE packets (4 bytes) (3,14) - Spare set to 0 (14 bytes)		Enabled only for Ground Testing Error bits set in LFI HK packet
5202	Ping/pong arbitration error	- Expected buffer (0/1) (2 bytes) (2,16) <0..1> - Actual buffer (0/1) (2 bytes) (2,16) <0..1> - Number of DAE packets (4 bytes) (3,14) - Spare set to 0 (12 bytes)		Enabled only for Ground Testing Error bits set in LFI HK packet
5203	Science data validation marker	- Frame number (0-59) (2 bytes) (3,12) <0..59>		Enabled only for Ground



	error		-Ping/Pong buffer (0/1) (2 bytes) (2,16) <0..1> Actual frame marker value (2 bytes) (2,16) -Expected frame marker value (2 bytes) (2,16) - Number of DAE packets (4 bytes) (3,14) - OBT of wrong frame (6 bytes) (9,17) - Spare set to 0 (2 bytes)		Testing Error bits set in LFI HK packet
5204	Science data validation error OBT		-Frame number (0-59) (2 bytes) (3,12) <0..59> -Ping/Pong buffer (0/1) (2 bytes) (2,16) <0..1> - Number of DAE packets (4 bytes) (3,14) - Actual OBT value (6 bytes) (9,17) -Expected OBT value (6 bytes) (9,17)		Enabled only for Ground Testing Error bits set in LFI HK packet
5205	Science data validation checksum error		-Ping/Pong buffer (0/1) (2 bytes) (2,16) <0..1> - OBT of first received frame (6 bytes) (9,17) - Number of DAE packets (4 bytes) (3,14) -Spare set to 0 (8 bytes)		Enabled only for Ground Testing Error bits set in LFI HK packet
5206	Science data acquisition time out		-Error type (2 bytes) (2,16) (See NOTE 6) -Ping/Pong buffer (0/1) (2 bytes) (2,16) <0..1> - Number of DAE packets (4 bytes) (3,14) -Spare (12 bytes)		Enabled only for Ground Testing Error bits set in LFI HK packet
5211	Science data overflow circular buffer		-Channel ID (1 byte) (2,8) -Processing type (1 byte) (2,8) <0..6> -Spare set to 0 (18 bytes)		Error bits set in LFI HK packet

NOTE 1.

-DPU/SPU:

=00 00h: DPU

=00 01h: SPU



NOTE 2.

-PM/DM:

=00 00h: PM
=00 01h: DM

NOTE 3.

-DSP error code:

10 01h: WD interrupt
10 02h: 1553 I/F interrupt

NOTE 4.

-SMCS communication error code:

00 01h: Disconnect error
00 02h: Parity error
00 04h: SMCS checksum error in reception
00 08h: SMCS receive buffer overflow
00 10h: SMCS checksum error in reception (Error Bit 4 of ESR1)
80 00h: SMCS lost interrupt

-Command: last command sent by control link for communication with DAE.

NOTE 5.

-AF ID:

00 01h: AF SWITCH_OFF_FEU
00 02h: AF ENBL-DISBL_SC_DET_PROC
00 04h: AF RESTART_ALL_1355_COMM

-Success/Failure:

00 00h: Success
00 01h: Failure

NOTE 6.

-Science data acquisition error type:

00 01h: Read ping: DAEC TX time out
00 02h: Read ping: DAEC RX time out
00 04h: Read pong: DAEC TX time out



00 08h: Read pong: DAEC RX time out
00 10h: Read DPRAM: DAEC TX1 time out
00 20h: Read DPRAM: DAEC TX2 time out
00 40h: Read DPRAM: DAEN RX time out
00 80h: Write 0 ping: DAEC TX time out
01 00h: Write 1 ping: DAEC TX time out
02 00h: Write 0 pong: DAEC TX time out
04 00h: Write 1 pong: DAEC TX time out

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN8] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.3.2 EXCEPTION REPORT – TM (5,2)

The general format for the “Source Packet Header” of this packet is identical to that of TM(5,1).

The value of the “Source Sequence Count” field is provided by a counter packet by packet. Packet Length: 0x25 depending on the size of the parameters.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 0101’	‘0000 0010’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
Event ID	2 bytes	See table below (2,16)
SID	2 bytes	(2,16)
Parameters	8 bytes	See table below
Event Sequence Counter	2 bytes	(3,12)
Parameters	12 bytes	See table below

The packet is terminated by 16 bits CRC field.



The following table reports the asynchronous events that generates a TM(5,2)

Event ID & SID	Event type	Parameters in event report		Description
5105	DPU-DAE reconnection failure	-Spare set to 0 (20 bytes)		Error in the 1355 communication

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN9] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.3.3 ERROR/ALARM REPORT – TM (5,4)

The general format for the “Source Packet Header” of this packet is identical to that of TM(5,1). The value of the “Source Sequence Count” field is provided by a counter packet by packet. Packet Length: 0x25 depending on the size of the parameters.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0000 0101’	‘0000 0100’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled together with the data contained into the packet.

Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
Event ID	2 bytes	See table below (2,16)
SID	2 bytes	(2,16)
Parameters	8 bytes	See table below
Event Sequence Counter	2 bytes	(3,12)
Parameters	12 bytes	See table below

The packet is terminated by 16 bits CRC field.



The following table reports the asynchronous events that generates a TM(5,4)

Event ID & SID	Event type	Parameters in event report		Description
5003	EDAC error double	-DPU/SPU (2 bytes) (2,16) (See NOTE 1 in chapter 11.3.1) -PM/DM (2 bytes) (2,16) (See NOTE 2 in chapter 11.3.1) -Wrong address (4 bytes) (2,32) -Wrong value 2 MSB (4 bytes) (2,32) -Wrong value 4 LSB (4 bytes) (2,32) - Spare set to 0 (4 bytes)		Error bits set in LFI HK packet
5031	SMCS HW communication error	-DPU/SPU (2 bytes) (2,16) (See NOTE 1 in chapter 11.3.1) -Error code (2 bytes) (2,16) (See NOTE 4 in chapter 11.3.1) Link number (2 bytes) (3,12) <1..3> Command (2 bytes) (2,16) (See NOTE 4 in chapter 11.3.1) - Spare set to 0 (12 bytes)		Error bits set in LFI HK packet
5102	SPU CPU workload exceeds allowed limit	-Spare set to 0 (20 bytes)		Error bits set in LFI HK packet
5103	FP temperature exceeds allowed limit	- Spare set to 0 (20 bytes)		Error bits set in LFI HK packet

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN10] for definition of LFI specific monitoring and definition parameters as described in [AD6].

11.4 EXAMPLE OF A TM PACKET TM(1,8)

To give an idea of how a TM packet looks like, an example of TM(1,8) “TC execution report failure” (APID: 1536, PI1: 39, PI2: 0, SPID: 128039340) is given in the figure below.



TM Packet Details

```

Simulated: N
Mnemonic: TC_1_8 0027      Description: TC_1_8 REBA OBT synch_verif

S/C ID: 490      G/S ID: 0      SLE ID: 0      OCC ID: 0
VCID: 0      HFA D/S: 65535

Data Unit Type: GOOD SP      Time Stamp Type: PG
Time Quality: G

APID: 1536      SSC: 10      Type: 1      Subtype: 8
PI1: 39      PI2: 0

SPID: 128039340      TPSD: -1      HFA Counter: 0
Filing: E      Distribution: E

Time Field: Y      Packet Period: 0 [msec]      CRC: ?
Event Severity: ?

```

TM Packet Parameter Data

```

Generation time: 2008.234.06.54.18.685      Reception time:
2008.234.06.54.20.547

```

TM Packet Raw Data

```

SC03-2000 Header:
0000:0000 0000 1A11 AD48 4074 0A00 1C11 AD48 795C 0800 0100 0000 EA01
0000 5C00 0000
0020:1138 FFFF 0000 0000 ACB9 A107 0000 0000 0000 0000 FFFF FFFF 10FF
0006 0A00 0108

```

```

Packet Raw Data:
0000:0E00 C00A 0015 0001 0800 5F3F 6F9A AF64 1E00 C803 0027 0000 0091
89D4

```

0E00 C00A 0015	Source Packet Header
0001 0800	Data Field Header: Type and Subtype
5F3F 6F9A AF64	Data Field Header: Time
1E00	TC packet ID
C803	Packet sequencer control
0027	Error Code
0000 0091	Parameters:
89D4	CRC field

11.5 EXAMPLE OF A TM PACKET TM(3,26)

To give an idea of how a TM packet looks like, an example of TM(3,26) “DAE default” (APID: 1538, PI1: 1111, PI2: 0, SPID: 121111369) is given in the figure below.



TM Packet Query Display

TM Packet Details

Simulated: N
Mnemonic: DAE Default Description: DAE Default Config HK Format
S/C ID: 490 G/S ID: 0 SLE ID: 0 OCC ID: 0 VCID: 4 HFA
D/S: 65535
Data Unit Type: GOOD SP Time Stamp Type: PG Time Quality: G
APID: 1538 SSC: 13342 Type: 3 Subtype: 26 PI1: 1111
PI2: 0
SPID: 121111369 TPSD: -1 HFA Counter: 0 Filing: E
Distribution: E
Time Field: Y Packet Period: 0 [msec] CRC: ? Event Severity:

TM Packet Parameter Data

Generation time: 2007.220.11.49.11.335 Reception time: 2007.220.11.49.16.088

TM Packet Raw Data

SCOS-2000 Header:
0000:0000 0000 B7AD B946 9A1F 0500 BCAD B946 565B 0100 0100 0000 EA01 0000 7603 0000
0020:1138 FFFF 0000 0000 4903 3807 0000 0000 0400 0000 FFFF FFFF 10FF 0206 1E34 031A

Packet Raw Data:

0000:0E02 F41E 032F 0003 1A00 5D4C 0C37 55F5 0457 00FA 00FA 00FA 00FA 00F1 00F1 00F1
0020:00F1 00D9 0076 0085 0097 00A6 008E 009A 008E 00A2 0094 008D 00B7 00F2 00F2 00F2
0040:00F2 00F7 00F7 00F6 00F7 0097 0070 007F 0091 006D 009D 00AC 0073 00B1 0087 009C
0060:00A5 00F1 00F2 00F1 00F1 0082 0082 0082 0082 00F1 00F1 00F1 00F1 00B2 00A3 00B2
0080:00A3 00AC 007C 007C 0079 0082 007F 0085 00B1 00F2 00F2 00F2 00F2 0080 0080 0080
00A0:0080 007F 00AC 009A 00AC 0072 0094 00AE 00A8 0084 00B4 0093 0081 00F2 00F1 00F1
00C0:00F1 00C8 00C8 00C8 00C8 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF
00E0:00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00C8 00C8 00C8 00C8 00FF 00FF 00FF
0100:00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00CD 00CD 00CD
0120:00CD 00CD 00CD 00CD 00CD 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF
0140:00FF 00CD 00CD 00CD 00CD 00CE 00CD 00CD 00CE 00FF 00FF 00FF 00FF 00FF 00FF 00FF
0160:00FF 00FF 00FF 00FF 00FF 00CD 00CD 00CD 00CD 00CD 00CD 00CD 00CD 00CD 00CD 00CD
0180:00CD 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00CD 00CD 00CD
01A0:00CD 00CD 00CE 00CE 00CD 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF
01C0:00FF 00CD 00CD 00CD 00CD 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
01E0:0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
0200:0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
0220:0000 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF
0240:00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF
0260:00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 00FF 0000 0000 0000
0280:0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
02A0:0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
02C0:0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
02E0:0000 0000 0000 0000 0001 0001 0001 0001 0001 0001 0001 0001 0001 0001 0001 0001
0300:0001 0001 0001 0001 0001 0001 0001 0001 0001 0001 0000 0000 0000 0000 0000 0000
0320:0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0462

0E02 F41E 032F
0003 1A00
5D4C 0C37 55F5
0457
00FA
0082
00C8
00CD
00CD
0000
00FF
0000
0001
0001
0000
0000
0462

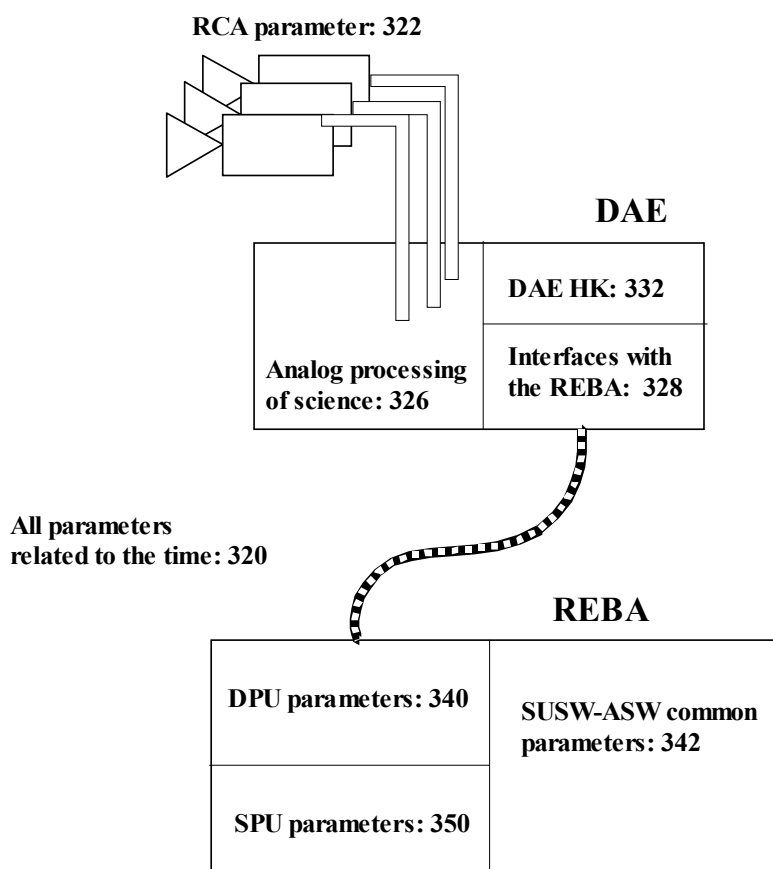
Source Packet header
Data Field Header Type and Subtype TM(1,8)
Time
SID
VGate 1
VGate 2
V Drain
I PS 1
I PS 2
RCA Gain
RCA Offset
I Drain
4KHz Switching A/C (0 = disabled)
4KHz Switching B/D (1 = enabled)
PS A/C Status
PS B/D Status
DC/DC converter status
CRC field



11.6 PACKETS POSITION ID

The last three numbers of packet SPID refer to the position of the group to which the packet is related. This is detailed in the table and picture below.

Pos ID	Group
320	All parameters related to the "Time"
322	All the parameters related to the setting of the RCAs
326	All the parameters related to the analog processing of the science signal
328	All the parameters related to the DAE side of the REBA/DAE interface
332	All the analog parameters collected by the DAE
340	All the parameters related to the processing in the DPU
342	All the parameters related to the SUSW and the corresponding managed by the ASW
350	All the parameters related to the processing in the SPU
369	Parameters related to more than one of the previous groups





12 SUMMARY OF INSTRUMENT TELECOMMAND DATA

12.1 SUMMARY OF TELECOMMAND PACKETS

In the following table is reported a preliminary list of the Telecommands available for LFI. Here they are subdivided by function and are implemented by means of the PS-ICD services.

		TC SCOS Name	Type	S- Type
DPU SUSW				
Start DPU SUSW	(Executed by DPU ASW)	LC001320	8	1
LOAD DPU ASW		LC030320	8	4
START DPU ASW		LC031320	8	1
CLEAR DPU TCS QUEUE		LC032320	8	4
HIGH LEVEL SW RESET DPU		LC033320	8	4
Load Memory Absolute Address	Load DPU RAM	LC218320	6	2
Load Memory Absolute Address	Load DPU EEPROM	LC218320	6	2
Check Memory Using Absolute Addresses	Check DPU memory	LC215320	6	9
Dump Memory Using Absolute Addresses	Dump DPU memory	LC214320	6	5
Perform Test Connection	Perform DPU connection test with CDMS	LC216320	17	1

DPU ASW				
START DPU ASW	(Executed by DPU SUSW)	LC031320	8	1
LOAD SPU ASW		LC034320	8	4
CLEAR DPU TCS QUEUE		LC035320	8	4
Load Memory Absolute Address	Load DPU EEPROM	LC218320	6	2
Check Memory Using Absolute Addresses	Check DPU memory	LC215320	6	9
Dump Memory Using Absolute Addresses	Dump DPU memory	LC214320	6	5
DUMP ABORT		LC212320	14	2
REPORT FUNCTION STATUS		LC088320	8	5
ENABLE TIME SYNCHRONIZATION	Enable REBA OBT synchronisation	LC213320	9	4
SYNCHRONISE REBA OBT TIME CODE		LC089320	9	5
VERIFY REBA OBT		LC090320	9	7
Activate low level synchronisation		LC050320	8	4
Report Enabled Packets	Report enabled TM packet types	LC217320	14	3
Perform Test Connection	Perform DPU connection test with CDMS	LC216320	17	1
TEST HIGH LEVEL CONNECTION DPU-SPU SUSW		LC036320	8	4
TEST HIGH LEVEL CONNECTION DPU-SPU ASW		LC037320	8	4
HW RESET SPU		LC038320	8	4
RESET DPU SMCS		LC039320	8	4



RESET DAE SMSC 1		LC040320	8	4
RESET DAE SMSC 2		LC041320	8	4
DPU CONNECT TO SPU		LC042320	8	4
ENABLE TM TRANSMISSION	Get DPU HW registers & EDAC failures	LC150320	14	1
ENABLE TM TRANSMISSION	Enable LFI HK TM transmission	LC150320	14	1
DISABLE TM TRANSMISSION	Disable LFI HK TM transmission	LC182320	14	2
ENABLE TM TRANSMISSION	Enable DAE HK TM transmission	LC150320	14	1
DISABLE TM TRANSMISSION	Disable DAE HK TM transmission	LC182320	14	2
ENABLE TM TRANSMISSION	Enable periodical diagnostic HK transmission	LC150320	14	1
DISABLE TM TRANSMISSION	Disable periodical diagnostic HK transmission	LC182320	14	2
ENABLE TM TRANSMISSION	Enable Science TM transmission	LC150320	14	1
DISABLE TM TRANSMISSION	Disable Science TM transmission	LC182320	14	2
ENABLE TM TRANSMISSION	Enable ACK/NACK transmission	LC150320	14	1
DISABLE TM TRANSMISSION	Disable ACK/NACK transmission	LC182320	14	2
ENABLE TM TRANSMISSION	Enable event transmission	LC150320	14	1
DISABLE TM TRANSMISSION	Disable event transmission	LC182320	14	2
ENABLE TM TRANSMISSION	Get statistics HK single packet	LC150320	14	1
ENABLE AF STOP_DET_PROC		LC043320	8	4
DISABLE AF STOP_DET_PROC		LC044320	8	4
ENABLE AF SWITCH_OFF_FEU		LC045320	8	4
DISABLE AF SWITCH_OFF_FEU		LC046320	8	4
PERFORM DPU MEMORYSCRUBBING		LC047320	8	4
ENABLE TM TRANSMISSION	Get DPU 1355 links error HK diagnostic packet	LC150320	14	1
ENABLE AF RESTART 1355 ALL COMM		LC048320	8	4
DISABLE AF RESTART 1355 ALL COMM		LC049320	8	4

DAE HK acquisition				
START DAE HK ACQUISITION SW TASK		LC005320	8	1
STOP DAE HK ACQUISITION SW TASK		LC016320	8	2

FP temperature monitoring				
Start FP Temperature Monitoring		LC006320	8	1
STOP FP TEMPERATURE		LC017320	8	2
SET FP TEMPERATURE LIMITS		LC069320	8	4



ENABLE TM TRANSMISSION	Get FPT-Out-Of-Limit counters	LC150320	14	1
RESET FPT OUT-OF-LIMIT COUNTER		LC070320	8	4

Science TM rate monitoring				
Start Science TM Rate Monitoring		LC008320	8	1
STOP SCIENCE TM RATE MONITORING		LC019320	8	2
SET EXPECTED TM RATE PARAMETER		LC083320	8	4
RESET SCIENCE TM COUNTER		LC084320	8	4
SET TM RATE TAU		LC086320	8	4
SET TM RATE PERIOD		LC085320	8	4
SET TM RATE STEP TABLE		LC082320	8	4
ENABLE TM TRANSMISSION		LC150320	14	1

Calibration channel switching				
START CALIBRATION CHANNEL SWITCHING		LC010320	8	1
STOP CALIBRATION CHANNEL SWITCHING		LC021320	8	2
SET SWITCHING PERIOD		LC087320	8	4

SPU SUSW				
START SPU SUSW	(Executed by SPU_ASW)	LC002320	8	1
SW RESET SPU		LC053320	8	4
Load Memory Absolute Address	Load SPU RAM	LC218320	6	2
Check Memory Using Absolute Addresses	Check SPU memory	LC215320	6	9
Dump Memory Using Absolute Addresses	Dump SPU memory	LC214320	6	5

SPU ASW				
START SPU ASW	(Executed by SPU_SUSW)	LC052320	8	1
Check Memory Using Absolute Addresses	Check SPU memory	LC215320	6	9
Dump Memory Using Absolute Addresses	Dump SPU memory	LC214320	6	5
Dump Memory Using Absolute Addresses	Dump DAE DPRAM-2	LC214320	6	5
RESET SPU SMCS		LC054320	8	4
ENABLE TM TRANSMISSION	Get SPU HW registers & EDAC failures	LC150320	14	1
SPU CONNECT TO DAE		LC055320	8	4
ENABLE TM TRANSMISSION	Get DAE SMCS-2 registers	LC150320	14	1
PERFORM SPU MEMORY SCRUBBING		LC056320	8	4
ENABLE TM TRANSMISSION	Get SPU 1355 links error HK diagnostic packet	LC150320	14	1

SPU CPU load monitoring				
START SPU CPU MONITORING		LC003320	8	1
STOP SPU CPU MONITORING		LC015320	8	2
RESET SPU CPU OUT OF LIMIT COUNTER	Reset Out-Of-limit counter	LC057320	8	4



DAE control				
START DAE CONTROL		LC004320	8	1
SET DAE DEFAULT CONFIGURATION	(channel)	LC100320	8	4
SET DAE DEFAULT CONFIGURATION	(RCA)	LC107320	8	4
ENABLE TM TRANSMISSION	Get DAE default configuration	LC150320	14	1
CONFIGURE DAE	(channel)	LC121320	8	4
CONFIGURE DAE	(RCA)	LC128320	8	4
CONFIGURE DAE BY DEFAULT		LC059320	8	4
ENABLE TM TRANSMISSION	Get DAE current configuration	LC150320	14	1
Dump Memory Using Absolute Addresses	Dump DAE DPRAM-1	LC214320	6	5
SAVE ACTUAL DAECONFIGURATION AS DEFAULT		LC060320	8	4
SYNCHRONISE DAE OBT		LC061320	8	4
VERIFY DAE OBT		LC062320	8	4
START DAE HK SEQUENCER		LC063320	8	4
STOP DAE HK SEQUENCER		LC064320	8	4
START DAE SCIENCE SEQUENCER		LC065320	8	4
STOP DAE SCIENCE SEQUENCER		LC066320	8	4
ENABLE TM TRANSMISSION	Get DAE SMCS-1 GPIO	LC150320	14	1
ENABLE TM TRANSMISSION	Get DAE SMCS-1 registers	LC150320	14	1
Enable_Disable DCDC converters		LC132320	8	4
ACTIVATE AF SWITCH_OFF_FEU		LC067320	8	4
ACTIVATE AF RESTART 1355 ALL COMM		LC091320	8	4
MASTER RESET		LC068320	8	4

Science processing				
Start Science Processing		LC007320	8	1
STOP SCIENCE PROCESSING		LC018320	8	2
SetREBASciParam	Offset, ReQuants, GMF1, GMF2	LC071320	8	4
Binning N-average	Set parameters nAverage's	LC075320	8	4
ENABLE TM TRANSMISSION	Offset, ReQuants, nAverage, GMF1, GMF2	LC150320	14	1
SET SCIENCE PROCESSING TYPES		LC076320	8	4
ENABLE A NEW CHANNEL		LC077320	8	4
DISABLE CHANNELS		LC078320	8	4
ENABLE DATA VALIDATION		LC079320	8	4
DISABLE DATA VALIDATION		LC080320	8	4
ACTIVATE AF STOP_DET_PROC		LC081320	8	4

Table 12.1-1 List of the available commands

	Function name		Function ID
Basic	DPU	DPU SUSW	00h



functions	DPU ASW	02h
Basic SPU functions	SPU SUSW	11h
	SPU ASW	12h
Specific functions	SPU CPU load monitoring	22h
	DAE control	23h
	DAE HK acquisition	24h
	FP temperature monitoring	25h
	Science processing	26h
	Science TM rate monitoring	27h
	Calibration channel switching	29h

Table 12.1-2 List of the SW Functions

12.1.1 LOAD MEMORY USING ABSOLUTE ADDRESSES – TC (6,2)

The general format for the “Packet Header” of this packet is the following:

Packet Header						
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Sequence Flags	Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
‘000’	‘1’	‘1’	‘110 0000 0000’ 0x600	‘11’		

The value of the “Sequence Count” field is provided by a counter packet by packet.
The value of the “Packet Length” field is defined according to the dimension of the packet.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0000 0110’	‘0000 0010’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

Application Data



DATA	SIZE	COMMENTS
Memory ID	2 bytes	See chapter 11.1.9
Start Address	2 bytes	
Spare	1 byte	
Length	1 byte	In units of SAUs
Data	N x 2 bytes	
Checksum	2 bytes	

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command list	REBA Command name	SCOS TC Name
Load DPU RAM (SUSW)	DS_LOAD	LC218320
Load DPU EEPROM (SUSW)	DS_LOAD_E	LC218320
Load DPU EEPROM (ASW)	DA_LOAD	LC218320
Load SPU RAM	SS_LOAD	LC218320

12.1.2 DUMP MEMORY USING ABSOLUTE ADDRESSES – TC (6,5)

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).
The value of the “Packet Length” field is 0xB.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0000 0110’	‘0000 0101’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

Application Data		
DATA	SIZE	COMMENTS
Memory ID	2 bytes	See chapter 11.1.9
Start Address	2 bytes	
Length	2 byte	In units of SAUs

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:



Command list	REBA Command name	SCOS TC Name	TM type/sub-type
Dump DPU memory (SUSW)	DS_DUMP_	LC214320	
Dump DPU memory (ASW)	DA_DUMP_	LC214320	
Dump SPU memory (SUSW)	SS_DUMP_	LC214320	6,6
Dump SPU memory (ASW)	SA_DUMP_	LC214320	6,6
Dump DAE DPRAM-2		LC214320	6,6
Dump DAE DPRAM-1		LC214320	6,6

12.1.3 CHECK MEMORY USING ABSOLUTE ADDRESSES – TC (6,9)

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).
The value of the “Packet Length” field is 0xB.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0000 0110’	‘0000 1001’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

The “Application Data” field is identical to that of TC(6,5)

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command list	REBA Command name	SCOS TC Name	TM type/sub-type
Check DPU memory (SUSW)	DS_CHECK	LC215320	
Check DPU memory (ASW)	DA_CHECK	LC215320	
Check SPU memory (SUSW)	SS_CHECK	LC215320	6,10
Check SPU memory (ASW)	SA_CHECK	LC215320	6,10



12.1.4 START FUNCTION – TC (8,1)

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0000 1000’	‘0000 0001’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

Application Data		
DATA	SIZE	COMMENTS
Function ID	1 byte	See the table below and refer to Table 12.1-2
Spare	1 byte	‘0000 0000’
SID	2 bytes	See table in appendix A of [AD5]
Parameters	N bytes	

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command list	REBA Command name	SCOS TC Name	Function ID	SID
Start DPU SUSW	DS_START	LC001320	00h	0
Start SPU SUSW	SS_START	LC002320	11h	0
Start DPU ASW	DSASWSTR	LC031320	02h	2
Start SPU ASW	SSASWSTR	LC052320	12h	2
Start SPU CPU monitoring	CL_START	LC003320	22h	0
Start DAE control	DC_START	LC004320	23h	0
Start DAE HK acquisition SW task	DH_START	LC005320	24h	0
Start FP temperature monitoring	FP_START	LC006320	25h	0
Start Science processing	SC_START	LC007320	26h	0
Start Science TM rate monitoring	RM_START	LC008320	27h	0
Start calibration channel switching	CALIBRATION	LC010320	29h	0



12.1.5 STOP FUNCTION – TC (8,2)

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).
The value of the “Packet Length” field is 0x7.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0000 1000’	‘0000 0010’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

Application Data		
DATA	SIZE	COMMENTS
Function ID	1 byte	See the table below and refer to Table 12.1-2
Spare	1 byte	

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command list	REBA Command name	SCOS TC Name	Function ID
Stop SPU CPU monitoring	CL_STOP_	LC015320	22h
Stop DAE HK acquisition SW task	DH_STOP_	LC016320	24h
Stop FP temperature monitoring	FP_STOP_	LC017320	25h
Stop Science processing	SC_STOP_	LC018320	26h
Stop Science TM rate monitoring	RM_STOP_	LC019320	27h
Stop calibration channel switching	CAL_STOP_	LC021320	29h

12.1.6 PERFORM ACTIVITY FUNCTION – TC (8,4)

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).

Data Field Header



CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
'0'	'000'	'1001' or 0001	'0000 1000'	'0000 0100'	'0000 0000'

The "Ack" field requires the acceptance report of the command but also the execution report.

Application Data		
DATA	SIZE	COMMENTS
Function ID	1 byte	See the table below and refer to Table 12.1-2
Activity ID	1 byte	See table below
SID	2 bytes	See table in appendix A of [AD5]
Parameters	N bytes	

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command	REBA Command name	SCOS TC Name	Function ID	Activity ID	SID
Load DPU ASW	DSASLOAD	LC030320	00h	201	5
Clear DPU TCs queue	DSQUECLR	LC032320	00h	203	0
High level SW reset DPU	DSDPURES	LC033320	00h	204	0
Load SPU ASW	SSASLOAD	LC034320	02h	105	5
Clear DPU TCs queue	DAQUECLR	LC035320	02h	203	0
Test high level connection DPU-SPU SUSW	DASSCTES	LC036320	02h	1	0
Test high level connection DPU-SPU ASW	DASACTES	LC037320	02h	2	0
HW Reset SPU	DASPURES	LC038320	02h	3	0
Reset DPU SMCS	DASMCRES	LC039320	02h	4	0
Reset DAE SMSC 1	DADS1RES	LC040320	02h	5	0
Reset DAE SMSC 2	DADS2RES	LC041320	02h	6	0
DPU connect to SPU	DASPUCON	LC042320	02h	7	0
Enable AF ENBL_DISBL_SC_DET_ PROC	DADETPRO	LC043320	02h	8	0
Disable AF ENBL_DISBL_SC_DET_ PROC	DDADETPRO	LC044320	02h	9	0
Enable AF	DAOFFFEU	LC045320	02h	10	0



SWITCH_OFF_FEU					
Disable AF SWITCH_OFF_FEU	DDAOFFFEU	LC046320	02h	11	0
Perform DPU memory scrubbing	P_DPU_MSCRU	LC047320	02h	13	0
Activate low level synchronisation	EAUIOBT_SYNC	LC050320	02h	15	0
Enable AF RESTART_1355_ALL_C OMM	AF_ENABL	LC048320	02h	16	0
Disable AF RESTART_1355_ALL_C OMM	AF_DISAB	LC049320	02h	17	0
Activate AF RESTART_1355_ALL_C OMM	AF_ACTIV	LC091320	02h	18	0
SW Reset SPU	SSSPURES	LC053320	11h	104	0
Reset SPU SMCS	SASMCRES	LC054320	12h	121	0
SPU connect to DAE	SADAECON	LC055320	12h	122	0
Perform SPU memory scrubbing	PSPUMEMSCRU	LC056320	12h	123	0
Reset SPU CPU Out-Of-Limit counter	RS_CPU_PU	LC057320	22h	2	0
Set DAE default configuration	DCDEFSET	LC100320 (channel) LC107320 (RCA)	23h	14	3201 to 3211
Configure DAE	DCACTSET	LC121320 (channel) LC128320 (RCA)	23h	2	3101 to 3111
Enable_Disable DCDC converters	SciDCDCSetup	LC132320	23h	2	3112
Configure DAE by default	DCDEFCON	LC059320	23h	1	0
Save current DAE configuration as default	DCDEFSAV	LC060320	23h	3	0
Synchronise DAE OBT	DCOBT SYN	LC061320	23h	5	0
Verify DAE OBT	DCOBT VER	LC062320	23h	6	0
Start DAE HK Sequencer	DCHKSSTA	LC063320	23h	7	0
Stop DAE HK Sequencer	DCHKSSTO	LC064320	23h	8	0



Start DAE Science Sequencer	DCSCSSTA	LC065320	23h	9	0
Stop DAE Science Sequencer	DCSCCSTO	LC066320	23h	10	0
Activate AF SWITCH_OFF_FEU	DCSOFFEU	LC067320	23h	13	0
Master Reset	MA_RE	LC068320	23h	41	0
Set FP temperature limits	FPLIMSET	LC069320	25h	1	3601
Reset FPT Out-Of-Limit counters	FPTOOLCO	LC070320	25h	2	0
Set parameters Offsets		LC071320	26h	129	3331
Set parameters ReQuants		LC071320	26h	130	3321
Set parameters GMF1	SCGMF1SET	LC071320	26h	131	3311
Set parameters GMF2	SCGMF2SET	LC071320	26h	138	3312
Set parameters nAverage's	SCNAVSET	LC075320	26h	132	3391
Set Science processing types	SCMODSET	LC076320	26h	133	3301
Enable a new channel	SCCHAENA	LC077320	26h	134	3302
Disable channels	SCCHADIS	LC078320	26h	135	3303
Enable data validation	SCDATVAL	LC079320	26h	136	0
Disable data validation	SCDATDIS	LC080320	26h	137	0
Activate AF ENBL-DISBL_SC_DET_PROC	SCSTPDET	LC081320	26h	151	3352
Set expected TM rate parameter	RMLIMSET	LC083320	27h	1	3701
Reset Science TM counter	SCMODRES	LC084320	27h	2	0
Set TM Rate Tau	TMTAUSER	LC086320	27h	3	3702
Set TM Rate Period	TMRAPSET	LC085320	27h	4	3703
Set TM Rate Steps Table	TMRASSET	LC082320	27h	5	3704
Set switching period	S_SW_P	LC087320	29h	201	3501

12.1.7 REPORT FUNCTION STATUS – TC (8,5)

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).
The value of the “Packet Length” field is 0x7.

Data Field Header



CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
'0'	'000'	'1001' or 0001	'0000 1000'	'0000 0101'	'0000 0000'

The “Ack” field requires the acceptance report of the command but also the execution report.

Application Data		
DATA	SIZE	COMMENTS
Function ID	1 byte	See the table in chapter 12.1.4
Spare	1 byte	'0000 0000'

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command	REBA Command name	SCOS TC Name	Function ID
REPORT FUNCTION STATUS	REP_FUN_STAT	LC088320	variable

12.1.8 ENABLE TIME SYNCHRONISATION – TC (9,4)

This command is used before a TC(9,5) to arm the synchronisation process.

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).
The value of the “Packet Length” field is 0x5.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
'0'	'000'	'1001' or 0001	'0000 1001'	'0000 0100'	'0000 0000'

The “Ack” field requires the acceptance report of the command but also the execution report.

No application data is foreseen for this TC packet. The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:



Command	REBA Command name	SCOS TC Name
Enable REBA OBTSynchronisation	DASYNENA	LC213320

12.1.9 TIME CODE – TC (9,5)

Once this command arrives to LFI, if the synchronisation procedure is armed, the instrument synchronises its internal clock to the time carried by the TC at the beginning of the next Frame.

The general format for the “Packet Header” of this packet is identical of that of TC(6,2). The value of the “Packet Length” field is 0xB.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0000 1001’	‘0000 0101’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

Application Data		
DATA	SIZE	COMMENTS
Time	6 bytes	Standard time format

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command	REBA Command name	SCOS TC Name
Synchronise REBA OBTS: Time code	DAREBSYN	LC089320

12.1.10 ENABLE TIME VERIFICATION – TC (9,7)

Once this command is issued to LFI it responds with a TM(9,9) carrying the time maintained by the instrument.

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).



The value of the “Packet Length” field is 0x5.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0000 1001’	‘0000 0111’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

No application data is foreseen for this TC packet. The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command	REBA Command name	SCOS TC Name
Verify REBA OBT	DAREBVER	LC090320

12.1.11 ENABLE TRANSMISSION OF TM PACKETS – TC (14,1)

These packets are used to direct the instrument to produce and deliver the TM packet indicated. Notice that the HK packets containing the data of the REBA cannot be enabled and disabled because are always produced. Moreover there are some packets that are only enabled and not disabled because once received these TC LFI respond with a single TM packet containing the information requested.

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).
The value of the “Packet Length” field is 0xB.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0000 1110’	‘0000 0001’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

Application Data		
DATA	SIZE	COMMENTS



N	2 bytes	Number of TM packets definitions from 1 to 20
Type	1 byte	Format of “Packet type” field
Sub-Type	1 byte	Format of “Packet Subtype” field
Packet ID	2 bytes	See AD(2)

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command list	REBA Command name	SCOS TC Name	N	TM type/ sub-type	SID
Get DPU HW registers & EDAC failures	DAHWRGET	LC150320	1	3,26	2021
Enable REBA HK TM transmission	DALHKENA	LC150320	1	3,25	202
Enable DAE HK TM transmission	DHEHKENA	LC150320	1	3,25	0 101 102
Enable periodical diagnostic HK transmission	SCHK_ENA	LC150320	1	3,26	0 300 301 302 303 304
Enable Science TM transmission	SCTM_ENA	LC150320	1	21,1 21,2 21,3	0 11 12 0 11 12 11
Enable ACK/NACK transmission	DAACKENA	LC150320	1	1,1 1,2 1,7 1,8	
Enable event transmission	DAEVTENA	LC150320	1	5,1 5,2 5,4	See § 11.3
Get statistics HK single packet	DASTAGET	LC150320	1	3,26	1301 1302 1303 1304
Get SPU HW registers	SAHWRGET	LC150320	1	3,26	2121
Get DAE SMCS-2 registers	SADSMGET	LC150320	1	3,26	2129
Get DAE default configuration	DCDEFGET	LC150320	1	3,26	1111
Get DAE current configuration	DCACTGET	LC150320	1	3,26	1101
Get DAE SMCS 1 GPIO	DCGPIGET	LC150320	1	3,26	2099
Get DAE SMCS 1 registers	DCSMCGET	LC150320	1	3,26	2029
Get FPT Out-Of-Limit counters		LC150320	1	3,26	938



Get parameters Offsets, ReQuants	SCPARGET	LC150320	1	3,26	2130
Get parameters nAverage's, GMFs	SCPARGET	LC150320	1	3,26	2131
Get TM_Rate_Steps_Table		LC150320	1	3,26	704
Get DPU 1355 links errors		LC150320	1	3,26	2022
Get SPU 1355 links errors		LC150320	1	3,26	2122
Enable TM packet transmission		LC150320	≤20	All	0 or specific SID

The following table containing all the enabled TM packets before and after a TC(14,1) procedure is applied.

TM type & subtype	SID	Description and notes
1, x	all	All enabled at start-up. Notice that TM(1,2) can not be disabled.
3, 25	all	All enabled at start-up.
3, 26	300, 301, 302, 303, 304	All disabled at start-up. Once enabled they produce continuous telemetry (periodical).
3, 26	938, 1101, 1111, 1301, 1302, 1303, 1304, 2021, 2029, 2099, 2121, 2129, 2130, 2131, 2022, 2122, 704	All disabled at start-up. Once enabled they produce single telemetry packets (non periodical).
5, x	all	All disabled at start-up
6, 6 and 6, 10	-	Always enabled
8, 6	-	Always enabled
9, 9	-	Always enabled
14, 4	-	Always enabled
17, 2	-	Always enabled
21, x	all	All enabled at start-up

12.1.12 DISABLE TRANSMISSION OF TM PACKETS – TC (14,2)

It is the opposite of the previous to disable the transmission (and the generation) of the indicated packets.

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).
The value of the “Packet Length” field is 0xB.



Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
'0'	'000'	'1001' or 0001	'0000 1110'	'0000 0010'	'0000 0000'

The "Ack" field requires the acceptance report of the command but also the execution report.

The "Application Data" field is identical to that of TC(14,1)

The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command list	REBA Command name	SCOS TC Name	N	TM type/ sub-type	SID
Disable REBA HK TM transmission	DALHKDIS	LC182320	1	3,25	202
Disable DAE HK TM transmission	DHEHKDIS	LC182320	1	3,25	0 101 102
Disable periodical diagnostic HK transmission	SCHK_DIS	LC182320	1	3,26	0 300 301 302 303 304
Disable Science TM transmission	SCTM_DIS	LC182320	1	21,1 21,2 21,3	0 11 12 0 11 12 11
Disable ACK/NACK transmission	DAACKDIS	LC182320	1	1,1 1,2 1,7 1,8	
Disable event transmission	DAEVTDIS	LC182320	1	5,1	See 11.3.1
Dump abort		LC212320	1	6,6	0
Disable TM packet transmission		LC182320	≤20	All	0 or specific SID

12.1.13 REPORT ENABLED TM PACKETS – TC (14,3)

Once this command arrives to LFI it respond with a TM(14,4) containing the list of the TM packets enabled to be delivered.



The general format for the “Packet Header” of this packet is identical of that of TC(6,2).
The value of the “Packet Length” field is 0x5.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0000 1110’	‘0000 0011’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

No application data is foreseen for this TC packet. The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command list	REBA Command name	SCOS TC Name	TM Type/sub- type
Report enabled TM packet types	DATMEGET	LC217320	14,4

12.1.14 TEST SERVICE – TC (17,1)

The general format for the “Packet Header” of this packet is identical of that of TC(6,2).
The value of the “Packet Length” field is 0x5.

Data Field Header					
CCSDS Secondary Header Flag	TC Packet PUS version Number	Ack	Packet Type	Packet Subtype	Spare
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits
‘0’	‘000’	‘1001’ or 0001	‘0001 0001’	‘0000 0001’	‘0000 0000’

The “Ack” field requires the acceptance report of the command but also the execution report.

No application data is foreseen for this TC packet. The packet is terminated by 16 bits CRC field.

The commands that use this service are reported in the following table:

Command list	REBA Command name	SCOS TC Name	TM type/sub- type



Perform DPU connection test with CDMS (SUSW)	DSDPCTES	LC216320	
Perform DPU connection test with CDMS (ASW)	DADPCTES	LC216320	17,2

12.2 REFLECTION OF TELECOMMANDS ON TM

After acknowledge of the commands some of their effects shall be verified by means of HK as per the following table.

TC-Packet Type / Subtype	TC Packet Name	Effect	Verification HK
TC(6,2)	Load Memory Using Absolute Addresses	Loads some data in a determined memory address	No – use dump command
TC(6,5)	Dump Memory Using Absolute Addresses	Dump some data to ground	No – see dump results TM(6,6)
TC(6,9)	Check Memory Using Absolute Addresses	Perform the checksum of a determined memory area and send the results to ground	No - see results on TM(6,10)
TC(8,1)	Start Function	Different for various commands	Different for various commands
TC(8,2)	Stop Function	Different for various commands	Different for various commands
TC(8,4)	Perform Activity of Function	Different for various commands	Different for various commands
TC(8,5)	Report Function Status	Triggers the generation of a status report	A TM(8,6) packet is generated
TC(9,4)	Enable Time Synchronisation	Enables the process of synchronisation of the instrument	No - see results with TM(9,9)
TC(9,5)	Time Code	Synchronise the instrument to the time code uploaded at the beginning of the next frame	Verification made with TM(9,9)
TC(9,7)	Enable Time Verification	Activates the process of verification of the local OBT of the instrument	LFI produces a TM(9,9)
TC(14,1)	Enable Tx of TM Packets	Activates the generation of one or more TM packet	LFI starts producing new TM packets
TC(14,2)	Disable Tx of TM Packets	Deactivates the generation of one or more TM packet	LFI stop producing some TM packets
TC(14,3)	Report Enabled TM Packets	Requires the generation of a TM(14,4) packet	A TM(14,4) packet is generated
TC(17,1)	Test Service	Check the connection with the S/C	A TM(17,2) packet



			is generated

12.3 DEFINITION OF TELECOMMAND SEQUENCES

No special telecommand sequence is foreseen. The LFI telecommands are organized in procedures as explained in detail in Paragraph 13.



13 INSTRUMENT OPERATIONS PROCEDURES

13.1 INSTRUMENT OPERATIONS PROCEDURES FOR COMMISSIONING AND CPV

13.1.1 OPERATION PROCEDURES FOR COMMISSIONING

The commissioning phase sequence is defined in the Testing Plan of the LFI instrument during the Planck Commissioning and CPV phase document [RD27]. In this section the high level procedures (and as a reference, the low level procedures) to be performed during the commissioning phase are given.

The list of operations to be performed during the LFI commissioning phase is reported below.

1. Commissioning activities
 - 1.1. Switch the REBA On
 - 1.1.1. REBA Power On by the satellite (see Table 13.2-61 Summary of the REBA and RAA power ON/OFF procedure)
 - 1.1.2. REBA communication check (see Table 13.2-20 REBA ASW Init, step 1)
 - 1.1.3. REBA hardware self check (see Table 13.2-20 REBA ASW Init, step 2 and 3)
 - 1.2. Commissioning of DPU memories (see §13.1.1.1, Table 13.1-1 and Table 13.1-2)
 - 1.2.1. Patch and dump of DRAM
 - 1.2.2. Patch and dump of PRAM
 - 1.2.3. Dump of EEPROM
 - 1.2.4. Patch of EEPROM
 - 1.2.5. Dump of PROM
 - 1.3. DPU ASW startup (see Table 13.2-20 REBA ASW Init, step 4 to 7)
 - 1.4. Event packets enabling (see Table 13.2-56 Event packets enabling)
 - 1.5. REBA synchronisation and verification (see Table 13.2-22 REBA synchronization)
-



- 1.6. DPU ASW startup (see Table 13.2-20 REBA ASW Init, step 8 to 10)
- 1.7. Commissioning of SPU memories (see § 13.1.1.2, Table 13.1-3 and Table 13.1-4)
 - 1.7.1. Patch and dump of PRAM
 - 1.7.2. Patch and dump DRAM
 - 1.7.3. Dump Expanded DRAM
 - 1.7.4. Dump PROM
- 1.8. SPU ASW startup (see Table 13.2-20 REBA ASW Init, step 11 to 14)
- 1.9. RAA Power On by the satellite (see Table 13.2-61 Summary of the REBA and RAA power ON/OFF procedure)
- 1.10. DAE switch on connection and HK retrieval (see Table 13.2-24 RAA On check and connection to REBA)
- 1.11. DAE synchronisation and verification (see Table 13.2-26 RAA synchronization)
- 1.12. Commissioning of DAE-SPU link memory
 - 1.12.1. Connect DAE SPU link (see Table 13.2-69)
 - 1.12.2. Commissioning of DAE memories (see §13.1.1.3, Table 13.1-5 and Table 13.1-6)
- 1.13. Start science processing
 - 1.13.1. Set Telemetry Rate (see Table 13.2-50 Setting the telemetry rate)
 - 1.13.2. All channels in Mode 1 (see Table 13.2-77 Set science processing mode, parameters LP166320 (mode A) = 1, LP167320 (mode B) = 1, parameter from LP116320 to LP119320 = FFFFh bit mask of the channels to be processed in mode A and parameter from LP120320 to LP123320 = 0000h bit mask of the channels to be processed in mode B)
 - 1.13.3. Set N_average to 256 for all channels (see Table 13.2-71 Definition of the N_Ave science processing parameters)
 - 1.13.4. SPU connection (see Table 13.2-34 Science activation, step 3)
 - 1.13.5. Start REBA Science processing (see Table 13.2-34 Science activation, step 4)
 - 1.13.6. Start DAE Science sequencer (see Table 13.2-34 Science activation, step 5)
 - 1.13.7. NRT data processed at the IW@MOC

The LFI is now in Stand-by mode.



It is envisaged that the commissioning procedure will not be completed within a single visibility period. During a non-visibility period, i.e. between two consecutive visibility periods, it is not foreseen to completely switch off the LFI instrument compatibly with being in a safety condition.

When the commissioning will be accomplished, it is foreseen that the LFI instrument would stay in a safety condition but not completely switched off, corresponding to the Standby Mode.

13.1.1.1 COMMISSIONING OF DPU MEMORIES

Topic	Description	Note
Purpose	To patch activity using OBSW management tool of ESOC	P_SVT_OBS_4114 P_SVT_OBS_4112 P_SVT_OBS_4110 P_SVT_OBS_4157
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA powered on and DPU SUSW running	
Initial satellite state	LFI Stand-by Mode	
End satellite state	LFI Stand-by Mode	
Reference procedures	1. Commissioning of DPU memories	see Table 13.1-2
Procedure predecessors		
Contingency procedures		

Table 13.1-1 Summary of the procedures for commissioning of DPU memories



STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Patch and dump of DRAM into OBSW tool					
1.1	Dump 32 SAU of DPU DRAM ^(*)	Dump memory with absolute address TC(6,5) Memory ID (DPU DRAM)	LC214320 LP139320 =1103h LP140320 =0000h LP141320 =0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.2	Check Memory Dump content			Check Memory Dump content in packet 120066369		
1.3	Patch of the 10 SAU of DPU DRAM	Patch memory with absolute address TC(6,5) Memory ID DPU DRAM	LC218320 LP139320 =1103h LP140320 =0000h LP156320 =000Ah LP157320 =XXX	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.4	Dump of 32 SAU of DPU DRAM	Dump memory with absolute address TC(6,5) Memory ID (DPU DRAM)	LC214320 LP139320 =1103h LP140320 =0000h LP141320 =0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.5	Check Memory Dump content			Check Memory Dump content in packet 120066369		
1.6	Check Memory Using Absolute Addresses	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320=1103h LP143320=0000h LP144320=0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.7	Patch of 32 SAU of DPU DRAM	Patch memory with absolute address	LC218320 LP139320 =1103h	Acknowledge by 120011342 (acceptance)		



		TC(6,5) Memory ID DPU DRAM	LP140320 =0000h LP156320 =0020h LP157320 = (see contents in step 1.1,1.2)	120017342 (execution)		
1.8	Dump of 32 SAU of DPU DRAM	Dump memory with absolute address TC(6,5) Memory ID (DPU DRAM)	LC214320 LP139320 =1103h LP140320 =0000h LP141320 =0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.9	Check Memory Using Absolute Addresses	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320=1103h LP143320=0000h LP144320=0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2	Patch and dump of PRAM into OBSW tool					
2.1	Dump 32 SAU of DPU PRAM ^(*)	Dump memory with absolute address TC(6,5) Memory ID (DPU PRAM)	LC214320 LP139320 =0100h LP140320 =0000h LP141320 =0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.2	Check Memory Dump content			Check Memory Dump content in packet 120066369		
2.3	Patch of the 10 SAU of DPU PRAM	Patch memory with absolute address TC(6,5) Memory ID DPU PRAM	LC218320 LP139320 =0100h LP140320 =0000h LP156320 =000Ah LP157320 =XXX	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.4	Dump of 32 SAU of DPU PRAM	Dump memory with absolute address TC(6,5) Memory ID (DPU	LC214320 LP139320 =0100h LP140320 =0000h LP141320 =0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		



2.5	Check Memory Dump content	PRAM)		Check Memory Dump content in packet 120066369		
2.6	Check Memory Using Absolute Addresses	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320=0100h LP143320=0000h LP144320=0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.7	Patch of 32 SAU of DPU PRAM	Patch memory with absolute address TC(6,5) Memory ID DPU PRAM	LC218320 LP139320 =0100h LP140320 =0000h LP156320 =0020h LP157320 = (see contents in step 2.1,2.2)	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.8	Dump of 32 SAU of DPU PRAM	Dump memory with absolute address TC(6,5) Memory ID (DPU PRAM)	LC214320 LP139320 =0100h LP140320 =0000h LP141320 =0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.9	Check Memory Using Absolute Addresses	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320=0100h LP143320=0000h LP144320=0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3	Dump of EEPROM into OBSW tool					
3.1	Dump 32 SAU of EEPROM (*)	Dump memory with absolute address TC(6,5) Memory ID (DPU EEPROM)	LC214320 LP139320 =0300h LP140320 = 0h LP141320 =20h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3.2	Check Memory Dump content			Check Memory Dump content in packet		



3.3	EEPROM Integrity Check (DPU ASW)	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320 =300h LP143320 =0h LP144320 =AF50h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3.4	Memory Check Report Abs Address			In packet 120610369, LM073369=61A9h TBC with OBS version. Present version 2.6, see table below (DPU ASW)		
3.5	EEPROM Integrity Check. Not used Slot1	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320 =300h LP143320 =AF50h LP144320 =50B0h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3.6	Memory Check Report Abs Address			In packet 120610369 LM073369=Slot1 TBC with OBS version. Present version 2.6, see table below (Slot1)		
3.7	EEPROM Integrity Check (SPU ASW)	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320 =301h LP143320 =0000h LP144320 =6CCEh	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3.8	Memory Check Report Abs Address			In packet 120610369 LM073369=49E8h TBC with OBS version. Present version 2.6, see table below (SPU ASW)		
3.9	EEPROM Integrity Check. Not used Slot2	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320 =301h LP143320 =6CCEh LP144320 =C1B2h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3.10	Memory Check Report			In packet 120610369		



	Abs Address			LM073369=Slot2 TBC with OBS version. Present version 2.6, see table below (Slot2)		
3.11	EEPROM Integrity Check. Not used Slot3	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320 =302h LP143320 =2F00h LP144320 =FFFFh	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3.12	Memory Check Report Abs Address			In packet 120610369 LM073369=Slot3 TBC with OBS version. Present version 2.6, see table below (Slot3)		
3.13	EEPROM Integrity Check. Not used Slot4	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320 =303h LP143320 =2EFFh LP144320 =D051h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3.14	Memory Check Report Abs Address			In packet 120610369 LM073369=Slot4 TBC with OBS version. Present version 2.6, see table below (Slot4)		
4	Patch and dump of EEPROM into OBSW tool					
4.1	Dump 10 SAU of EEPROM (*)	Dump memory with absolute address TC(6,5) Memory ID (DPU EEPROM)	LC214320 LP139320 =0300h LP140320 =D000h LP141320 =0Ah	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
4.2	Check Memory Dump content			Check Memory Dump content in packet 120066369. Save		



				memory Dump content to be patched in next step 4.7		
4.3	Patch 10 SAU of EEPROM	Patch memory with absolute address TC(6,5) Memory ID (DPU EEPROM)	LC218320 LP139320 =0300h LP140320 =D000h LP156320 =000Ah LP157320 =XXX	Acknowledge by 120011342 (acceptance) 120017342 (execution)		NO
4.4	Dump of the same 10 SAU of EEPROM	Dump memory with absolute address TC(6,5) Memory ID (DPU EEPROM)	LC214320 LP139320 =0300h LP140320 =D000h LP141320 =0Ah	Acknowledge by 120011342 (acceptance) 120017342 (execution)		NO
4.5	Check Memory Dump content			Check Memory Dump content in packet 120066369		
4.6	Check Memory Using Absolute Addresses	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320=0300h LP143320=D000h LP144320=0Ah	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
4.7	Patch of the same 10 SAU of EEPROM	Patch memory with absolute address TC(6,5) Memory ID (DPU EEPROM)	LC218320 LP139320 =0300h LP140320 =D000h LP156320 =000Ah LP157320 = (see contents in step 4.1,4.2)	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
4.8	Dump of the same 10 SAU of EEPROM	Dump memory with absolute address TC(6,5) Memory ID (DPU EEPROM)	LC214320 LP139320 =0300h LP140320 =D000h LP141320 =0Ah	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
4.9	Check Memory Dump			Check Memory Dump		



	content			content in packet		
4.10	Check Memory Using Absolute Addresses	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320=0300h LP143320=D000h LP144320=0Ah	Acknowledge by 120066369 120011342 (acceptance) 120017342 (execution)		
5	Dump of PROM into OBSW tool					
5.1	Dump 32 SAU of PROM (*)	Dump memory with absolute address TC(6,5) Memory ID (DPU PROM)	LC214320 LP139320 =0000h LP140320 = 0h LP141320 =20h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
5.2	Check Memory Dump content			Check Memory Dump content in packet 120066369		

Table 13.1-2 Commissioning of DPU memories

Note (*): the dimension and position of the memory area to be dumped will be selected using the OBSW management tool. It is expected that this area is not used by the currently running SUSW.

Type	Nominal	Redundant
ASW DPU	61A9h	61A9h
Slot1	CA61	67B2
ASW SPU	49E8h	49E8h
Slot2	4494	4494
Slot3	156	156
Slot4	B573	B573



13.1.1.2 COMMISSIONING OF SPU MEMORIES

Topic	Description	Note
Purpose	To commission SPU memories	P_SVT_OBS_4212 P_SVT_OBS_4214 P_SVT_OBS_4247 P_SVT_OBS_4257
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	10 minutes	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA powered on, DPU ASW and SPU SUSW running	
Initial satellite state	LFI Stand-by Mode	
End satellite state	LFI Stand-by Mode	
Reference procedures	1. Commissioning of SPU memories	see Table 13.1-4
Procedure predecessors		
Contingency procedures		

Table 13.1-3 Summary of the procedures for commissioning of SPU memories

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Patch and dump of SPU PRAM into OBSW tool					



1.1	Dump 32 SAU of SPU PRAM (*)	Dump memory with absolute address TC(6,5) mem ID SPU Program RAM	LC214320 LP139320 = 8100h LP140320 = 0000h LP141320 = 0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.2	Check Memory Dump content			Check Memory Dump content in packet 120066369		
1.3	Patch of the 10 SAU of SPU PRAM	Patch memory with absolute address TC(6,5) Memory ID SPU PRAM	LC218320 LP139320 =8100h LP140320 =0000h LP156320 =000Ah LP157320 =XXX	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.4	Dump of 32 SAU of SPU PRAM	Dump memory with absolute address TC(6,5) Memory ID (SPU PRAM)	LC214320 LP139320 =8100h LP140320 =0000h LP141320 =0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.5	Check Memory Dump content			Check Memory Dump content in packet 120066369		
1.6	Check Memory Using Absolute Addresses	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320=8100h LP143320=0000h LP144320=0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.7	Patch of 32 SAU of SPU PRAM	Patch memory with absolute address TC(6,5) Memory ID SPU PRAM	LC218320 LP139320 =8100h LP140320 =0000h LP156320 =0020h LP157320 = (see contents in step 1.1,1.2)	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
1.8	Dump of 32 SAU of	Dump memory	LC214320	Acknowledge by		



	SPU PRAM	with absolute address TC(6,5) Memory ID (SPU PRAM)	LP139320 =8100h LP140320 =0000h LP141320 =0020h	120011342 (acceptance) 120017342 (execution)		
1.9	Check Memory Using Absolute Addresses	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320=8100h LP143320=0000h LP144320=0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2	Patch and dump of SPU DRAM into OBSW tool					
2.1	Dump 32 SAU of SPU DRAM(*)	Dump memory with absolute address TC(6,5) mem ID SPU Data RAM	LC214320 LP139320 = 9103h LP140320 = 0000h LP141320 = 0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.2	Check Memory Dump content			Check Memory Dump content in packet 120066369		
2.3	Patch of the 10 SAU of SPU DRAM	Patch memory with absolute address TC(6,5) Memory ID SPU DRAM	LC218320 LP139320 =9103h LP140320 =0000h LP156320 =000Ah LP157320 =XXX	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.4	Dump of 32 SAU of SPU DRAM	Dump memory with absolute address TC(6,5) Memory ID (SPU DRAM)	LC214320 LP139320 =9103h LP140320 =0000h LP141320 =0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.5	Check Memory Dump content			Check Memory Dump content in packet 120066369		
2.6	Check Memory Using Absolute Addresses	Check Memory Using Absolute	LC215320 LP142320=9103h	Acknowledge by 120011342 (acceptance)		



		Addresses TC(6,9)	LP143320=0000h LP144320=0020h	120017342 (execution)		
2.7	Patch of 32 SAU of SPU DRAM	Patch memory with absolute address TC(6,5) Memory ID SPU DRAM	LC218320 LP139320 =9103h LP140320 =0000h LP156320 =0020h LP157320 = (see contents in step 1.1,1.2)	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.8	Dump of 32 SAU of SPU DRAM	Dump memory with absolute address TC(6,5) Memory ID (SPU DRAM)	LC214320 LP139320 =9103h LP140320 =0000h LP141320 =0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.9	Check Memory Using Absolute Addresses	Check Memory Using Absolute Addresses TC(6,9)	LC215320 LP142320=9103h LP143320=0000h LP144320=0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3	Dump of SPU expanded DRAM into OBSW tool					
3.1	Dump 32 SAU of SPU expanded DRAM ^(*)	Dump memory with absolute address TC(6,5) mem ID SPU exp. Data RAM	LC214320 LP139320 = 9200h LP140320 = 0000h LP141320 = 0020h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		
3.2	Check Memory Dump content			Check Memory Dump content in packet 120066369		
4	Dump of SPU PROM into OBSW tool					
4.1	Dump 32 SAU of SPU PROM ^(*)	Dump memory with absolute	LC214320 LP139320 = 8000h	Acknowledge by 120011342 (acceptance)		



		address TC(6,5) mem ID SPU PROM	LP140320 = 0000h LP141320 = 0020h	120017342 (execution)		
4.2	Check Memory Dump content			Check Memory Dump content in packet 120066369		

Table 13.1-4 Commissioning of SPU memories

Note (*): the dimension and position of the memory area to be dumped will be selected using the OBSW management tool.

13.1.1.3 COMMISSIONING OF DAE MEMORIES

Topic	Description	Note
Purpose	To Dump DAE SMCS1 and Ping and Pong buffers	P_SVT_OBS_4343 P_SVT_OBS_4345
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	10 minutes	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI DAE Set-Up Mode	
End satellite state	LFI DAE Set-Up Mode	
Reference procedures	1. Commissioning of DAE memories	see Table 13.1-6
Procedure predecessors		



Contingency procedures

Table 13.1-5 Summary of the procedures for commissioning of the DAE memories

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Dump of DAE SMCS1 into OBSW tool					
1.1	Dump 32 SAU of DAE SMCS1 (*)	Dump memory with absolute address TC(6,5) mem ID DAE SMCS1 DPRAM	LC214320 LP139320 = F400h LP140320 = 0000h LP141320 = 0020h			
1.2	Check Memory Dump content			Check Memory Dump content in packet 120066369		
2	Dump of DAE Ping and Pong into OBSW tool			Acknowledge by 120011342 (acceptance) 120017342 (execution)		
2.1	Dump 2880 SAU of Ping buffers(*)	Dump memory with absolute address TC(6,5) mem ID DAE Ping Buffer	LC214320 LP139320 = F600h LP140320 = 0000h LP141320 = 0B40h			
2.2	Check Memory Dump content			Check Memory Dump content in packet 120066369		
2.3	Dump 2880 SAU of Pong buffers(*)	Dump memory with absolute address TC(6,5) mem ID DAE Ping Buffer	LC214320 LP139320 = F600h LP140320 = 1000h LP141320 = 0B40h			



2.4	Check Memory Dump content			Check Memory Dump content in packet		
				120066369		

Table 13.1-6 Commissioning of DAE memories

Note (*): the dimension and position of the memory area to be dumped will be selected using the OBSW management tool.

13.1.2 OPERATION PROCEDURES FOR CPV

The CPV phase sequence is defined in the Testing Plan of the LFI instrument during the Planck Commissioning and CPV phase document [RD27]. In this section the high level procedures (and as a reference, the low level procedures) to be performed during CPV phase are given.

The list of operations to be performed during the LFI CPV phase is reported below (note that the order is not representative and is instead defined in [RD27]):

2. CPV activities
 - 2.1. SWITCH ON LFI AT CPV, §13.1.2.2 (N/A by now)
 - 2.2. INIZIALIZATION, § 13.2.25
 - 2.3. FUNCTIONAL ACTIVITIES
 - 2.3.1. SPIKE TESTS, §13.1.2.1
 - 2.3.2. CRYO01, §13.1.2.3
 - 2.3.3. DRAIN CURRENTS VERIFICATION, §13.1.2.4
 - 2.3.4. CRYO02, §13.1.2.5
 - 2.4. TUNING ACTIVITIES
 - 2.4.1. PHASE SHIFTER TUNING, §13.1.2.6
 - 2.4.2. ACA MATRIX TUNING, §13.1.2.7
 - 2.4.3. DAE OFFSET AND GAIN TUNING, §13.1.2.8
 - 2.4.4. REBA TUNING, §13.1.2.10



- 2.5. REFERENCE TEST, §13.1.2.9
- 2.6. LFI CONFIGURATION TO NOMINAL, §13.1.2.11
- 2.7. LFI TO HFI SUSCEPTIBILITY, §13.1.2.12

Note that at the end of the CPV phase, the LFI will be in Normal Science Mode, completely tuned, in the nominal configuration necessary to start the first survey.

Note also that these are the procedures defined by now and mostly used during CSL TV/TB tests. These procedure are now under discussion within the LFI and with MOC in order to optimize them for flight operations.

The final tuned values obtained during TV/TB test campaign are saved in EEPROM. By now, the default 4 KHz switching channel is the B/D everywhere even if during the tests it turned out that for RCA24 should switch on A/C (see NCR 4341) but for CPV testing purpose this would be anyway the best configuration to start with.

For many tests, when real time data analysis is required, LFI IOT will have to open a dedicated TQL session (Time Quick Look analysis tool). This will take a few minutes and a waiting time is foreseen.

In order to verify the correct configuration at each step of the tests sequences, in the procedures three columns have been added indicating status of 4 KHz switching, PS status and Power groups and biases values to be used. The meaning of the symbols is the following:

Agenda for LFI configuration during CPV								
4KHz	—	N/A	0	All disabled	A/C	A/C enabled	B/D	B/D enabled
PS status	—	N/A	0	All status 0	A/C	Status A/C 1	B/D	Status B/D 1
Biases	—	N/A	Zero	Zero biases conditions	cryo	Cryo biases conditions		
Power groups	—	N/A	On	Power groups on	Off	Power groups off		
i	Referring to general element i under test							
$[-i]$	Except element i under test							
$< i$	Up to element i under test (excluded)							
$\leq i$	Up to element to i under test (included)							



j	<i>j</i> letter is always referring to Power Groups (1 to 4)
m	<i>m</i> letter is always referring to ACA inside RCA (1 to 4)
n	<i>n</i> letter is always referring to ACA (00h to 2Bh corresponding to the 44 channels)
k	<i>k</i> letter is always referring always to RCA (18 to 28)
*	New DEFAULT, updated after corresponding test

13.1.2.1 SPIKE TEST

Topic	Description	Note
Purpose	To define the procedures for Spike Tests.	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	10 minutes	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI DAE Set-Up Mode	
End satellite state	LFI DAE Set-Up Mode	
Reference procedures	1. Spike Test procedures	see Table 13.1-8
Procedure predecessors		
Contingency procedures		

Table 13.1-7 Summary of the procedures for Spike tests

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY



1			Wait for IOT confirmation			
2	Disable DAE HK Sequencer No more DAE HK TM is produced	Stop DAE HK sequencer TC(8,4)	LC064320	Acknowledge by 120011342 acceptance) 120017342 (execution)		
3			Wait for 1 hour for data collection			
4	Enable DAE HK Sequencer	Start DAE HK sequencer TC(8,4)	LC063320			
5			Wait for 1 hour for data collection			
6			Wait for IOT confirmation			

Table 13.1-8 Spike Test procedures

13.1.2.2 SWITCH ON LFI AT CPV

Topic	Description	Note
Purpose	Switch On the LFI first time	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	10 minutes	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI DAE Set-Up Mode	
End satellite state	LFI DAE Set-Up Mode	



Reference procedures	1. LFI switch on at CPV	see Table 13.1-10
Procedure predecessors		
Contingency procedures		

Table 13.1-9 Summary of the procedures for Switching on the LFI

	Name of Procedure	Reference	Note	Time
0	Wait for IOT confirmation			
1				
2				
3				
4	Wait for IOT confirmation			

Table 13.1-10 LFI Switched on at CPV

Note: By now the so called switch on procedure is included in the last part of the commissioning phase, see 13.1.1 step 1.13. This paragraph and tables are left here if additional procedures will turn out to be necessary before the next Cryo01 test.

13.1.2.3 CRYO01

Topic	Description	Note
Purpose	CRYO01 The main objective of the test is to perform a complete functional test of LFI to ensure the functionality of each subunit of the instrument. This test could be taken as a reference point for the same test that has been performed during CSL TV/TB tests	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	



Time criticality	No criticalities	
Expected duration	13 hrs	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI DAE Set-Up Mode	
End satellite state	LFI Normal Science Mode (this will be the LFI mode as soon as the first power group is switched on)	
Reference procedures	1. Cryo01	see Table 13.1-12
Procedure predecessors		
Contingency procedures		

Table 13.1-11 Summary of the procedures for Cryo01

	Name of Procedure	Reference	Note	Time	4KHz	PS	Bias
0	Initial configuration		Waiting for IOT confirmation		—	—	—
1	RCA Activation	Table 13.2-67	One Power group at time j is switched on (j). Check TM is procedure and take note of the BEM Output from TQL. Wait for IOT verification on I-EGSE. The order to be followed is the one described in warning 02. Up to this point, only RCAs belonging to the power group already tested are biased with cryo biases.	1 Min	$0 < k$	$0 < k$	$on \leq j$ $cryo < k$
2	Initialization	Table 13.2-65	The initialization should be applied ONLY on RCAs belonging to the power group just switched on				
3			Start test on the RCA k in the				



			corresponding power group j. Follow the order in warning 01				
			Start test on the first half RCA				
4	Configure Parameters RCA	Table 13.2-28, step 2.1 to 2.10	The ACA1 of the RCA k is biased with Cryo values Check if the expected change in V output is seen. Wait for IOT verification on I-EGSE.	2 Min			On $\leq j$ cryo < k zero k but cryo m=1
5	Change P/S status (A/C)	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 1 and wait for IOT verification on I-EGSE (refer to Recovery action § 13.1.2.13.1)	2 Min + 2 Min acquiring data time	A/C		
6	4KHz Enabling (A/C)	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching. The separation of SKY and REF is seen as expected. Wait for IOT verification on I-EGSE (refer to Recovery action § 13.1.2.13.1)	2 Min + 2 Min acquiring data time		A/C	
7	4KHz Disabling (A/C)	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching,	1 Min	0		
8	Change PS status (A/C)	Table 13.2-28, step 2.15 to 2.18	All PS are biased in status 0	2 Min + 2 Min acquiring data time		0	
9	Configure Parameters RCA	Table 13.2-28, step 2.1 to 2.10	The ACA 1 is switched off with zero biases conditions	2 Min			On $\leq j$ cryo < k zero k
10	Configure Parameters RCA	Table 13.2-28, step 2.1 to 2.10	The ACA 2 is switched on and PS is biased. The expected change in V output is seen. Wait for IOT verification on I-EGSE	2 Min			On $\leq j$ cryo < k zero k but cryo m=2
9	Change PS status (B/D)	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 1 and check on TQL the change of the tag of sky and ref. Wait for IOT verification on I-	2 Min + 2 Min acquiring		B/D	



			EGSE (refer to recovery action § 13.1.2.13.1)	data time			
10	4KHz Enabling (B/D)	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching. The separation of SKY and REF is seen as expected. Wait for IOT verification on I-EGSE. (refer to recovery action § 13.1.2.13.1)	2 Min + 2 Min acquiring data time	B/D		
11	4KHz Disabling (B/D)	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching,	1 Min	0		
12	Change PS status (B/D)	Table 13.2-28, step 2.15 to 2.18	All PS are biased in status 0	2 Min + 2 Min acquiring data time		0	
12a	Configure Parameters RCA	Table 13.2-28, step 2.1 to 2.10	The ACA 1 is switched back on (TBD see note below). Wait for IOT verification on I-EGSE	2 Min			On $\leq j$ cryo < k zero k but cryo m=1,2
13			Repeat from step 3 to step 12 for the second half of the same RCA				
			Start test on the second half RCA				
14	Configure Parameters RCA	Table 13.2-28, step 2.1 to 2.10	The ACA3 of the RCA k is biased with Cryo values Check if the expected change in V output is seen. Wait for IOT verification on I-EGSE.	2 Min			On $\leq j$ cryo < k zero k but cryo m=1,2,3
15	Change P/S status (A/C)	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 1 and wait for IOT verification on I-EGSE (refer to recovery action § 13.1.2.13.1)	2 Min + 2 Min acquiring data time	A/C		
16	4KHz Enabling (A/C)	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching. The separation of SKY and REF is seen as expected. Wait for IOT verification on I-EGSE (refer to recovery action § 13.1.2.13.1)	2 Min + 2 Min acquiring data time		A/C	
17	4KHz Disabling (A/C)	Table 13.2-28,	Disable 4KHz switching,	1 Min	0		



		step 2.19 to 2.22					
18	Change PS status (A/C)	Table 13.2-28, step 2.15 to 2.18	All PS are biased in status 0	2 Min + 2 Min acquiring data time		0	
19	Configure Parameters RCA	Table 13.2-28, step 2.1 to 2.10	The ACA 3 is switched off with zero biases conditions	2 Min			On $\leq j$ cryo $< k$ cryo m=1,2 zero m=3,4
20	Configure Parameters RCA	Table 13.2-28, step 2.1 to 2.10	The ACA 4 is switched on and PS is biased. The expected change in V output is seen. Wait for IOT verification on I-EGSE	2 Min			On $\leq j$ cryo $< k$ cryo m=1,2,4 zero m=3
21	Change PS status (B/D)	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 1 and check on TQL the change of the tag of sky and ref. Wait for IOT verification on I-EGSE (refer to recovery action § 13.1.2.13.1)	2 Min + 2 Min acquiring data time		B/D	
22	4KHz Enabling (B/D)	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching. The separation of SKY and REF is seen as expected. Wait for IOT verification on I-EGSE. (refer to recovery action § 13.1.2.13.1)	2 Min + 2 Min acquiring data time	B/D		
23	4KHz Disabling (B/D)	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching,	1 Min	0		
24	Change PS status (B/D)	Table 13.2-28, step 2.15 to 2.18	All PS are biased in status 0	2 Min + 2 Min acquiring data time		0	
24a	Configure Parameters RCA	Table 13.2-28, step 2.1 to 2.10	The ACA 3 is switched back on (TBD see note below). Wait for IOT verification on I-EGSE	2 Min			On $\leq j$ cryo $\leq k$



25	Check ACA		Take note of Drain currents.	5 min			On $\leq j$ Cryo $\leq k$
26			Test finished on RCA k				
27			Repeat from step 3 to 26 until all the RCAs of the Power group are tested.		0	0	
28			Wait for IOT confirmation.				
39			Repeat from 0 to 28 until all the power groups are on.		0	0	On Cryo
	Final configuration				0	0	On Cryo

Table 13.1-12 Cryo01

Note: it is still TBD the possibility to put “zero biases configuration” after ½ RCA is tested in step 12a and 24a instead of putting the cryo biases back on.

Warnings:

Warning 00: IOT is expecting OOL alarm on the current consumption of the FEM during the execution of the AMB_01_CSL test because DataBase is expecting all the RCA on. The final check on DB is requested only when all the RCA are switched on (Step14).

Warning 01: To deliver power to the FEM DC/DC converters, DAE must be activated via the TC LC132320 (Step2 in table above). The DC/DC converters do not follow the same order of the power groups so the following table must be taken in mind before applying the right values in the LP parameters.

DC/DC converters	Power Group	RCA	Reference LP	Reference LM
#2	#1	RCA 18 RCA 26	LP064320	LM422332
#1	#2	RCA 19-20 RCA 28	LP063320	LM421332



#3	#3	RCA 21-22 RCA 24 RCA 27	LP065320	LM423332
#4	#4	RCA 23 RCA 25	LP066320	LM424332

Warning 02: The CRYO_01 test is foreseen to start when the FPU temperature reaches 40K, and in principle it could gain time because for functionality LFI doesn't need 20K at FPU. But it might be the case that at this temperature the scientific signal coming out from some RCAs could be too high and saturates the ADC of the BEU. For this reason LFI IOT suggests to start the CRYO_01 procedure with the RCAs for which any saturation effect is not expected:

Power Group #1 (RCA 18 and 26)
Power Group #4 (RCA 23 and 25)
Power Group #3 (RCA 21-22-24 and 27)
Power Group #2 (RCA 19-20 and 28)

If even using this order the RCA output signals are saturating a dedicated recovery procedure shall be executed. The procedure is described in 13.1.2.13.2.

Warning 03: The detector ID number 18 and 19 of RCA 28 must not exercised in the same way of the others. During FM tests a “soft” procedure has been used to avoid saturation effect, the steps to be performed are described in § 13.4.3.

13.1.2.4 DRAIN CURRENTS VERIFICATION

Topic	Description	Note
Purpose	Drain currents verification	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	



Time criticality	No criticalities	
Expected duration	3 hrs	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI Normal Science Mode	
End satellite state	LFI Normal Science Mode	
Reference procedures	1. Drain currents verification	see Table 13.1-14
Procedure predecessors		
Contingency procedures		

Table 13.1-13 Summary of the procedures for Drain current verification

	Name of Procedure	Reference	Note	Time
0	Wait for IOT confirmation			
1	Update RCA parameters	Table 13.2-28, step 2.1 to 2.2	Apply the values 1 to N=9 of Vg1 and wait 20 second for each step on the first ACA of the FEMs Under Test	3 hrs
2	Update RCA parameters	Table 13.2-28, step 2.1 to 2.2	Apply the Vg1 Cryo values on the first ACA of the FEMs Under Test	
3			Repeat step 1 and 2 for all the other 3 ACAs of the FEMs under test	
4	Update RCA parameters	Table 13.2-28, step 2. 3 and 2.4	Apply the values 1 to N=9 of Vg2 and wait 20 second for each step on the first ACA of the FEMs Under Test	
5	Update RCA parameters	Table 13.2-28, step 2. 3 and 2.4	Apply the Vg2 Cryo values on the first ACA of the FEMs Under Test	
6			Repeat step 4 and 5 for all the other 3 ACAs of the FEMs under test	



	Name of Procedure	Reference	Note	Time
7			Repeat step 1 to 6 for all the FEMs	
12	Wait for IOT confirmation			

Table 13.1-14 Drain current verification

13.1.2.5 CRYO02

Topic	Description	Note
Purpose	Cryo02 procedures Indeed the aim of the test is to have a stable acquisition of data before ground tests and in flight, in order to perform a sure comparison between the two runs.	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	2 hrs	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI Normal Science Mode	
End satellite state	LFI Normal Science Mode	
Reference procedures	1. Cryo02	see Table 13.1-16
Procedure predecessors		
Contingency procedures		

Table 13.1-15 Summary of the procedures for Cryo02



	Name of Procedure	Reference	Note	Time	4KHz	PS	Bias
	Initial Configuration				A/C	0	ON cryo
1			Wait for IOT confirmation				
2			Check that the 4KHz switching is enabled.	< 2 Min			
3			Acquire data in stable condition	30 Min			
4	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	Change the P/S status of B/D to 1			B/D	
5			Acquire data in stable condition	30 Min			
6	4KHZ switching	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching on A/C		0		
7	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	set P/S status on A/C and B/D on 0			0	
8	4KHZ switching	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching on B/D	< 2 Min	B/D		
9			Acquire data in stable condition	30 Min			
10	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	Change the A/C status to 1	< 2 Min		A/C	
11			Acquire data in stable condition	30 Min			
12			Take note of voltage output and of the BEU temperature				
13			Wait for IOT confirmation.				



	Final configuration				B/D	A/C	ON Cryo

Table 13.1-16 Cryo02

13.1.2.6 PHASE SHIFTER TUNING

Topic	Description	Note
Purpose	Phase Shifter Tuning. The test is performed only on the 33 and 44 GHz RCAs, as on the 70 GHz radiometers the currents are maximized in order to reduce the transition time of the output signal between the two states of the PS. In principle the nominal bias condition derived from the RAA tests shall be the optimal one. The test is performed on each ACA, biasing each channel separately. For this purpose the ACA coupled with the one under test is switched-off. The phase switch is activated, thus producing two different output signal traces for the radiometer under test when the PS is not balanced. The balancing philosophy is described in the procedure	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	6 hrs	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI Normal Science Mode	
End satellite state	LFI Normal Science Mode	



Reference procedures	1. Phase Shifter tuning	see Table 13.1-18
Procedure predecessors		
Contingency procedures		

Table 13.1-17 Summary of the procedures for Phase Shifter Tuning

To speed up the time need to perform the procedure the same procedure is parallelized at its best. Basically two RCAs per time are exercised and to minimize coupling between the two the RCAs belong to different power groups, a suggested order could be the following

RCA 24 and RCA 25
RCA 26 and RCA 27
RCA 28

The last RCA will be exercised in stand alone condition.

Each RCA has got four ACAs and in the same order of how the SCOS TC are build the first ACA is coupled with the second and the third with the fourth. The sequence here described starts switching Off the first ACA and change the RCA configuration of the second one. Its configuration is changed in order to cover a square matrix of different values of I1 and I2 that are the two currents that are delivered to the two diodes of the PS in that ACA. The currents can be modified via TC. Once the matrix is covered the ACA is switched Off and its coupled ACA is switched ON. Once again a matrix of different values in I1 and I2 is applied also to this ACA. When both ACAs of the same RCA are exercised the procedure continues with the other twos. The procedure is repeated until all the RCAs are exercised.

	Name of Procedure	Reference	Note	4KHz	PS	Bias
	Initial configuration			B/D	A/C	ON cryo
1	Wait IOT confirmation		Start performing the test in parallel on defined RCAs k (see "Test Sequence" above)			
2			Testing first ½ RCAs (k)			
3	Configure RCA parameters	Table 13.2-28, step 2.1 to 2.10	The first ACA is switched Off and the second one is Under Test (ACA UT) and left on.			ON cryo [-k]:



						zero m=1
4	Update RCA parameters	Table 13.2-28, step 2.7 to 2.10	Apply the Matrix on m=2 (I1, I2) and wait 10 second for each step			Test on m=2
5	Configure RCA parameters. see steps 5.1 and 5.2	Table 13.2-28, step 2.1 to 2.10	The second ACA is switched Off and the first one becomes the one Under Test and is switched back on.			
5.1	Configure RCA parameters	Table 13.2-28, step 2.1 to 2.10	The second ACA is switched Off			ON cryo [-k]: zero m=1,2
5.2	Configure RCA parameters	Table 13.2-28, step 2.1 to 2.10	The first ACA becomes the one Under Test and is switched back on. For RCA28: switch on softly 1 and 2 and then switch off 2.			ON cryo [-k]: zero m=2
6	4KHZ Switching	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching on B/D	0		
7	4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching on A/C	A/C		
8	Update RCA parameters	Table 13.2-28, step 2.7 to 2.10	Apply the Matrix on m=1 (I1, I2) and wait 10 second for each step			Test on m=1
9	Configure RCA parameters	Table 13.2-28, step 2.1 to 2.10	Apply nominal cryo values in two tested ACAs (m=1,2). For RCA28: switch off m=1, then switch on softly 1 and 2.			ON cryo
10	4KHZ Switching	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching on A/C	0		
11	4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching on B/D	B/D		
12			Testing second ½ RCA			
13	Configure RCA parameters	Table 13.2-28, step 2.1 to 2.10	The third ACA is switched Off and the fourth one is Under Test (ACA UT) and left on.			ON cryo [-k]: zero m=3



14	Configure RCA parameters	Table 13.2-28, step 2.7 to 2.10	Apply the Matrix on m=4 (I1, I2) and wait 10 second for each step			Test on m=4
15	Configure RCA parameters: see steps 15.1 and 15.2		The fourth ACA is switched Off and the third one becomes the one Under Test and is switched back on.			
15.1	Configure RCA parameters	Table 13.2-28, step 2.1 to 2.10	The fourth ACA is switched Off			ON cryo [-k]: zero m=3,4
15.2	Configure RCA parameters	Table 13.2-28, step 2.1 to 2.10	The third ACA becomes the one Under Test and is switched back on.			ON cryo [-k]: zero m=4
16	4KHZ Switching	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching on B/D	0		
17	4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching on A/C	A/C		
18	Configure RCA parameters	Table 13.2-28, step 2.7 to 2.10	Apply the Matrix on m=3 (I1, I2) and wait 10 second for each step			Test on m=3
19	Configure RCA parameters	Table 13.2-28, step 2.1 to 2.10	Apply nominal cryo values in two tested ACAs (m=3,4).			ON cryo
20	4KHZ Switching	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching on A/C	0		
21	4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching on B/D	B/D		
22			Wait for IOT confirmation			
23			Repeat the procedure from 1 to 22 Until all RCAs are exercised: (see "Test Sequence" above). RCA28 is stand-alone: see table below			
24	Final configuration			B/D	A/C	ON cryo



Table 13.1-18 Phase Shift tuning verification

After the test, the LFI IOT is in charge to produce an optimized table of I1 and I2 parameters that shall be uploaded before next step:

	Name of Procedure	Reference	Note	4KHz	PS	Bias
	Initial configuration			B/D	A/C	ON cryo
1	Configure RCA parameters	Table 13.2-28, step 2.7 to 2.10	Apply to all RCA P/S optimized values and check in HK telemetry. Check if the biases values obtained from data analysis correspond to the one obtained during the ground test campaign. (new I1, I2 values).	B/D	A/C	ON Cryo
2	Configure RCA parameters	Table 13.2-28, step 2.15 to 2.22	Also new default P/S and 4KHz could be defined and set if optimization is different from the default set after ground tests.	B/D*	A/C*	ON cryo
3	Save DAE Actual Default Configuration	Table 13.2-75				

13.1.2.7 ACA MATRIX TUNING

Topic	Description	Note
Purpose	ACA Matrix tuning The scope of this test is to check the optimisation of the radiometer noise temperature by tuning the Vg1 and VG2 of every LNA for each channel. Given the two radiometer channels M1 and M2, when tuning channel M1 (Vg1,Vg2), channel M2 (which is coupled to channel M1 through the two hybrids) is	



	still on with (Vg1,Vg2) nominal value set.. Channels S1 and S2 are on, in order not to impact on the overall power dissipation on the FPU thus affecting its temperature stability (this test has to be done if and only if FPU temperature is stabilized after TSA tuning).). The procedure is repeated for all other instrument channels. To speed up the execution of the procedure the sequence is build in order to perform the tuning in two different ACAs in parallel. The chosen ACAs are belonging to different power groups in order to minimize the coupling between radiometers biases. The sequence to follow is indicated in the below table.	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	8 hrs	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI Normal Science Mode	
End satellite state	LFI Normal Science Mode	
Reference procedures	1. ACA matrix tuning	see Table 13.1-20
Procedure predecessors		
Contingency procedures		

Table 13.1-19 Summary of the procedures for ACA matrix tuning



RCA Under Tests in parallel
RCA 18 + RCA 21
RCA 19 + RCA 22
RCA 20 + RCA 23
RCA 25 + RCA 24
RCA 26 + RCA 27
RCA 28

	Name of Procedure	Reference	Note	4KHz	PS	Bias
0			Start analysing RCAs k according to the order given above in "Objectives of the test"			
	Initial configuration			B/D*	A/C*	ON cryo
1			Wait for IOT confirmation			
2	4KHZ switching	Table 13.2-28, step 2.19 to 2.22	Disabling 4KHz switching on in the RCAs under tests	B/D* [-k]		
3	Configure RCA Parameters		RCAs under test are biased with the zero currents values. After 1 minute of data collection. The RCAs are biased again with Cryo values (Refers to Warning09)			
3.1	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	RCAs under test are biased with the zero currents values.			ON cryo[-k] zero k
3.2			1 minute of data collection			
3.3	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	The RCAs are biased again with Cryo values (Refers to Warning09)			ON cryo
4	4KHZ switching	Table 13.2-28, step 2.19 to 2.22	Enabling 4KHz switching on in the FEMs under test using same configuration saved after PS tuning test (§13.1.2.6)	B/D*		
5			Start test on ACA1			



6	Update Channel Configuration:	Table 13.2-28, step 2.1 to 2.4	Apply first point of Matrix Tuning Table for VG1 and VG2 in ACA1 and wait 40 s.			Test on ACA m=1
7	Update RCA parameters	Table 13.2-28, step 2.1 to 2.4	Apply Matrix Tuning Table for VG1 and VG2 on ACA1 (Warning 06).			test on ACA m=1
8	Update RCA parameters	Table 13.2-28, step 2.1 to 2.10	Recover Cryo Biases setting in the ACA1			ON cryo
9			Start test on ACA2			
10	Update Channel Configuration:	Table 13.2-28, step 2.1 to 2.4	Apply first point of Matrix Tuning Table for VG1 and VG2 in ACA2 and wait 40 s.			Test on ACA m=2
11	Update RCA parameters	Table 13.2-28, step 2.1 to 2.4	Apply Matrix Tuning Table for VG1 and VG2 on ACA2 (Warning 06).			test on ACA m=2
12	Update RCA parameters	Table 13.2-28, step 2.1 to 2.10	Recover Cryo Biases setting in the ACA2			ON cryo
13			Start test on ACA3			
14	Update Channel Configuration:	Table 13.2-28, step 2.1 to 2.4	Apply first point of Matrix Tuning Table for VG1 and VG2 in ACA3 and wait 40 s.			Test on ACA m=3
15	Update RCA parameters	Table 13.2-28, step 2.1 to 2.4	Apply Matrix Tuning Table for VG1 and VG2 on ACA3 (Warning 06).			test on ACA m=3
16	Update RCA parameters	Table 13.2-28, step 2.1 to 2.10	Recover Cryo Biases setting in the ACA3			ON cryo
17			Start test on ACA4			
18	Update Channel Configuration:	Table 13.2-28, step 2.1 to 2.4	Apply first point of Matrix Tuning Table for VG1 and VG2 in ACA4 and wait 40 s.			Test on ACA m=4
19	Update RCA parameters	Table 13.2-28, step 2.1 to 2.4	Apply Matrix Tuning Table for VG1 and VG2 on ACA4 (Warning 06).			test on ACA m=4



20	Update RCA parameters	Table 13.2-28, step 2.1 to 2.10	Recover Cryo Biases setting in the ACA4			ON cryo
21			Test finished on all ACA of RCA k			
22	4KHZ switching	Table 13.2-28, step 2.19 to 2.22	Disabling 4KHz switching on in the RCAs k	B/D* [-k]		
23	Update RCA parameters		RCAs k under test are biased with zero currents values. After 1 minute of data collection. The RCAs are biased again with Cryo values			
23.1	Update RCA parameters	Table 13.2-28, step 2.1 to 2.10	RCAs k under test are biased with zero currents values.			ON RCA[-k] zero k
23.2			1 minute of data collection.			
23.3	Update RCA parameters	Table 13.2-28, step 2.1 to 2.10	RCAs k under test are biased again with Cryo values. For RCA28, see warning 03			ON cryo
24	4KHZ switching	Table 13.2-28, step 2.19 to 2.22	Enabling 4KHz switching on in the RCAs k just tested	B/D*		
25			Wait for IOT confirmation			
26			Test finished on RCAs k			
27			Repeat steps 1-26 for all RCAs according to the order given above in "Objectives of the test"			
28	Data file Check		The data file must be checked by IOT operator in order to be sure that the data are available before changing the temperature of the 4K stage.	B/D*	A/C*	ON cryo

Table 13.1-20 ACA matrix tuning verification

Warnings:



Warning 04: Just at the beginning of the Matrix sequence the FEMs under tests are biased with zero current values (step 3 in table above) in order to have a reference point of the signal with the BEM only. The same procedure will be repeated at the end of the Matrix sequence (step 23). The reason to perform this step is two folds. First it gives a trigger of the start of the Matrix tuning sequence that could be used for an automatic data analysis procedure. Second, and more important, the comparison of the BEM only signal at the beginning and at the end of the sequence gives the possibility to correct the output respect changes in the BEM offset.

Warning 05: RCA 28 shall be switched on again after the switch off using the “Soft” procedure (see §13.4.3).

Warning 06: The proposed way to implement the matrix tuning is to pass the V_{g1} and V_{g2} values ordered in such a way that the expected drain currents are ordered in a continuously increasing way. This solutions will allow to:

- 1) have a custom grid of values among witch to move, discarding in advance all the nonsense couple of biases;
- 2) include particular values important to be verified (as the values explored during instrument level and RCA level tests) to check for method validity and differences;
- 3) have a regular variation of biases, producing an expected regular variation of currents.

Warning 07: When the first point of the Matrix Tuning is biased, LFI is left in data acquisition for 40 s. For the other points the time between each step is 10 seconds for 44 and 30 GHz and 20 seconds for 70 GHz.

Warning 08: For each ACA a Matrix of (V_{G1} , V_{G2}) values must be followed. Due to a different behaviours of the RCAs each Matrix is applicable only to the ACA for which is created.

Warning 09: The table of Cryo values must be checked by IOT before running the test. It might be the case that some biases values are different from ground tests and a new table should be produced.

After the whole set of ACA tuning tests is finished and the data analysis is completed, the LFI IOT is in charge to produce an optimized table of V_{g1} and V_{g2} parameters that shall be uploaded:

	Name of Procedure	Reference	Note	4KHz	PS	Bias



	Initial configuration			B/D*	A/C*	ON cryo
1	Configure RCA parameters	Table 13.2-28, step 2.1 to 2.4	Apply to all RCA Vg1 and Vg2 optimized values and check in HK telemetry. Check if the biases values obtained from data analysis correspond to the one obtained during the ground test campaign. (new Vg1, Vg2 values).	B/D*	A/C*	ON cryo*
3	Save DAE Actual Default Configuration	Table 13.2-75				

13.1.2.8 DAE OFFSET AND GAIN TUNING

Topic	Description	Note
Purpose	DAE Offset and Gain tuning The objective of this test is to exercise the offset circuitry in order to verify the DAE offset and gain values at the end of the amplifier chain. During the FM test was discovered that the offset value applied by circuitry has some dependence from the input signal, so a sort of calibration/adjustment activity is foreseen to obtain data that could be checked for performances of the instrument.	
Constraints on use	Procedure to be started during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	25 hrs	



Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI Normal Science Mode	
End satellite state	LFI Normal Science Mode	
Reference procedures	1. DAE offset and gain tuning	see Table 13.1-22
Procedure predecessors		
Contingency procedures		

Table 13.1-21 Summary of the procedures for DAE offset and gain tuning

	Name of Procedure	Reference	Note	Time	4KHz	PS	Bias
0	Initial configuration		Wait for IOT confirmation		B/D*	A/C*	ON cryo*
1	Configure RCA parameters	Table 13.2-28, step 2.13 to 2.14	Set the gain values at which perform the loop on offset values				
2	Configure RCA parameters	Table 13.2-28, step 2.11 to 2.12	Exercise all the offset Values in succession (from 255 to 0DEC) in all the RCA together	2 hrs and 30 Min			
3	Configure RCA parameters	Table 13.2-28, step 2.11 to 2.12	All Offset Values are set back to default values (255 dec)	1 Min			
4			Check Data Wait for IOT confirmation				
5			Repeat step 1 to 4 until all Gain values are exercised. See note and table below				
6	Final configuration				B/D*	A/C*	ON cryo*
4	Perform data analysis		Data Analysis can be performed offline.				

Table 13.1-22 DAE offset and gain tuning verification



Note: the test is performed at different gain values:

Gain (decimal)	Status
0	1
1	2
2	4
3	8
4	16
8	3
9	6
10	12
11	24
15	48

After the DAE Offset and Gain tuning tests is finished and the data analysis is completed, the LFI IOT is in charge to produce an optimized table of Offset and Gain parameters that shall be uploaded:

	Name of Procedure	Reference	Note	4KHz	PS	Bias
	Initial configuration			B/D*	A/C*	ON cryo
1	Configure RCA parameters	Table 13.2-28, step 2.11 to 2.14	Apply to all RCA Vg1 and Vg2 optimized values and check in HK telemetry. Check if the biases values obtained from data analysis correspond to the one obtained during the ground test campaign. (new Vg1, Vg2 values).	B/D*	A/C*	ON cryo*
2	Save DAE Actual Default Configuration	Table 13.2-75				

13.1.2.9 REFERENCE TEST

Topic	Description	Note



Purpose	Reference Test The objective of the test is to perform a complete functional test of the radiometric part in stable temperature condition. The sequence of the test is completely different from the Functional test (Phase 5-02-c) because all the radiometers are already on. The aim of this test is also to perform a functional test that mimics the one that will be done during flight and will be the reference point for any other functional test during mission. (For instance if there is the need to perform a functional test in one of the radiometer because some problem occurred, there is in principle no need to switch off all the other radiometers to perform the test. All radiometers are kept on and in this way science can be stored). This is more a reference point than a functional one because at this point LFI is surely functioning as expected so procedure could be faster than the one used during the CRYO-01 and data analysis could be done in parallel with other activity.	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	4 hrs	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU	



	ASW running, science activated	
Initial satellite state	LFI Normal Science Mode	
End satellite state	LFI Normal Science Mode	
Reference procedures	1. Reference Test	see Table 13.1-24
Procedure predecessors		
Contingency procedures		

Table 13.1-23 Summary of the procedures for Reference Test

	Name of Procedure	Reference to [RD06]	Note	4KHz	PS	Bias
0			Start performing the test in parallel on RCA 18 and 21 (see table above)	B/D	A/C	ON cryo*
1			Wait for IOT verification			
2	Configure RCA Parameters	See Table 13.2-28, step 2.1 to 2.10	Switch off the first two ACA of the RCA Under Test applying Zero biases condition			ON cryo* [-k]: ACA* [-1,2]
3	Configure P/S polarization	See Table 13.2-28, step 2.15 to 2.18	All PS are biased in status 0 of the RCA under Test		A/C [-k]	
4	Disabling 4KHz Switching	See Table 13.2-28, step 2.19 to 2.22	Disabled the 4KHz switching on AC and on BD of the RCA under test	B/D [-k]		
5			Wait 1 minute for data collection			
6	Configure RCA Parameters	See Table 13.2-28, step 2.1 to 2.10	LNA of 1st ACA of the RCA is switched on (the one corresponding to A/C). See the Table for Cryo Biases that is the outcome of the ACA Tuning.			ON cryo* [-k]: ACA* [-2]
7			Wait 1 minute for data collection			
8	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 1 on A/C		A/C	
9			Wait 1 minute for data collection			



10	Enabling 4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Enable the 4KHz switching on A/C of FEM Under Test	B/D [-k] A/C k		
11			Wait 1 minute for data collection			
12	Disabling 4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching on A/C of FEM Under Test	B/D [-k]		
13	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 0 on A/C of FEM Under Test		A/C [-k]	
14	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	Switch off the ACA under test (A/C) applying Zero biases condition			ON cryo* [-k]: ACA* [-1,2]
15	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	LNA of 2nd ACA of the 1/2 FEM Under Test is switched on (the one corresponding to B/D). See the Table for Cryo Biases that is the outcome of the ACA Tuning.			ON cryo* [-k]: ACA* [-1]
16			Wait 1 minute for data collection			
17	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 1 on B/D of FEM Under Test		A/C [-k] B/D k	
18			Wait 1 minute for data collection			
19	Enabling 4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching on B/D of FEM Under Test	B/D		
20			Wait 1 minute for data collection			
21	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	LNA of the 1st ACA of the RCA Under Test is switched on (the one corresponding to A/C).			ON cryo*
22			Second half FEM			
23	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	Switch off the second 1/2 FEM Under Test applying Zero biases condition			ON cryo* [-k]: ACA* [-3,4]
24	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	All PS are biased in status 0 of the 1/2 FEM under Test		A/C [-k]	



25	Disabling 4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Disabled the 4KHz switching on AC and on BD of the 1/2 FEM under test	B/D [-k]		
26			Wait 1 minute for data collection			
27	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	LNA of 1st ACA of the FEM is switched on (the one corresponding to A/C). See the Table for Cryo Biases that is the outcome of the ACA Tuning.			ON cryo* [-k]: ACA* [-4]
28			Wait 1 minute for data collection			
29	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 1 on A/C		A/C	
30			Wait 1 minute for data collection			
31	Enabling 4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Enable the 4KHz switching on A/C of FEM Under Test	B/D [-k] A/C k		
32			Wait 1 minute for data collection			
33	Disabling 4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Disable 4KHz switching on A/C of FEM Under Test	B/D [-k]		
34	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 0 on A/C of FEM Under Test		A/C [-k]	
35	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	Switch off the ACA under test (A/C) applying Zero biases condition			ON cryo* [-k]: ACA* [-3,4]
36	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	LNA of 4th ACA of the FEM Under Test is switched on (the one corresponding to B/D). See the Table for Cryo Biases that is the outcome of the ACA Tuning.			ON cryo* [-k]: ACA* [-3]
37			Wait 1 minute for data collection			
38	Configure P/S polarization	Table 13.2-28, step 2.15 to 2.18	Change the PS status to 1 on B/D of FEM Under Test		A/C [-k] B/D k	
39			Wait 1 minute for data collection			



40	Enabling 4KHz Switching	Table 13.2-28, step 2.19 to 2.22	Enable 4KHz switching on B/D of FEM Under Test	B/D		
41			Wait 1 minute for data collection			
42	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	LNA of the third ACA of the FEM Under Test is switched on (the one corresponding to A/C).			ON cryo*
43			Wait for IOT verification			ON cryo*
44			Repeat from step 1 to step 43 in order to complete all the RCAs. The test is in parallel (see table above) apart from RCA28			

Table 13.1-24 Reference test

13.1.2.10 REBA TUNING

Topic	Description	Note
Purpose	REBA tuning Some parameters in the REBA have to be optimized in function of the signal input to have the best performance of the compressor. The optimization is done by software but there is the need to acquire some data for each radiometer in Type one mode with nominal N Averaging parameters.	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	10 minutes	
Ground Equipment pre-requisites	LFI HK decoding capability.	



Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI Normal Science Mode	
End satellite state	LFI Normal Science Mode	
Reference procedures	1. REBA tuning	see Table 13.1-26
Procedure predecessors		
Contingency procedures		

Table 13.1-25 Summary of the procedures for REBA tuning

The test will be performed in 4 sets in order to stay within the LFI TM bandwidth (48 kbps for Normal Science Mode). The order to be used is:

	RCA Chain	Radiometer Channel				Mask 1	Mask 2	Mask 3	Mask 4
set 1	RCA27	00	01			C7FC	0000	0000	0000
	RCA24		01	10	11				
	RCA21	00	01	10	11				
	RCA22	00	01						
set 2	RCA27			10	11	3803	FC00	0000	0000
	RCA24	00							
	RCA22			10	11				
	RCA23	00	01	10	11				
	RCA25	00	01						
set 3	RCA25			10	11	0000	03CF	C080	0000
	RCA28	00	01						
	RCA20	00	01	10	11				
	RCA19	00	01						
	RCA26	00							
set 4	RCA28			10	11	0000	0030	3F70	0000



RCA19			10	11				
RCA18	00	01	10	11				
RCA16		01	10	11				

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Stop DAE science sequencer.	Stop DAE science sequencer TC(8,4)	LC066320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
2	Stop science processing. From this moment onward, science TM (21,x) is not produced anymore.	Stop science processing TC(8,2)	LC018320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
3	Verify science processing is stopped	REBA HK TM(3,25)		Receive packet ID 120202369 parameter LM576350 bit 15 = 0 and verify TM(21,x) is no more arriving		
4	Set N_average to type 1		Table 13.2-71 Definition of the N_Ave science processing parameters	LM401350 to LM422350 to their nominal values		
5	Change Science Processing type. Accordingly each RCA will belong to processing mode A and/or B (see § 15.1.3).	Set Science Processing TC(8,4)	Table 13.2-36 Change science processing mode step 3 to 5	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
6	Verify the arrival of science packets or science processing activation	Diagnostic and Nominal Data Science Report TM(21,x), REBA HK TM(3,25)		Receive packet ID (120011369 AND/OR 120012369 AND/OR 120211369 AND/OR 120213369) OR 120202369, parameter LM576350 bit15=1		



7	Verify Telemetry	REBA TM(3,25)	HK		Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350=00h Det Mask A0 LM561350=00h Det Mask A1 LM562350=00h Det Mask A2 LM563350=00h Det Mask A3 LM564350=00h Det Mask A4 LM565350=00h Det Mask A5 LM570350=00h Det Mask B0 LM571350=00h Det Mask B1 LM572350=00h Det Mask B2 LM573350=00h Det Mask B3 LM574350=00h Det Mask B4 LM575350=00h Det Mask B5		
8	Enable Science Channel for data acquisition	Enable a new Channel TC(8.4)		LC077320 LP116320=C7FCh LP117320=0000h LP118320=0000h LP119320=0000h LP120320=0000h LP121320=0000h LP122320=0000h LP123320=0000h	Receive Packets ID 120011342 and 120017342		
9	Verify Telemetry	REBA TM(3,25)	HK		Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350=C7h Det Mask A0 LM561350=FCh Det Mask A1 LM562350=00h Det Mask A2 LM563350=00h Det Mask A3 LM564350=00h Det Mask A4 LM565350=00h Det Mask A5		



				LM570350=00h Det Mask B0 LM571350=00h Det Mask B1 LM572350=00h Det Mask B2 LM573350=00h Det Mask B3 LM574350=00h Det Mask B4 LM575350=00h Det Mask B5		
10			Acquire data for 45 Min			
11	Disable the channels	Disable Channels TC(8.4)	LC078320 LP116320=C7FCh LP117320=0000h LP118320=0000h LP119320=0000h LP120320=0000h LP121320=0000h LP122320=0000h LP123320=0000h	Receive Packets ID 120011342 and 120017342		
12	Verify Telemetry	REBA TM(3,25)	HK	Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350=00h Det Mask A0 LM561350=00h Det Mask A1 LM562350=00h Det Mask A2 LM563350=00h Det Mask A3 LM564350=00h Det Mask A4 LM565350=00h Det Mask A5 LM570350=00h Det Mask B0 LM571350=00h Det Mask B1 LM572350=00h Det Mask B2 LM573350=00h Det Mask B3 LM574350=00h Det Mask B4 LM575350=00h Det Mask B5		
13			Wait for IOT			



14	Enable Science Channel for data acquisition	Enable a new Channel TC(8.4)	confirmation LC077320 LP116320=3803h LP117320=FC00h LP118320=0000h LP119320=0000h LP120320=0000h LP121320=0000h LP122320=0000h LP123320=0000h	Receive Packets ID 120011342 and 120017342		
15	Verify Telemetry	REBA HK TM(3,25)		Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350=38h Det Mask A0 LM561350=03h Det Mask A1 LM562350=FCh Det Mask A2 LM563350=00h Det Mask A3 LM564350=00h Det Mask A4 LM565350=00h Det Mask A5 LM570350=00h Det Mask B0 LM571350=00h Det Mask B1 LM572350=00h Det Mask B2 LM573350=00h Det Mask B3 LM574350=00h Det Mask B4 LM575350=00h Det Mask B5		
16			Acquire data for 45 Min			
17	Disable the channels	Disable Channels TC(8.4)	LC078320 LP116320=3803h LP117320=FC00h LP118320=0000h LP119320=0000h LP120320=0000h	Receive Packets ID 120011342 and 120017342		



			LP121320=0000h LP122320=0000h LP123320=0000h				
18	Verify Telemetry	REBA TM(3,25)	HK		Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350=00h Det Mask A0 LM561350=00h Det Mask A1 LM562350=00h Det Mask A2 LM563350=00h Det Mask A3 LM564350=00h Det Mask A4 LM565350=00h Det Mask A5 LM570350=00h Det Mask B0 LM571350=00h Det Mask B1 LM572350=00h Det Mask B2 LM573350=00h Det Mask B3 LM574350=00h Det Mask B4 LM575350=00h Det Mask B5		
19			Wait for IOT confirmation				
20	Enable Science Channel for data acquisition	Enable a new Channel TC(8.4)	LC077320 LP116320=0000h LP117320=03CFh LP118320=C080h LP119320=0000h LP120320=0000h LP121320=0000h LP122320=0000h LP123320=0000h	Receive Packets ID 120011342 and 120017342			
21	Verify Telemetry	REBA TM(3,25)	HK		Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350=00h Det Mask A0		



				LM561350=00h Det Mask A1 LM562350=03h Det Mask A2 LM563350=CFh Det Mask A3 LM564350=C0h Det Mask A4 LM565350=80h Det Mask A5 LM570350=00h Det Mask B0 LM571350=00h Det Mask B1 LM572350=00h Det Mask B2 LM573350=00h Det Mask B3 LM574350=00h Det Mask B4 LM575350=00h Det Mask B5		
22			Acquire data for 45 Min			
23	Disable the channels	Disable TC(8.4)	Channels	LC078320 LP116320=0000h LP117320=03CFh LP118320=C080h LP119320=0000h LP120320=0000h LP121320=0000h LP122320=0000h LP123320=0000h	Receive Packets ID 120011342 and 120017342	
24	Verify Telemetry	REBA TM(3,25)	HK		Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350=00h Det Mask A0 LM561350=00h Det Mask A1 LM562350=00h Det Mask A2 LM563350=00h Det Mask A3 LM564350=00h Det Mask A4 LM565350=00h Det Mask A5 LM570350=00h Det Mask B0 LM571350=00h Det Mask B1	



				LM572350=00h Det Mask B2 LM573350=00h Det Mask B3 LM574350=00h Det Mask B4 LM575350=00h Det Mask B5		
25			Wait for IOT confirmation			
26	Enable Science Channel for data acquisition	Enable a new Channel TC(8.4)	LC077320 LP116320=0000h LP117320=0030h LP118320=3F70h LP119320=0000h LP120320=0000h LP121320=0000h LP122320=0000h LP123320=0000h	Receive Packets ID 120011342 and 120017342		
27	Verify Telemetry	REBA HK TM(3,25)		Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350=00h Det Mask A0 LM561350=00h Det Mask A1 LM562350=00h Det Mask A2 LM563350=30h Det Mask A3 LM564350=3Fh Det Mask A4 LM565350=70h Det Mask A5 LM570350=00h Det Mask B0 LM571350=00h Det Mask B1 LM572350=00h Det Mask B2 LM573350=00h Det Mask B3 LM574350=00h Det Mask B4 LM575350=00h Det Mask B5		
28			Acquire data for 45 Min			
29	Disable the channels	Disable Channels	LC078320	Receive Packets ID 120011342		



		TC(8.4)	LP116320=0000h LP117320=0030h LP118320=3F70h LP119320=0000h LP120320=0000h LP121320=0000h LP122320=0000h LP123320=0000h	and 120017342		
30	Verify Telemetry	REBA TM(3,25)	HK	Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350=00h Det Mask A0 LM561350=00h Det Mask A1 LM562350=00h Det Mask A2 LM563350=00h Det Mask A3 LM564350=00h Det Mask A4 LM565350=00h Det Mask A5 LM570350=00h Det Mask B0 LM571350=00h Det Mask B1 LM572350=00h Det Mask B2 LM573350=00h Det Mask B3 LM574350=00h Det Mask B4 LM575350=00h Det Mask B5		
31			Wait for IOT confirmation			

Table 13.1-26 REBA tuning verification

After the REBA tuning test is finished and the data analysis is completed, the LFI IOT is in charge to produce an optimized table of the REBA parameters that shall be uploaded:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Science Deactivation		See § 13.2.11, Table 13.2-38		5 min	



2	Definition Science parameters		See § 13.2.12, Table 13.2-40		30 min	
3	Set processing Type to Nominal (T5)		See § 13.2.31, Table 13.2-77	This is the Nominal condition as in flight operation	5 Min	
4	REBA Diagnostic		See § 13.2.33, Table 13.2-81 step 4			
5	Collect data in type 5			Check Telemetry counter every 4 s. Wait for LFI IOT confirmation		
6	REBA Diagnostic		See § 13.2.33, Table 13.2-81 step 5			

13.1.2.11 LFI CONFIGURATION TO NOMINAL

Topic	Description	Note
Purpose	LFI configuration to nominal The objective of the test is to put the LFI in its nominal configuration	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU ASW running, science activated	
Initial satellite state	LFI Normal Science Mode	
End satellite state	LFI Normal Science Mode	
Reference procedures	1. LFI configuration to nominal	see Table 13.1-30



Procedure predecessors		
Contingency procedures		

Table 13.1-27 Summary of the procedures for LFI to nominal configuration

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Start channel switching		See §13.2.6, Table 13.2-28 step 3.1			
2	Start Monitor functions		See § 13.2.13, Table 13.2-42			
3	Set FPT threshold		See § 13.2.14, Table 13.2-44, step 7 and 8			

Table 13.1-28 LFI to nominal configuration

13.1.2.12 LFI TO HFI SUSCEPTIBILITY

Topic	Description	Note
Purpose	LFI to HFI susceptibility The objective of the test is to let check HFI instrument if there is any kind of disturbance while LFI is changing its status	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	2 hrs	
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on, DPU ASW and SPU	



	ASW running, science activated	
Initial satellite state	LFI Normal Science Mode	
End satellite state	LFI Normal Science Mode	
Reference procedures	1. LFI to HFI susceptibility	see Table 13.1-30
Procedure predecessors		
Contingency procedures		

Table 13.1-29 Summary of the procedures for LFI to HFI susceptibility

	Name of Procedure	Reference	Note	Time	4KHz	PS	Bias
1			Wait for IOT confirmation		B/D*	A/C*	ON cryo*
2	Deactivation of LFI Monitor function	See §13.2.19					
3	Stop Channel Switching	See §13.2.6, Table 13.2-28 step 3.2					
4	4KHz Switching	See §13.2.6, Table 13.2-28, step 2.19 to 2.22	The 4KHz switching is disabled.	5 Min	0		
5	Science deactivation	See §13.2.11, Table 13.2-38	No more Science telemetry is coming	2 Min			
6	Configure RCA parameters	See §13.2.6, Table 13.2-28, step 2.1 to 2.10	The FEM are switched off. No more current is delivered to FPU.	5 Min	0	0	ON zero
7	Disable DAE HK sequencer	Send LC064320 with no parameters (see § 13.1.2.1, Table 13.1-8 step 2)	No more DAE telemetry is coming	2 Min			
8			HFI is acquiring data	30 Min			
9	Enable DAE HK sequencer	Send LC063320 with no parameters (see § 13.1.2.1, Table 13.1-8 step 4)	If an unexpected disturbance is found LFI will be switched on step by step in order to let HFI do some data analysis at each step. This could disentangle the origin of the disturbance.				
10	Science activation Type 5	See §13.2.9, Table 13.2-34, step 4 and 5					
11	Set Default DAE	See §13.2.32, Table 13.2-79	The default was saved with RCA28 set to		B/D*	A/C*	ON



	configuration		zero Biases				cryo*[-28] zero 28
12	Perform Soft Switch on RCA28	See Warning 03 in § 13.1.2.3	Note that the Tuned Bias Values of RCA 28 must be uploaded. IOT is in charge to check the consistency of these values before uploading them.				ON cryo*
13	Start Channel Switching	See §13.2.6, Table 13.2-28 step 3.1					
14	Start of LFI monitor functions	See § 13.2.13, Table 13.2-42					
15			Wait for IOT confirmation		B/D*	A/C*	ON cryo*

Table 13.1-30 LFI to HFI susceptibility verification

Note that this procedure has to be reviewed after the results of the data analysis of TV/TB tests.

13.1.2.13 CONTINGENCY PROCEDURE FOR CPV

13.1.2.13.1 P/S SEPARATION NOT VISIBLE

If during the functional test is not visible any separation between the two traces of SKY and REF signal it might be possible that in the temperature configuration present during the test the P/S are matched. To ensure the functionality of the P/S units the I1 current must be modified and the following procedure shall be followed.

	Name of Procedure	Reference	Note	Time	4KHz	PS	Bias
1	Configure RCA Parameters	Table 13.2-28, step 2.7 to 2.8	Only I1 values are changed. LFI IOT is in charge to give AIT TAS-F the right table to be uploaded where the I1 values are stored	1 Min			
2			Check on TQL if separation is visible. Wait for IOT confirm	5 min			



13.1.2.13.2 SATURATION OF SCIENTIFIC SIGNAL

The aim of this procedure is to recover the output of the scientific signal if saturation occurs. This might be the case during CRYO-01 where the temperature of the 4K load (REF sample) is quite high respect to the optical shield (SKY sample). To recover saturation a DAE offset could be applied to the RCA/Channel where the saturation is visible. LFI IOT is in charge to provide the correct numbers to be applied in the format agreed. The procedure to be followed is described in the following table:

	Name of Procedure	Reference	Note	Time	4KHz	PS	Bias
1	Configure RCA Parameters	Table 13.2-28, step 2.11 to 2.12	Apply correct values of DAE Offset to all Channels. In principle the DAE gain is kept to its minimum value (0h)	1 Min			

13.2 INSTRUMENT OPERATIONS PROCEDURES FOR NOMINAL OPERATIONS

In this paragraph the operation procedures of the LFI instrument during nominal operations are described. For each procedure a brief summary of its functions and a more detailed description of the whole procedure and of its steps are given.

A summary of the Operations Procedure of the LFI instrument during nominal operations is reported in the table below.

PROCEDURE NAME	DESCRIPTION	PROCEDURE	STATUS	NOTE
REBA ASW INIT	Paragraph 13.2.2	Table 13.2-20	Done	
REBA SYNCHRONIZATION	Paragraph 13.2.3	Table 13.2-22	Done	
RAA ON CHECK AND CONNECTION TO REBA	Paragraph 13.2.4	Table 13.2-24	Done	
RAA SYNCHRONIZATION	Paragraph 13.2.5	Table 13.2-26	Done	
RCA ACTIVATION, RCA DE-ACTIVATION	Paragraph 13.2.6	Table 13.2-28	Done	
UPDATE OF THE RCA PARAMETERS	Paragraph 13.2.7	Table 13.2-30	Done	
UPDATE OF THE DEFAULT RCA SETTINGS	Paragraph 13.2.8	Table 13.2-32	Done	
SCIENCE ACTIVATION	Paragraph 13.2.9	Table 13.2-34	Done	
CHANGE SCIENCE PROCESSING PARAMETERS	Paragraph 13.2.10	Table 13.2-36	Done	



SCIENCE DE-ACTIVATION	Paragraph 13.2.11	Table 13.2-38	Done	
DEFINITION OF THE SCIENCE PROCESSING PARAMETERS	Paragraph 13.2.12	Table 13.2-40	Done	
STARTING THE MONITORING FUNCTIONS	Paragraph 13.2.13	Table 13.2-42	Done	
VERIFYING THE MONITORING FUNCTIONS	Paragraph 13.2.14	Table 13.2-44	Done	
ENABLING THE AUTONOMOUS FUNCTIONS	Paragraph 13.2.15	Table 13.2-46	Done	
TESTING THE AUTONOMOUS FUNCTIONS	Paragraph 13.2.16	Table 13.2-48	Done	
SETTING THE TELEMETRY RATE	Paragraph 13.2.17	Table 13.2-50	Done	
DISABLING THE AUTONOMOUS FUNCTIONS	Paragraph 13.2.18	Table 13.2-52	Done	
DISABLING THE MONITORING FUNCTIONS	Paragraph 13.2.19	Table 13.2-54	Done	
EVENT PACKETS ENABLING	Paragraph 13.2.20	Table 13.2-56	Done	
SCIENCE DC-DC SWITCH OFF	Paragraph 13.2.21	Table 13.2-58	Done	
RAA OFF CHECK	Paragraph 13.2.22	Table 13.2-60	Done	
REBA AND RAA POWER ON/OFF BY THE SATELLITE	Paragraph 13.2.23	Table 13.2-61	Done	
RESETTING THE TELEMETRY COUNTER	Paragraph 13.2.24	Table 13.2-63	Done	
INIZIALIZATION	Paragraph 13.2.25	Table 13.2-65	Done	
SCIENCE DC-DC CONVERTERS SWITCH ON	Paragraph 13.2.26	Table 13.2-67	Done	
SPU CONNECTION	Paragraph 13.2.27	Table 13.2-69	Done	
DEFINITION OF THE N AVE SCIENCE PROCESSING PARAMETERS	Paragraph 13.2.28	Table 13.2-71	Done	
SCRUB REBA MEMORIES	Paragraph 13.2.29	Table 13.2-73	Done	
UPDATE ALL DEFAULT RCA SETTINGS	Paragraph 13.2.30	Table 13.2-75	Done	
SET SCIENCE PROCESSING MODES	Paragraph 13.2.31	Table 13.2-77	Done	
SET DEFAULT DAE CONFIGURATION	Paragraph 13.2.32	Table 13.2-79	Done	
REBA TM DIAGNOSTIC	Paragraph 13.2.33	Table 13.2-81	Done	

Table 13.2-7 Summary of the LFI instrument procedures (nominal operations)

All these procedures are required in order to operate the LFI during the nominal operation period. In fact the procedures that most probably will be applied are the ones corresponding to the transitions between the various modes (described in details in chapter 8) which are a combination of the procedures described in Table 13.2-7 and in the following paragraphs (13.2.2 to 13.2.22) and corresponding tables. For this purpose the next paragraph (13.2.1) is dedicated to the procedures necessary to define the transition between the different LFI modes.



13.2.1 LFI TRANSITION PROCEDURES

The procedures corresponding to the transitions between the LFI operation modes are given in the following paragraphs as specified in the Figure 13-1 and in the table below.

Operating Mode Transition	Nominal Operations	Reference Tables	Procedure Name
OFF to Standby	Paragraph 13.2.1.1 Par. 13.2.23 Par. 13.2.2 Par. 13.2.20 Par. 13.2.3	Table 13.2-9 Table 13.2-61 Table 13.2-20 Table 13.2-56 Table 13.2-22	REBA Power On by the Satellite REBA ASW Init Event Packet Enabling REBA Synchronization
Standby to OFF	Paragraph 13.2.1.2 Par. 13.2.23	Table 13.2-10 Table 13.2-61	REBA Power Off by the Satellite
Standby to DAE Set-up	Paragraph 13.2.1.3 Par. 13.2.23 Par. 13.2.4 Par. 13.2.5	Table 13.2-11 Table 13.2-61 Table 13.2-24 Table 13.2-26	RAA Power On by the Satellite RAA On Check and Connection to REBA RAA Synchronization
DAE Set-up to Standby	Paragraph 13.2.1.4 Par. 13.2.23 Par. 13.2.22	Table 13.2-12 Table 13.2-61 Table 13.2-60	RAA Power Off by the Satellite RAA Off Check
DAE Set-up to Normal Science	Paragraph 13.2.1.7 Par. 13.2.17 Par. 13.2.31 Par. 13.2.12 Par. 13.2.9 Par. 13.2.26 Par. 13.2.6 Par. 13.2.13	Table 13.2-15 Table 13.2-50 Table 13.2-77 Table 13.2-40 Table 13.2-34 Table 13.2-67 Table 13.2-28 Table 13.2-42	Setting the Telemetry Rate Set Science processing type Definition of the Science Processing Parameters Science Activation Science DC-DC Switch on RCA Activation Starting the Monitoring Functions
Normal Science to DAE Set-up	Paragraph 13.2.1.8 Par. 13.2.19 Par. 13.2.6	Table 13.2-16 Table 13.2-54 Table 13.2-28	Disabling the Monitoring Functions RCA De-activation



	Par. 13.2.11 Par. 13.2.21	Table 13.2-38 Table 13.2-58	Science De-activation Science DC-DC switch off
Extended Science to Normal Science	Paragraph 13.2.1.9 Par. 13.2.17	Table 13.2-17 Table 13.2-50	Setting the Telemetry Rate
Normal Science to Extended Science	Paragraph 13.2.1.10 Par. 13.2.17	Table 13.2-18 Table 13.2-50	Setting the Telemetry Rate

Table 13.2-8 Summary of the transition procedures with the corresponding paragraph and table references. In parenthesis the reference to the specific procedures as described in more details in the next paragraphs

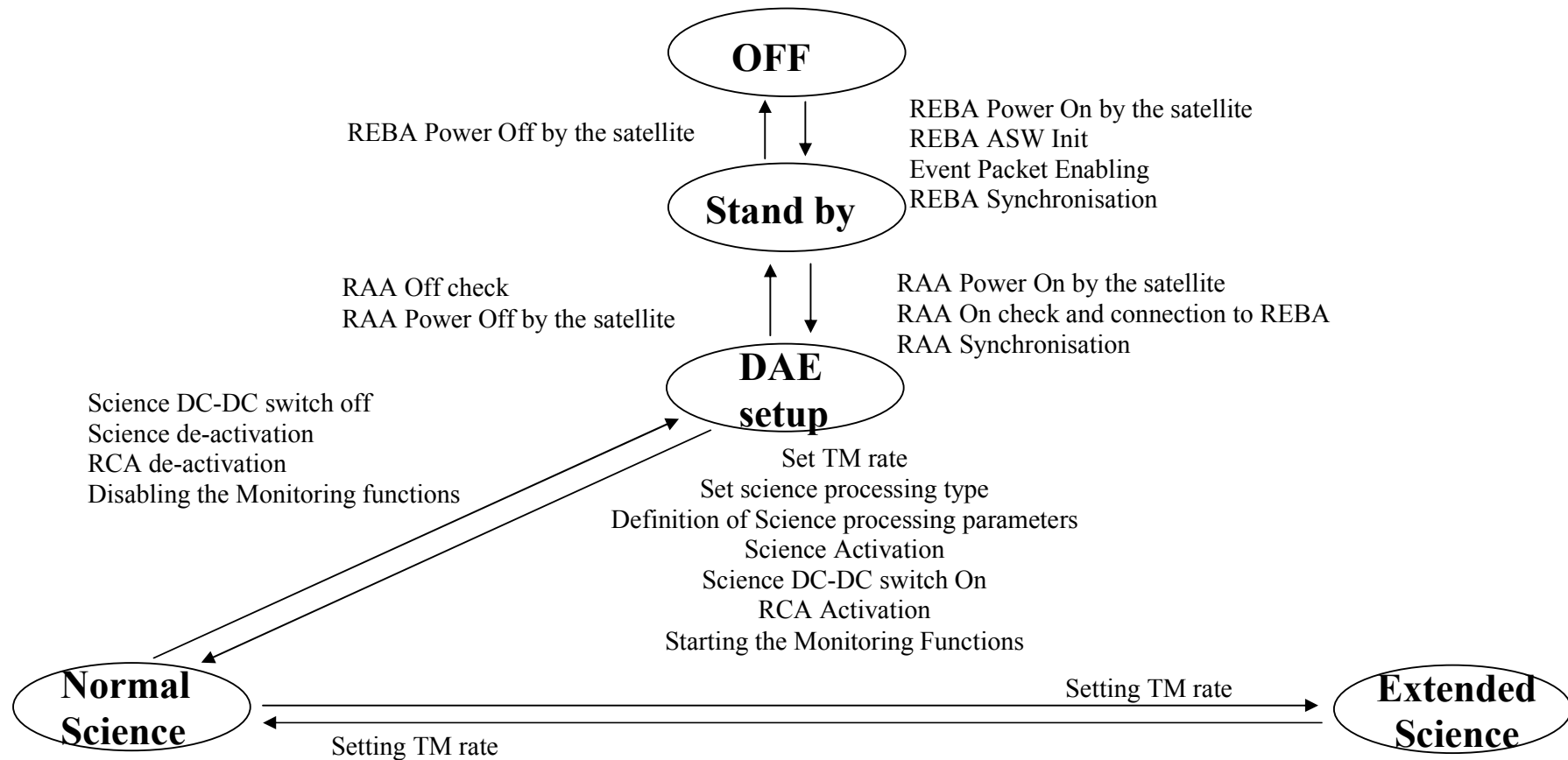


Figure 13-1 LFI transition procedures



13.2.1.1 OFF TO STANDBY

This is the first step to switch on the LFI and bring the LFI from the OFF to the STANDBY mode.

The procedure consists of four steps:

1. REBA POWER ON BY THE SATELLITE	see procedure in Table 13.2-61
2. REBA ASW INIT	see procedure in Table 13.2-20
3. EVENT PACKET ENABLING	see procedure in Table 13.2-56
4. REBA SYNCHRONIZATION	see procedure in Table 13.2-22

Topic	Description	Note
Purpose	To bring the LFI from the OFF to the STANDBY mode.	PFLN SON
Constraints on use	The RAA power supply should not be applied for safety reason. Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is powered ON by the satellite; the RAA is OFF.	
Initial satellite state	LFI in OFF mode	
End satellite state	LFI in STANDBY mode	
Reference procedures	1. REBA power on by the satellite	see Table 13.2-61



	2. REBA ASW Init	see Table 13.2-20
	3. Event packet enabling	see Table 13.2-56
	4. REBA synchronization	see Table 13.2-22
Procedure predecessors	None	
Contingency procedures		

Table 13.2-9 Summary of the transition procedure from the LFI OFF to STANDBY mode

13.2.1.2 STANDBY TO OFF

This is the last step to switch off the LFI and bring the LFI from the STANDBY to the OFF mode.

The procedure consists of one single step:

1. REBA POWER OFF BY THE SATELLITE see procedure in Table 13.2-61

Topic	Description	Note
Purpose	To bring the LFI from the STANDBY to the OFF mode.	PFLNSOF
Constraints on use	The power supply to the RAA should be removed. Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	Less than 5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is ON and synchronized; the RAA is OFF.	
Initial satellite state	LFI in STANDBY mode	



End satellite state	LFI in OFF mode	
Reference procedures	1. REBA power off by the satellite	see Table 13.2-61
Procedure predecessors	DAE setup to Standby	
Contingency procedures		

Table 13.2-10 Summary of the transition procedure from the LFI STANDBY to OFF mode

13.2.1.3 STANDBY TO DAE SET-UP

This procedure brings the LFI from the STANDBY to the DAE Set-up mode.

The procedure consists of three steps:

1. RAA POWER ON BY THE SATELLITE see procedure in Table 13.2-61
2. RAA ON CHECK AND CONNECTION TO REBA see procedure in Table 13.2-24
3. RAA SYNCHRONIZATION see procedure in Table 13.2-26

Topic	Description	Note
Purpose	To bring the LFI from the STANDBY to the DAE Set-up mode.	PFLNSDN
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is ON and synchronized; the RAA is powered ON by the satellite.	
Initial satellite state	LFI in STANDBY mode	



End satellite state	LFI in DAE Set-up mode	
Reference procedures	1. RAA power on by the satellite 2. RAA on check and connection to REBA 3. RAA synchronization	see Table 13.2-61 see Table 13.2-24 see Table 13.2-26
Procedure predecessors	OFF to Standby	
Contingency procedures		

Table 13.2-11 Summary of the transition procedure from the LFI STANDBY to DAE SET-UP mode

13.2.1.4 DAE SET-UP TO STANDBY

This procedure brings the LFI from the DAE Set-up to the STANDBY mode.

The procedure consists of two steps:

1. RAA POWER OFF BY THE SATELLITE see procedure in Table 13.2-61
2. RAA OFF CHECK see procedure in Table 13.2-60

Topic	Description	Note
Purpose	To bring the LFI from the DAE Set-up to the STANDBY mode.	PFLNSSF
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	Less than 5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is ON and synchronized; the RAA is ON, connected to the REBA and	



	synchronized; no RCA is active.	
Initial instrument state	LFI in DAE Set-up mode	
End instrument state	LFI in STANDBY mode	
Reference procedures	1. RAA power off by the satellite 2. RAA off check	see Table 13.2-61 see Table 13.2-60
Procedure predecessors	Normal Science to DAE setup or Extended Science to DAE setup	
Contingency procedures		

Table 13.2-12 Summary of the transition procedure from the LFI DAE SET-UP to STANDBY mode

13.2.1.5 DAE SET-UP TO EXTENDED SCIENCE

N/A

Topic		
Purpose		
Constraints on use		
Time criticality		
Expected duration		
Ground Equipment pre-requisites		
Satellite pre-requisites		
LFI instrument pre-requisites		
Initial satellite state		
End satellite state		
Reference procedures		



Procedure predecessors		
Contingency procedures		

Table 13.2-13 Summary of the transition procedure from the LFI DAE SET-UP to EXTENDED SCIENCE mode N/A

13.2.1.6 EXTENDED SCIENCE TO DAE SET-UP

N/A

Topic	Description	Note
Purpose		
Constraints on use		
Time criticality		
Expected duration		
Ground Equipment pre-requisites		
Satellite pre-requisites		
LFI instrument pre-requisites		
Initial satellite state		
End satellite state		
Reference procedures		
Procedure predecessors		
Contingency procedures		

Table 13.2-14 Summary of the transition procedure from the LFI EXTENDED SCIENCE to DAE SET-UP mode

13.2.1.7 DAE SET-UP TO NORMAL SCIENCE

This procedure brings the LFI from the DAE Set-up to the NORMAL SCIENCE mode.



The procedure consists of seven steps:

1. SETTING THE TELEMETRY RATE	see procedure in Table 13.2-50
2. SET SCIENCE PROCESSING TYPE	see procedure in Table 13.2-77
3. DEFINITION OF THE SCIENCE PROCESSING PARAMETERS	see procedure in Table 13.2-40
4. SCIENCE ACTIVATION	see procedure in Table 13.2-34
5. SCIENCE DC-DC SWITCH ON	see procedure in Table 13.2-67
6. RCA ACTIVATION	see procedure in Table 13.2-28
7. STARTING OF THE MONITORING FUNCTIONS	see procedure in Table 13.2-42

Topic	Description	Note
Purpose	To bring the LFI from the DAE Set-up to the NORMAL SCIENCE mode.	PFLCSNN
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	30 minutes	TBC Assuming the parameters are already defined and loaded as TPF
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is ON and synchronized; the RAA is ON, connected and synchronized to the REBA that manages the LFI; all RCAs are active.	
Initial satellite state	LFI in DAE Set-up mode	
End satellite state	LFI in NORMAL SCIENCE mode	



Reference procedures	1. Setting the telemetry rate 2. Set science processing type 3. Definition of the science processing parameters 4. Science activation 5. Science DC-DC switch on 6. RCA activation 7. Starting of the monitoring functions	see Table 13.2-50 see Table 13.2-77 see Table 13.2-40 see Table 13.2-34 see Table 13.2-67 see Table 13.2-28 see Table 13.2-42
Procedure predecessors	Standby to DAE Setup	
Contingency procedures		

Table 13.2-15 Summary of the transition procedure from the LFI DAE SET-UP to NORMAL SCIENCE mode

13.2.1.8 NORMAL SCIENCE TO DAE SET-UP

This procedure brings the LFI from the NORMAL SCIENCE to the DAE Set-up mode.

The procedure consists of four steps:

1. DISABLING THE MONITORING FUNCTIONS	see procedure in Table 13.2-54
2. RCA DE-ACTIVATION	see procedure in Table 13.2-28 (*)
3. SCIENCE DE-ACTIVATION	see procedure in Table 13.2-38
4. SCIENCE DC-DC SWITCH OFF	see procedure in Table 13.2-58

Topic	Description	Note
Purpose	To bring the LFI from the NORMAL SCIENCE to the DAE Set-up mode.	PFLCSDF
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC



Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is ON and synchronized; the RAA is ON, connected to the REBA and synchronized; all RCAs are active.	
Initial satellite state	LFI in NORMAL SCIENCE mode	
End satellite state	LFI in DAE Set-up mode	
Reference procedures	1. Disabling of the monitoring functions 2. RCA de-activation 3. Science de-activation 4. Science DC-DC switch off	see Table 13.2-54 see Table 13.2-28 (*) see Table 13.2-38 see Table 13.2-58
Procedure predecessors	N/A	
Contingency procedures		

Table 13.2-16 Summary of the transition procedure from the LFI NORMAL SCIENCE to DAE SET-UP mode

Note (*): For the de-activation the procedure is the same as the activation but the values to be set are those that power off the RCA items

13.2.1.9 EXTENDED SCIENCE TO NORMAL SCIENCE

This procedure brings the LFI from the EXTENDED SCIENCE to the NORMAL SCIENCE mode.

The procedure consists of a single steps:

1. SETTING THE TELEMETRY RATE see procedure in Table 13.2-50(*)

Topic	Description	Note



Purpose	To bring the LFI from the EXTENDED SCIENCE to the NORMAL SCIENCE mode.	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is ON and synchronized; the RAA is ON, connected to the REBA and synchronized; all RCAs are active.	
Initial satellite state	LFI in EXTENDED SCIENCE mode	
End satellite state	LFI in NORMAL SCIENCE mode	
Reference procedures	1. Setting the telemetry rate	see Table 13.2-50 ^(*)
Procedure predecessors	DAE Setup to Extended Science	
Contingency procedures		

Table 13.2-17 Summary of the transition procedure from the LFI EXTENDED SCIENCE to NORMAL SCIENCE mode

Note ^(*): To go from the “extended science mode” to the “normal Science mode”, the procedure is the same as to go from the “normal Science mode” to the “extended science mode” (see next paragraph 13.2.1.10), but the values to be set are those corresponding to the normal science mode (48 kbps for Normal Science, > 48 kbps for Extended Science Mode).

13.2.1.10 NORMAL SCIENCE TO EXTENDED SCIENCE

This procedure brings the LFI from the NORMAL SCIENCE to the EXTENDED SCIENCE mode.



The procedure consists of a single steps:

1. SETTING THE TELEMETRY RATE see procedure in Table 13.2-50

Topic	Description	Note
Purpose	To bring the LFI from the NORMAL SCIENCE to the EXTENDED SCIENCE mode.	
Constraints on use	The share of allowed science telemetry between HFI and LFI is suitably updated. Procedure to be applied during the visibility period (DTCP).	Allowed science TM > 48 kbps
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is ON and synchronized; the RAA is ON, connected to the REBA and synchronized; all RCAs are active.	
Initial satellite state	LFI in NORMAL SCIENCE mode	
End satellite state	LFI in EXTENDED SCIENCE mode	
Reference procedures	1. Setting the telemetry rate	see Table 13.2-50
Procedure predecessors	DAE Setup to Normal Science	
Contingency procedures		

Table 13.2-18 Summary of the transition procedure from the LFI NORMAL SCIENCE to EXTENDED SCIENCE mode



13.2.2 REBA ASW INIT

The REBA ASW Init procedure is described in the tables below.

Topic	Description	Note
Purpose	First step to activate LFI. To activate the REBA, verify that is “alive” and it is able to communicate on the 1553B S/C bus, receiving TLCs and sending TLM packets.	PFLN SON step 8 to 21
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	LFI REBA Power On (see procedure in § 13.2.23, Table 13.2-61)	Only the Nominal or Redundant REBA can be powered On
Initial satellite state	LFI unknown state: intermediate between OFF and Standby Mode (REBA is on but software is not initialised)	see Table 13.2-9
End satellite state	LFI Standby Mode	
Reference procedures	1. REBA ASW Init	see Table 13.2-20
Procedure predecessors	REBA Power On by the Satellite	
Contingency procedures		



Table 13.2-19 Summary of the REBA ASW Init procedure

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the arrival of Telemetry Packets	REBA SUSW HK TM(3,25), SID=201		The Ground Segment receives the packet ID 120201342 once per second	Less than 30 s	See Contingency Procedure
1a	Check current			Verify the Power of REBA ≤ 0.5 A @28 Volt (see parameter WM809565)		
1b	Check REBA power consumption	Planck LFI REBA Susw HK TM(3,25)		In packet ID 120201342, LM101342=0001h LM121342=30°C±10°C LM122342=30°C±10°C LM123342=30°C±10°C LM124342=1.9°±10% LM125342=40mA±10% LM126342=30mA±10% LM127342=0.0230mA LM128342=5V±10% LM129342=15V±10% LM130342=-15V±10% LM131342=-15V±10% LM132342=0.9V±10% LM133342=9.2V±10% LM104342=00 01h LM105342=01 04h LM107342=All Zero LM108342=All zero parameters LFI Status TH1-TM(SPUBoard) TH1-TM(DPUBoard) TH1-TM(PSUBoard) VCC_Current TM 15VP Current TM 15VN Current TM 15VN 1553 Curr. TM VCC V TM 15VP V TM 15VN V TM 15VN 1553 V TM Voffset TM Vgain TM Software ID DPU sw version DPU SUSW Errors DPU SUSW Errors		
2	Verify the connection	Test Connection TC(17,1)	LC216320	Receive Packets ID 120011342 and 120172340		
3	Check Error	Memory	LC214320	Receive Packets ID 120011342 and 120017342	No delay	No automatic



	Detection Parameter: Memory Dump performed on DPU Data RAM in order to check its integrity	Dump TC(6,5)	parameters LP139320 = 1100h LP140320 = 0h LP141320 = 11h	and 120066369 with contents LM050369=1100h LM051639= 0000h LM052369=0011h LM053369=0000 0001h LM054369=03F7 FFFFh LM055369=0000 8B69h LM056369=0000 8B69h LM057369=0000 0000h LM058639=0000 0000h LM059369=0000 0000h LM060369=00000000h (according to sw version)		recovery is recommended . Please notify the wrong result to IOT/IAC and try to power REBA off and on again. If TC failure see Note ⁽⁰⁾ ;
4	Check the EEPROM content	Memory Check TC(6,9)	LC215320 parameters LP142320 = 300h LP143320 = 0h LP144320 = af50h (according to sw version)	Receive Packets ID 120011342 and 120017342 and 120610369 with contents LM073369=61a9h (according to sw version)	No delay	If TC failure see Note ⁽⁰⁾ ; If wrong checksum: manual recovery
5	Load ASW command, The application software is copied from EEPROM to DPU RAM in 6 steps. Parameters change according to sw version (DPU 2.6)		TC(8,4), FID=00h, Activity ID=201, SID=5			
5.1	Load DPU ASW	Load ASW TC(8,4)	LC030320 parameters	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If TC failure see Note ⁽⁰⁾



			LP150320 = 3h LP151320 = 0h LP152320 = 11h LP153320 = 30000h LP154320 = 1032h			
5.2	Load DPU ASW	Load ASW TC(8,4)	LC030320 parameters LP150320 = 3h LP151320 = 1032h LP152320 = 11h LP153320 = 3FC00h LP154320 = 8h	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If TC failure see Note ⁽⁰⁾
5.3	Load DPU ASW	Load ASW TC(8,4)	LC030320 parameters LP150320 = 3h LP151320 = 103Ah LP152320 = 1h LP153320 = 0h LP154320 = 100h	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If TC failure see Note ⁽⁰⁾
5.4	Load DPU ASW	Load ASW TC(8,4)	LC030320 parameters LP150320 = 3h LP151320 = 113Ah LP152320 = 1h LP153320 = 100h LP154320 = Fh	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If TC failure see Note ⁽⁰⁾
5.5	Load DPU ASW	Load ASW TC(8,4)	LC030320 parameters LP150320 = 3h	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If TC failure see Note ⁽⁰⁾



			LP151320 = 1149h LP152320 = 1h LP153320 = 200h LP154320 = 81h				
5.6	Load DPU ASW	Load ASW TC(8,4)	LC030320 parameters LP150320 = 3h LP151320 = 11Cah LP152320 = 1h LP153320 = 1000h LP154320 = 9D86h	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If TC failure see Note ⁽⁰⁾	
6	Start DPU ASW. The application software in the RAM is run.	Start ASW TC(8,1)	LC031320 parameters LP150320 = 1h LP155320 = 1002h	Verify the arrival of Telemetry Packets ID 120202369 once every 4 seconds	Less than 1 s	If TM is not arriving see Note ⁽⁰⁾ In case of wrong status of ASW go to power cycling.	
7	Verify the status of parameters DPU DSP HW error	REBA ASW HK TM(3,25)		Receive packet ID LM500340 = 0 LM206342=0002h LM207342=0260h LM501340=0h LM519340=0h LM520340=1h LM521340=1h LM523340=0h LM524340=0h LM525340=0h LM526340=0h LM527340=0h	120202369 parameters REBA HK ID DPU SW Version DPU ASW errors Monitoring Enabled Monitoring Enabled Monitoring Enabled Monitor Not Active Monitor Not Active Monitor Not Active AF is not running AF is not running	4 s	TBD



				LM528340=0h LM529340=0h LM543340=0000h LM544340=0004h LM544340=0005h LM546340=0000h LM547340=A800h LM548340=00h LM554350=0000h LM555350=0000h LM211342=30°C±10°C LM212342=30°C±10°C LM213342=30°C±10°C LM214342=2.75°±10% LM215342=40mA±10% LM216342=32mA±10% LM217342=0.023°±10% LM218342=5.0V±10% LM219342=15V±10% LM220342=-15V±10% LM221342=-15V±10% LM222342=0.8V±10% LM223342=9.2V±10%	AF is not running Monitor Errors DPU task Status DPU HK status: both values are correct DPU registers Error DPU HW Errors DPU FIFO Errors DPU SW Errors TH1 SPU Board TH1 DPU Board TH1 PSU Board VCC Current 15 VP Current 15 VN Current 15 VN 1553 Current VCC Voltage 15 VP voltage 15 VN voltage 15 VN 1553 Voltage V Offset V gain		
7a	REBA synchronization		See § 13.2.3	REBA synchronization achieved			
8	DPU connect to SPU		TC(8,4) FID=02h, Activity ID=7, SID=0		Less than 1 s (TBC)		
8.1	Reset DPU SMCS	Reset TC(8,4)	LC039320	Acknowledge by 120011342 (acceptance) 120017342 (execution)		If TC failure see Note ⁽⁰⁾	
8.2	DPU connect to SPU	Connect TC(8,4)	LC042320	Acknowledge by 120011342 (acceptance) 120017342 (execution)		If TC failure see Note ⁽⁰⁾ If acceptance failure see §	



8.3	Test high level connection DPU-SPU SUSW	Test the connection TC(8,4)	LC036320	Acknowledge by 120011342 (acceptance) 120017342 (execution)		13.3.2 If TC failure see Note ⁽⁰⁾ If acceptance failure see § 13.3.2
9	Verify the status of parameter Software ID	REBA HK TM(3,25)		Acknowledgement by Telemetry Packets ID 120202369, parameter LM206342=0102h LM543340=0080h DPU Task Status LM544340=0004h, 0005h DPU HK Status: TM values changing depending on which HK pkt the REBA is sending, Both values correct LM546340=0000h DPU HK errors	No delay	TBD
10	Check Error Detection Parameter. Memory Dump performed on SPU Data RAM in order to check its integrity.	Memory Dump TC(6,5)	LC214320 parameters LP139320 = 9100h LP140320 = 0h LP141320 = 11h	Receive Packets ID 120011342 and 120017342 and 120066369 with contents LM050369=9100h LM051639=0000h LM052369=0011h LM053369=0000 0001h LM054369=0007 FFFFh LM055369=0000 6823h LM056369=0000 6823h LM057369=0000 0000h LM058639=0000 0000h LM059369=0000 0000h LM060369=0000 0000h (according to sw version)	No delay	No automatic recovery is recommended . Please notify the wrong result to IOT/IAC and try to power REBA off and on again. If TC failure see Note ⁽⁰⁾ ,
11	Check the EEPROM content	Memory Check TC(6,9)	LC215320 parameters LP142320 = 301h LP143320 = 0h LP144320 = 6cceh	Receive Packets ID 120011342 and 120017342 and 120610369 with contents LM073369=49e8h (according to sw version)		If TC failure see Note ⁽⁰⁾ , If wrong checksum: manual



			(according to sw version)		recovery
12	Load SPU ASW from DPU EEPROM to SPU RAM. Parameters change according to sw version (SPU 2.3)		TC(8,4), FID=02h, Activity ID=105, SID=5		Less than 20 s
12.1	Load SPU ASW	Load ASW TC(8,4)	LC034320 parameters LP150320 = 3h LP151320 = 10000h LP152320 = 91h LP153320 = 30000h LP154320 = 06fah	Acknowledge by 120011342 (acceptance) 120017342 (execution)	If TC failure see Note ⁽⁰⁾
12.2	Load SPU ASW	Load ASW TC(8,4)	LC034320 parameters LP150320 = 3h LP151320 = 106fAh LP152320 = 91h LP153320 = 7FC00h LP154320 = 8h	Acknowledge by 120011342 (acceptance) 120017342 (execution)	If TC failure see Note ⁽⁰⁾
12.3	Load SPU ASW	Load ASW TC(8,4)	LC034320 parameters LP150320 = 3h LP151320 =	Acknowledge by 120011342 (acceptance) 120017342 (execution)	If TC failure see Note ⁽⁰⁾



			10702h LP152320 = 81h LP153320 = 0h LP154320 = 100h			
12.4	Load SPU ASW	Load ASW TC(8,4)	LC034320 parameters LP150320 = 3h LP151320 = 10802h LP152320 = 81h LP153320 = 100h LP154320 = Fh	Acknowledge by 120011342 (acceptance) 120017342 (execution)		If TC failure see Note ⁽⁰⁾
12.5	Load SPU ASW	Load ASW TC(8,4)	LC034320 parameters LP150320 = 3h LP151320 = 10811h LP152320 = 81h LP153320 = 200h LP154320 = 81h	Acknowledge by 120011342 (acceptance) 120017342 (execution)		If TC failure see Note ⁽⁰⁾
12.6	Load SPU ASW	Load ASW TC(8,4)	LC034320 parameters LP150320 = 3h LP151320 = 10892h LP152320 = 81h LP153320 = 1000h LP154320 = 643ch	Acknowledge by 120011342 (acceptance) 120017342 (execution)		If TC failure see Note ⁽⁰⁾
13	Start SPU ASW	Start ASW TC(8,1)	LC052320 parameters LP150320 = 81h LP155320 = 1002h	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If TM is not arriving see Note ⁽⁰⁾ In case of wrong status



						of ASW go to power cycling.
14	Verify the status of parameter Software ID	REBA HK TM(3,25)		Acknowledgement by Telemetry Packets ID 120202369 parameter LM206342 = 0202h LM206342=0202h SW Running LM556350=0230h SW Version (TBC) LM543340=00 C0h DPU Task Status LM544340=0004h, 0005h DPU HK Status: both values are correct LM546340=0000h DPU HK errors LM551340=0000h SMSC Errors LM552340=4007h DPU 1355 Link status LM553340=0000h 1355 Commun LM579350=A800h SPU register error LM580350=0000h SPU HW errors LM591350=0000h SPU FIFO errors LM592350=0000h SPU SW errors LM586350=0000h SMSC Errors LM587350=000Fh SPU 1355 Link status LM588350=0000h 1355 Link error LM202342=05h LFI in Stand By mode	No delay	TBD
15	Check current			Verify the Power of REBA is 815 mA $\pm 10\%$ @28 Volt (see parameter WM809565)		

Table 13.2-20 REBA ASW Init

Note (0) In case of TC failure, see Par. 13.3.3, item # 1.



13.2.3 REBA SYNCHRONIZATION

The REBA synchronization procedure is described in the tables below.

Topic	Description	Note
Purpose	To synchronize the REBA.	PFLN SON step 23 The procedure written below is the LFI internal procedure which is different from the one produced by MOC
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA power is on, REBA ASW is initialized (see Table 13.2-19).	
Initial satellite state	LFI Standby Mode	see Table 13.2-9
End satellite state	LFI Standby Mode	
Reference procedures	1. REBA synchronization	see Table 13.2-22
Procedure predecessors		
Contingency procedures		

Table 13.2-21 Summary of the REBA synchronization procedure



STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Enable REBA time synchronization	Enable Time Synch TC(9,4)	LC213320	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	
2	Set the Time Code (*)	Set Time TC(9,5)	LC089320 parameter LP171320 = OBT coarse time, parameter LP172320 = OBT fine time	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If execution is failed 128039340, repeat step 1 TBC
3	Verify the REBA synchronization	Verify Time TC(9,7)	LC090320	Acknowledge by 120011342 (acceptance) 120017342 (execution) Receive packet ID 120099320 parameter LM004320 = OBT (4 byte coarse + 2 byte fine)	Less than 1 s	
4	Check the REBA time with a TBD reference time		TBD by the MCS	The two times should agree within 10 s		

Table 13.2-22 REBA synchronization

(*) Note that this telecommand is produced by CDMS once the TM(9,9) is sent from ground [AD-1].

13.2.4 RAA ON CHECK AND CONNECTION TO RAA

In this paragraph the RAA On check and connection to REBA procedure is described as reported in the tables below.

Topic	Description	Note



Purpose	To connect the DAE with the REBA and verify that they are able to communicate through the 1355 I/Fs.	PFLNSDN step 1, 3, 4
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	2 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA powered, ASW running and synchronized RAA power on (see § 13.2.23, Table 13.2-61).	
Initial satellite state	LFI Stand-by Mode (TBC)	
End satellite state	LFI DAE Set-Up Mode	
Reference procedures	1. RAA On check and connection to REBA	see Table 13.2-24
Procedure predecessors		
Contingency procedures		

Table 13.2-23 Summary of the RAA switch-On and connection to REBA

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the LFI status	REBA HK TM(3,25)		Receive Packet ID 120202369 and verify parameter LM202342 = 101b	4 s	Check REBA synchronization, see Table 13.2-22 steps 3 and 4
2	Reset DAE SMSC 2	Reset SMCS2	LC041320	Receive Packets ID 120011342 and 120017342		



3	Reset DAE SMSC 1	TC(8,4) Reset SMCS1 TC(8,4)	LC040320	Receive Packets ID 120011342 and 120017342		
4	Reset DPU SMCS	Reset DPU SMCS TC(8,4)	LC039320	Receive Packets ID 120011342 and 120017342		
5	DPU connect to SPU	Connect TC(8,4)	LC042320	Receive Packets ID 120011342 and 120017342		
6	Start DAE control	Start DAE control TC(8,1)	LC004320	Receive Packets ID 120011342 and 120017342		
7	Start DAE HK sequencer	Start DAE HK sequencer TC(8,4)	LC063320	Receive Packets ID 120011342 and 120017342		
8	Start DAE HK acquisition software task. From this point onward, the DAE HK TM is acquired with a frequency of 1 Hz and available every 4 s	Start DAE HK acquisition TC(8,1)	LC005320	Receive Packets ID 120011342 and 120017342 and 120102369 (note: cyclically every 4 s)		
9	Verify TM	Planck LFI REBA HK TM(3,25)		Receive packet ID parameters LM543340=00F0h LM546340=0000h LM551340=0000h LM552340=6FF7h	120202369 with DPU Task Status DPU HK errors DPU 1355 SMCS DPU 1355 Status	
10	Verify TM	Planck LFI REBA HK TM(3,25)		LM101332=30°C±10 LM102332=30°C±10 LM105332=5V±10%	Service DC/DC temp Science 1 temp Service V out	



				LM107332=0.47A±10%	Service Primary current		
				LM108332=30°C±10	Science 2 temp		
				LM111332=30°C±10	Science 3 temp		
				LM114332=30°C±10	Science 4 temp		
				LM207332=30°C±10	Left Bem Temp		
				LM209332=30°C±10	Left Fem temp		
				LM211332=30°C±10	Left DAQ temp		
				LM307332=30°C±10	Right Bem Temp		
				LM309332=30°C±10	Right Fem temp		
				LM311332=30°C±10	Right DAQ temp		
				LM401328=0h	PING Status		
				LM402328=0h	PONG Status		
				LM411328=02h	GPIO-1 Status		
				LM413328=02h	GPIO-1 Status		
				LM421332=0h	Science DC/DC 1 status		
				LM422332=0h	Science DC/DC 2 status		
				LM423332=0h	Science DC/DC 3 status		
				LM424332=0h	Science DC/DC 4 status		

Table 13.2-24 RAA On check and connection to REBA

13.2.5 RAA SYNCHRONIZATION

In this paragraph the RAA synchronization procedure is described as reported in the tables below.

Topic	Description	Note
Purpose	To connect the DAE with the REBA and synchronize the DAE time with the REBA time.	PFLCATX step 2, 3
Constraints on use	Procedure to be applied during the visibility period (DTCP).	



Time criticality	No criticalities	
Expected duration	2 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA powered, ASW running and synchronized RAA power on (see § 13.2.23, Table 13.2-61).	
Initial satellite state	LFI DAE Set-up Mode	
End satellite state	LFI DAE Set-Up Mode	
Reference procedures	1. RAA synchronization	see Table 13.2-26
Procedure predecessors		
Contingency procedures		

Table 13.2-25 Summary of the RAA synchronization procedure

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Synchronize DAE OBT	TC(8,4)	LC061320	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If TC failure see Note ⁽⁰⁾
2	Verify DAE OBT	TC(8,4)	LC062320	Acknowledge by 120011342 (acceptance) 120017342 (execution)	Less than 1 s	If TC failure see Note ⁽⁰⁾

Table 13.2-26 RAA synchronization

Note (0) In case of TC failure, see Par. 13.3.3, item # 1.



13.2.6 RCA ACTIVATION AND DE-ACTIVATION

In this paragraph the RCA activation and de-activation procedures are described as reported in the tables below.

Topic	Description	Note
Purpose	To set the RCA settings stored in the REBA.	PFLCSRC,PFLCSWA, PFLCSWD
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA DPU established and synchronized.	
Initial satellite state		
– RCA activation	- LFI Normal or Extended Science Mode	see Table 13.2-13, Table 13.2-15
– RCA de-activation	- LFI Normal or Extended Science Mode	see Table 13.2-14, Table 13.2-16
End satellite state		
– RCA activation	- LFI Normal or Extended Science Mode	
– RCA de-activation	- LFI Normal or Extended Science Mode	
Reference procedures	1. RCA activation	see Table 13.2-28



	2. RCA de-activation	see Table 13.2-28
Procedure predecessors		
Contingency procedures		

Table 13.2-27 Summary of the procedures to activate and de-activate RCAs

Note this activity does not foresee the activation of science processing (see Table 13.2-34 for this action).

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVER Y
1	Verify the corresponding power group (Science DC-DC) 1 to 4 is ON (according to the order in table in § 6.2.1.3.4.1).	DAE Fast HK TM(3,25)		In the packet 120102369 the corresponding parameters LM421332, or LM422332, or LM423323, or LM424332 = 1	64 s	
2	Configure the RCA parameters. At the first switch on, the values are the ones that will result from the CPV phase. Up to that moment the TPF files (containing the values of the parameters) will not be final.					If TC failure see Note ⁽⁰⁾
2.1	Configure Vgate1 that is the gate voltage of the first amplifier stage in each FEM	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C1Dh (Vgate1) (*)	Receive Packets ID and 120011342 120017342		



2.2	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM001322 to LM044322		
2.3	Configure Vgate2 that is the gate voltage of the second amplifier stage in each FEM	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C1Eh (Vgate2) (*)	Receive Packets ID 120011342 and 120017342		
2.4	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM101322 to LM144322		
2.5	Configure Voltage drain of each amplifier of the FEMs	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C1Fh (Drain) (*)	Receive Packets ID 120011342 and 120017342		
2.6	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM201322 to LM244322		
2.7	Configure Iswitch1 that	Configure DAE	LC121320	Receive Packets ID		



	is the current that drives the first diode of each phase shifter	TC(8,4)	parameter LP158320 = C20h (Iswitch1) (*)	120011342 and 120017342		
2.8	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM151322 to LM194322		
2.9	Configure Iswitch2 that is the current that drives the second diode of each phase shifter	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C21h (Iswitch2) (*)	Receive Packets ID 120011342 and 120017342		
2.10	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM401322 to LM444322		
2.11	Configure Offset that is the offset circuitry of DAE before ADC converter	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C23h (Offset) (*)	Receive Packets ID 120011342 and 120017342		
2.12	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters		



				from LM101326 to LM144326		
2.13	Configure Gain that is the gain circuitry of DAE before ADC converter	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C22h (Gain) (*)	Receive Packets ID 120011342 and 120017342		
2.14	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM001326 to LM044326		
2.15	Configure Pol A-C that sets the polarization status A-C phase shifters	Configure DAE TC(8,4)	LC128320 parameter LP159320 = C26h (Pol A-C) (*)	Receive Packets ID 120011342 and 120017342		
2.16	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM301322 to LM311322		
2.17	Configure Pol B-D that sets the polarization status B-D phase shifters	Configure DAE TC(8,4)	LC128320 parameter LP159320 = C27h (Pol B-D) (*)	Receive Packets ID 120011342 and 120017342		
2.18	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1,	Receive Packets ID 120011342, 120017342 and check the correctness		



			LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	of the uploaded parameters in packet ID 121101369 parameters from LM321322 to LM331322		
2.19	Configure En/Dis A-C that sets 4 kHz switching of the A-C phase shifters	Configure DAE TC(8,4)	LC128320 parameter LP159320 = C24h (En/Dis A-C) (*)	Receive Packets ID 120011342 and 120017342		
2.20	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM251322 to LM261322		
2.21	Configure En/Dis B-D that sets 4 kHz switching of the B-D phase shifters	Configure DAE TC(8,4)	LC128320 parameter LP159320 = C25h (En/Dis B-D) (*)	Receive Packets ID 120011342 and 120017342		
2.22	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM451322 to LM461322		
3	Starting and stopping the calibration channel switching. See § 15.1.3 for a description. Note					



	that science must already be started.				
3.1	Starting the calibration channel switching (RCA activation)	Start calibration channel switching TC(8,1) (****)	LC010320	Receive Packets ID 120011342, 120017342 and in packet ID 120202369, parameter LM559350 = 0, LM596350 = Fh, LM576350 = 7h	If failure see § 13.3.2. If TC acceptance failure see Note ⁽⁰⁾
3.2	Stopping the calibration channel switching Starting the calibration channel switching (RCA de-activation)	Stop calibration channel switching TC(8,2) (****)	LC021320	Receive Packets ID 120011342, 120017342 and in packet ID 120202369, parameter LM559350 = 0, LM596350 = Fh, LM576350 = 3h	If failure see § 13.3.2. If TC acceptance failure see Note ⁽⁰⁾

Table 13.2-28 The RCA activation (de-activation ())**

(*) Fill all the remaining parameters of the command with the corresponding values of the selection mask and the corresponding item

(**) For the de-activation the procedure is the same but the values to be set are those that power off the RCA items

(****) Select procedure 3.1 for the RCA activation and 3.2 for the RCA de-activation.

Note (0) In case of TC failure, see Par. 13.3.3, item # 1.

Note 1:

Depending on the SID, configuration values and configuration mask may refer to detectors, horns or DC/DC converters. If SID refers to detectors the 44 parameter values of the list and the 44 bits of configuration mask are used; if SID refers to horns only 11 values of the list and 11 bits of configuration mask are used leaving the rest as spare. SID referring to DC/DC converters are not used in this context.

For a detailed explanation of how masks should be filled, refer to [AN1], “Appendix B – SCOS 2K MASK PARAMETERS”.



That is,

Configuration mask definition

Bit 0 (MSB) to Bit 63 (LSB) defines the detector, horn or DC/DC converter affected by the TC. This depends on the SID.

- If SID refers to configuration of detectors (SIDs 3101 to 3107):

Bit (i) = 1, for i=0 to 43, sets a value for detector i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 43, means detector i is not affected by the TC.

Bit (i), for i=44 to 63 spare (not used, set to zero)

- If SID refers to configuration of horns (SIDs 3108 to 3111):

Bit (i) = 1, for i=0 to 10, sets a value for horn i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 10, means horn i is not affected by the TC.

Bit (i), for i=11 to 63 spare (not used, set to zero)

Note 2:

a) Detector mask definition

Bit 0 (MSB) to Bit 63 (LSB) defines the detector affected by the TC.

Bit (i) = 1, for i=0 to 43, sets a value for detector i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 43, means detector i is not affected by the TC.

Bit (i), for i=44 to 63 spare (not used, set to zero)

b) Horn mask definition

Bit 0 (MSB) to Bit 15 (LSB) defines the horn affected by the TC.

Bit (i) = 1, for i=0 to 10, sets a value for horn i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 10, means radiometer i is not affected by the TC.

Bit (i), for i=11 to 15 spare (not used, set to zero)



The structure of the data field of packet is given in the following tables for the three corresponding cases: detectors and RCAs.

Application Data for Detectors		
DATA	SIZE	COMMENTS
Function ID	1 byte	23h
Activity ID	1 byte	2h
SID	2 bytes	3101÷3107
Ch0	2 bytes	0 – 255
Ch1	2 bytes	0 – 255
Ch2	2 bytes	0 – 255
Ch3	2 bytes	0 – 255
Ch4	2 bytes	0 – 255
Ch5	2 bytes	0 – 255
Ch6	2 bytes	0 – 255
Ch7	2 bytes	0 – 255
Ch8	2 bytes	0 – 255
Ch9	2 bytes	0 – 255
Ch10	2 bytes	0 – 255
Ch11	2 bytes	0 – 255
Ch12	2 bytes	0 – 255
Ch13	2 bytes	0 – 255
Ch14	2 bytes	0 – 255
Ch15	2 bytes	0 – 255
Ch16	2 bytes	0 – 255
Ch17	2 bytes	0 – 255
Ch18	2 bytes	0 – 255

Application Data for RCAs		
DATA	SIZE	COMMENTS
Function ID	1 byte	23h
Activity ID	1 byte	2h
SID	2 bytes	3108÷3111
RCA0	2 bytes	0 – 255
RCA1	2 bytes	0 – 255
RCA2	2 bytes	0 – 255
RCA3	2 bytes	0 – 255
RCA4	2 bytes	0 – 255
RCA5	2 bytes	0 – 255
RCA6	2 bytes	0 – 255
RCA7	2 bytes	0 – 255
RCA8	2 bytes	0 – 255
RCA9	2 bytes	0 – 255
RCA10	2 bytes	0 – 255
Spare	132 bytes	X
Mask bit 0	1 bit	0 – 1
Mask bit 1	1 bit	0 – 1
Mask bit 2	1 bit	0 – 1
Mask bit 3	1 bit	0 – 1
Mask bit 4	1 bit	0 – 1
Mask bit 5	1 bit	0 – 1
Mask bit 6	1 bit	0 – 1



Ch19	2 bytes	0 - 255
Ch20	2 bytes	0 - 255
Ch21	2 bytes	0 - 255
Ch22	2 bytes	0 - 255
Ch23	2 bytes	0 - 255
Ch24	2 bytes	0 - 255
Ch25	2 bytes	0 - 255
Ch26	2 bytes	0 - 255
Ch27	2 bytes	0 - 255
Ch28	2 bytes	0 - 255
Ch29	2 bytes	0 - 255
Ch30	2 bytes	0 - 255
Ch31	2 bytes	0 - 255
Ch32	2 bytes	0 - 255
Ch33	2 bytes	0 - 255
Ch34	2 bytes	0 - 255
Ch35	2 bytes	0 - 255
Ch36	2 bytes	0 - 255
Ch37	2 bytes	0 - 255
Ch38	2 bytes	0 - 255
Ch39	2 bytes	0 - 255
Ch40	2 bytes	0 - 255
Ch41	2 bytes	0 - 255
Ch42	2 bytes	0 - 255
Ch43	2 bytes	0 - 255
Mask bit 0	1 bit	0 - 1
Mask bit 1	1 bit	0 - 1

Mask bit 7	1 bit	0 - 1
Mask bit 8	1 bit	0 - 1
Mask bit 9	1 bit	0 - 1
Mask bit 10	1 bit	0 - 1
Spare	53 bit	X



Mask bit 2	1 bit	<i>0 - 1</i>
Mask bit 3	1 bit	<i>0 - 1</i>
Mask bit 4	1 bit	<i>0 - 1</i>
Mask bit 5	1 bit	<i>0 - 1</i>
Mask bit 6	1 bit	<i>0 - 1</i>
Mask bit 7	1 bit	<i>0 - 1</i>
Mask bit 8	1 bit	<i>0 - 1</i>
Mask bit 9	1 bit	<i>0 - 1</i>
Mask bit 10	1 bit	<i>0 - 1</i>
Mask bit 11	1 bit	<i>0 - 1</i>
Mask bit 12	1 bit	<i>0 - 1</i>
Mask bit 13	1 bit	<i>0 - 1</i>
Mask bit 14	1 bit	<i>0 - 1</i>
Mask bit 15	1 bit	<i>0 - 1</i>
Mask bit 16	1 bit	<i>0 - 1</i>
Mask bit 17	1 bit	<i>0 - 1</i>
Mask bit 18	1 bit	<i>0 - 1</i>
Mask bit 19	1 bit	<i>0 - 1</i>
Mask bit 20	1 bit	<i>0 - 1</i>
Mask bit 21	1 bit	<i>0 - 1</i>
Mask bit 22	1 bit	<i>0 - 1</i>
Mask bit 23	1 bit	<i>0 - 1</i>
Mask bit 24	1 bit	<i>0 - 1</i>
Mask bit 25	1 bit	<i>0 - 1</i>
Mask bit 26	1 bit	<i>0 - 1</i>
Mask bit 27	1 bit	<i>0 - 1</i>
Mask bit 28	1 bit	<i>0 - 1</i>



Mask bit 29	1 bit	0 - 1
Mask bit 30	1 bit	0 - 1
Mask bit 31	1 bit	0 - 1
Mask bit 32	1 bit	0 - 1
Mask bit 33	1 bit	0 - 1
Mask bit 34	1 bit	0 - 1
Mask bit 35	1 bit	0 - 1
Mask bit 36	1 bit	0 - 1
Mask bit 37	1 bit	0 - 1
Mask bit 38	1 bit	0 - 1
Mask bit 39	1 bit	0 - 1
Mask bit 40	1 bit	0 - 1
Mask bit 41	1 bit	0 - 1
Mask bit 42	1 bit	0 - 1
Mask bit 43	1 bit	0 - 1
Spare	20 bit	x

Nota 3:

Due to additional protection reasons, at start up the bias lines of all the FEMs are disabled. The sequence of RAA switch-on should foresee first the setting of at least one Vgate1 and one Vgate2, then, at the setting of at least one Vdrain, all the bias lines of the FEMs are enabled.

13.2.7 UPDATE RCA PARAMETERS

In this paragraph the procedure to update the RCA parameters is described as reported in the tables below.

Topic	Description	Note



Purpose	To update the RCA parameters stored in the REBA.	PFLCS1C,PFLCS2C, PFLCSNC,PFLCSXC, PFLCSYC,PFLCSGC, PFLCSOC,PFLCSAC, PFLCSBC,PFLCSCC, PFLCSDC
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA DPU established and synchronized.	
Initial satellite state	LFI Normal or Extended Science	recovery action TBW
End satellite state	LFI Normal or Extended Science	
Reference procedures	1. Update the RCA parameters	see Table 13.2-30
Procedure predecessors		
Contingency procedures		

Table 13.2-29 Summary of the procedures to update the RCA parameters

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the corresponding power group 1 to 4 is ON	DAE Fast HK TM(3,25)		In the packet 120102369 the corresponding parameters	4 s	



	(according to the order in table in § 6.2.1.3.4.1)			LM421332, or LM422332, or LM423323, or LM424332 = 1		
2	Update the RCA parameters. See Table 13.2-28 step 2 for the correspondance of the RCA parameter with the scos name.	Configure DAE TC(8,4)	LC121320 parameter LP158320 = TBD or LC128320 parameter LP159320 = TBD (***) (*)	Receive Packets ID 120011342, and 120017342		If TC failure see Note ⁽⁰⁾
3	Verify the RCA parameters	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, and 120017342, in the packet ID 121101369 the corresponding parameters according to step 2		

Table 13.2-30 Update the RCA parameters

(*) Fill all the remaining parameters of the command with the corresponding values of the selection mask and the corresponding item

(***) Select the RCA parameters to be updated filling the command with the corresponding value, from C1Dh to C27h (see Table 13.2-28, point 2, for the correspondance of the value with the selected RCA parameter).

Note (0) In case of TC failure, see Par. 13.3.3, item # 1.

Note 1:

Depending on the SID, configuration values and configuration mask may refer to detectors, horns or DC/DC converters. If SID refers to detectors the 44 parameter values of the list and the 44 bits of configuration mask are used; if SID refers to horns only 11 values of the list and 11 bits of



configuration mask are used leaving the rest as spare and; if SID refers to DC/DC converters only 4 values of the list and 4 bits of configuration mask are used leaving the rest as spare.

For a detailed explanation of how masks should be filled, refer to [AN1], “Appendix B – SCOS 2K MASK PARAMETERS”.

That is,

Configuration mask definition

Bit 0 (MSB) to Bit 63 (LSB) defines the detector, horn or DC/DC converter affected by the TC. This depends on the SID.

- If SID refers to configuration of detectors (SIDs 3101 to 3107):

Bit (i) = 1, for i=0 to 43, sets a value for detector i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 43, means detector i is not affected by the TC.

Bit (i), for i=44 to 63 spare (not used, set to zero)

- If SID refers to configuration of horns (SIDs 3108 to 3111):

Bit (i) = 1, for i=0 to 10, sets a value for horn i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 10, means horn i is not affected by the TC.

Bit (i), for i=11 to 63 spare (not used, set to zero)

- If SID refers to configuration of DC/DC converters (SID 3112):

Bit (i) = 1, for i=0 to 3, sets a value for detector i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 3, means detector i is not affected by the TC.

Bit (i), for i=4 to 63 spare (not used, set to zero)

Note 2:

a) Detector mask definition

Bit 0 (MSB) to Bit 63 (LSB) defines the detector affected by the TC.



Bit (i) = 1, for i=0 to 43, sets a value for detector i, the value is the ith value of SID.

Bit (i) = 0, for i=0 to 43, means detector i is not affected by the TC.

Bit (i), for i=44 to 63 spare (not used, set to zero)

b) Horn mask definition

Bit 0 (MSB) to Bit 15 (LSB) defines the horn affected by the TC.

Bit (i) = 1, for i=0 to 10, sets a value for horn i, the value is the ith value of SID.

Bit (i) = 0, for i=0 to 10, means radiometer i is not affected by the TC.

Bit (i), for i=11 to 15 spare (not used, set to zero)

The structure of the data field of packet is given in the following tables for the three corresponding cases: detectors, RCAs and DC/DC converters.

Application Data for Detectors		
DATA	SIZE	COMMENTS
Function ID	1 byte	23h
Activity ID	1 byte	2h
SID	2 bytes	3101÷3107
Ch0	2 bytes	0 – 255
Ch1	2 bytes	0 – 255
Ch2	2 bytes	0 – 255
Ch3	2 bytes	0 – 255
Ch4	2 bytes	0 – 255
Ch5	2 bytes	0 – 255
Ch6	2 bytes	0 – 255
Ch7	2 bytes	0 – 255
Ch8	2 bytes	0 – 255
Ch9	2 bytes	0 – 255

Application Data for RCAs		
DATA	SIZE	COMMENTS
Function ID	1 byte	23h
Activity ID	1 byte	2h
SID	2 bytes	3108÷3111
RCA0	2 bytes	0 – 255
RCA1	2 bytes	0 – 255
RCA2	2 bytes	0 – 255
RCA3	2 bytes	0 – 255
RCA4	2 bytes	0 – 255
RCA5	2 bytes	0 – 255
RCA6	2 bytes	0 – 255
RCA7	2 bytes	0 – 255
RCA8	2 bytes	0 – 255
RCA9	2 bytes	0 – 255

Application Data for DC/DC converters		
DATA	SIZE	COMMENTS
Function ID	1 byte	23h
Activity ID	1 byte	2h
SID	2 bytes	3112
DC/DC 0	2 bytes	0 – 255
DC/DC 1	2 bytes	0 – 255
DC/DC 2	2 bytes	0 – 255
DC/DC 3	2 bytes	0 – 255
Spare	176 bytes	x



Ch10	2 bytes	0 – 255
Ch11	2 bytes	0 – 255
Ch12	2 bytes	0 – 255
Ch13	2 bytes	0 – 255
Ch14	2 bytes	0 – 255
Ch15	2 bytes	0 – 255
Ch16	2 bytes	0 – 255
Ch17	2 bytes	0 – 255
Ch18	2 bytes	0 – 255
Ch19	2 bytes	0 - 255
Ch20	2 bytes	0 - 255
Ch21	2 bytes	0 - 255
Ch22	2 bytes	0 - 255
Ch23	2 bytes	0 - 255
Ch24	2 bytes	0 - 255
Ch25	2 bytes	0 - 255
Ch26	2 bytes	0 - 255
Ch27	2 bytes	0 - 255
Ch28	2 bytes	0 - 255
Ch29	2 bytes	0 - 255
Ch30	2 bytes	0 - 255
Ch31	2 bytes	0 - 255
Ch32	2 bytes	0 - 255
Ch33	2 bytes	0 - 255
Ch34	2 bytes	0 - 255
Ch35	2 bytes	0 - 255
Ch36	2 bytes	0 - 255

RCA10	2 bytes	0 – 255
Spare	132 bytes	<i>x</i>
Mask bit 0	1 bit	0 - 1
Mask bit 1	1 bit	0 - 1
Mask bit 2	1 bit	0 - 1
Mask bit 3	1 bit	0 - 1
Mask bit 4	1 bit	0 - 1
Mask bit 5	1 bit	0 - 1
Mask bit 6	1 bit	0 - 1
Mask bit 7	1 bit	0 - 1
Mask bit 8	1 bit	0 - 1
Mask bit 9	1 bit	0 - 1
Mask bit 10	1 bit	0 - 1
Spare	53 bit	<i>x</i>



Ch37	2 bytes	0 - 255
Ch38	2 bytes	0 - 255
Ch39	2 bytes	0 - 255
Ch40	2 bytes	0 - 255
Ch41	2 bytes	0 - 255
Ch42	2 bytes	0 - 255
Ch43	2 bytes	0 - 255
Mask bit 0	1 bit	0 - 1
Mask bit 1	1 bit	0 - 1
Mask bit 2	1 bit	0 - 1
Mask bit 3	1 bit	0 - 1
Mask bit 4	1 bit	0 - 1
Mask bit 5	1 bit	0 - 1
Mask bit 6	1 bit	0 - 1
Mask bit 7	1 bit	0 - 1
Mask bit 8	1 bit	0 - 1
Mask bit 9	1 bit	0 - 1
Mask bit 10	1 bit	0 - 1
Mask bit 11	1 bit	0 - 1
Mask bit 12	1 bit	0 - 1
Mask bit 13	1 bit	0 - 1
Mask bit 14	1 bit	0 - 1
Mask bit 15	1 bit	0 - 1
Mask bit 16	1 bit	0 - 1
Mask bit 17	1 bit	0 - 1
Mask bit 18	1 bit	0 - 1
Mask bit 19	1 bit	0 - 1



Mask bit 20	1 bit	<i>0 - 1</i>
Mask bit 21	1 bit	<i>0 - 1</i>
Mask bit 22	1 bit	<i>0 - 1</i>
Mask bit 23	1 bit	<i>0 - 1</i>
Mask bit 24	1 bit	<i>0 - 1</i>
Mask bit 25	1 bit	<i>0 - 1</i>
Mask bit 26	1 bit	<i>0 - 1</i>
Mask bit 27	1 bit	<i>0 - 1</i>
Mask bit 28	1 bit	<i>0 - 1</i>
Mask bit 29	1 bit	<i>0 - 1</i>
Mask bit 30	1 bit	<i>0 - 1</i>
Mask bit 31	1 bit	<i>0 - 1</i>
Mask bit 32	1 bit	<i>0 - 1</i>
Mask bit 33	1 bit	<i>0 - 1</i>
Mask bit 34	1 bit	<i>0 - 1</i>
Mask bit 35	1 bit	<i>0 - 1</i>
Mask bit 36	1 bit	<i>0 - 1</i>
Mask bit 37	1 bit	<i>0 - 1</i>
Mask bit 38	1 bit	<i>0 - 1</i>
Mask bit 39	1 bit	<i>0 - 1</i>
Mask bit 40	1 bit	<i>0 - 1</i>
Mask bit 41	1 bit	<i>0 - 1</i>
Mask bit 42	1 bit	<i>0 - 1</i>
Mask bit 43	1 bit	<i>0 - 1</i>
Spare	20 bit	<i>x</i>

Nota 3:



Due to additional protection reasons, at start up the bias lines of all the FEMs are disabled. The sequence of RAA switch-on should foresee first the setting of at least one Vgate1 and one Vgate2, then, at the setting of at least one Vdrain, all the bias lines of the FEMs are enabled.

13.2.8 UPDATE DEFAULT RCA SETTINGS

In this paragraph the procedure to update the default RCA settings is described as reported in the tables below.

Topic	Description	Note
Purpose	To update the default RCA settings stored in the REBA.	PFLCSDP
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA DPU established and synchronized.	
Initial satellite state	LFI Normal or Extended Science	see recovery action TBW
End satellite state	LFI Normal or Extended Science	
Reference procedures	1. Update the default RCA settings	see Table 13.2-32
Procedure predecessors		
Contingency procedures		



Table 13.2-31 Summary of the procedures to update the default RCA settings

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Configure the default RCA parameters. This sets the dae default configuration per channel (LC100320, 44 values) or per RCA (LC107320, 11 values). The RCA parameters is chosen according to the SID (see Table 13.2-28, step 2)	Configure DAE TC(8,4)	LC100320 parameter LP160320 = TBD or LC107320 parameter LP161320 = TBD (***) (*)			
2	Verify the RCA parameters	Get DAE default configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 457h	Receive Packets ID 120011342, and 120017342, in the packet ID 121111369 the corresponding parameters according to step 1		

Table 13.2-32 Update the default RCA settings

(*) Fill all the remaining parameters of the command with the corresponding values of the selection mask and the corresponding item
(***) Select the RCA parameters to be updated filling the command with the corresponding value, from C1Dh to C27h (see Table 13.2-28, step 2, for the correspondance of the value with the selected RCA parameter).

Note (0) In case of TC failure, see Par. 13.3.3, item # 1.



Note 1:

Depending on the SID, configuration values and configuration mask may refer to detectors or horns. If SID refers to detectors the 44 parameter values of the list and the 44 bits of configuration mask are used; if SID refers to horns only 11 values of the list and 11 bits of configuration mask are used leaving the rest as spare.

For a detailed explanation of how masks should be filled, refer to [AN1], “Appendix B – SCOS 2K MASK PARAMETERS”.

That is,

Configuration mask definition

Bit 0 (MSB) to Bit 63 (LSB) defines the detector or horn affected by the TC. This depends on the SID.

- If SID refers to configuration of detectors (SIDs 3201 to 3207):

Bit (i) = 1, for i=0 to 43, sets a value for detector i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 43, means detector i is not affected by the TC.

Bit (i), for i=44 to 63 spare (not used, set to zero)

- If SID refers to configuration of horns (SIDs 3208 to 3211):

Bit (i) = 1, for i=0 to 10, sets a value for horn i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 10, means horn i is not affected by the TC.

Bit (i), for i=11 to 63 spare (not used, set to zero)

Note 2:

a) Detector mask definition

Bit 0 (MSB) to Bit 63 (LSB) defines the detector affected by the TC.

Bit (i) = 1, for i=0 to 43, sets a value for detector i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 43, means detector i is not affected by the TC.

Bit (i), for i=44 to 63 spare (not used, set to zero)



b) Horn mask definition

Bit 0 (MSB) to Bit 15 (LSB) defines the horn affected by the TC.

Bit (i) = 1, for i=0 to 10, sets a value for horn i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 10, means radiometer i is not affected by the TC.

Bit (i), for i=11 to 15 spare (not used, set to zero)

The structure of the data field of packet is given in the following tables for the two corresponding cases: detectors and RCAs.

Application Data for Detectors		
DATA	SIZE	COMMENTS
Function ID	1 byte	23h
Activity ID	1 byte	Eh
SID	2 bytes	3201÷3207
Ch0	2 bytes	0 – 255
Ch1	2 bytes	0 – 255
Ch2	2 bytes	0 – 255
Ch3	2 bytes	0 – 255
Ch4	2 bytes	0 – 255
Ch5	2 bytes	0 – 255
Ch6	2 bytes	0 – 255
Ch7	2 bytes	0 – 255
Ch8	2 bytes	0 – 255
Ch9	2 bytes	0 – 255
Ch10	2 bytes	0 – 255
Ch11	2 bytes	0 – 255
Ch12	2 bytes	0 – 255

Application Data for RCAs		
DATA	SIZE	COMMENTS
Function ID	1 byte	23h
Activity ID	1 byte	Eh
SID	2 bytes	3208÷3211
RCA0	2 bytes	0 – 255
RCA1	2 bytes	0 – 255
RCA2	2 bytes	0 – 255
RCA3	2 bytes	0 – 255
RCA4	2 bytes	0 – 255
RCA5	2 bytes	0 – 255
RCA6	2 bytes	0 – 255
RCA7	2 bytes	0 – 255
RCA8	2 bytes	0 – 255
RCA9	2 bytes	0 – 255
RCA10	2 bytes	0 – 255
Spare	132 bytes	x
Mask bit 0	1 bit	0 – 1



Ch13	2 bytes	0 – 255
Ch14	2 bytes	0 – 255
Ch15	2 bytes	0 – 255
Ch16	2 bytes	0 – 255
Ch17	2 bytes	0 – 255
Ch18	2 bytes	0 – 255
Ch19	2 bytes	0 - 255
Ch20	2 bytes	0 - 255
Ch21	2 bytes	0 - 255
Ch22	2 bytes	0 - 255
Ch23	2 bytes	0 - 255
Ch24	2 bytes	0 - 255
Ch25	2 bytes	0 - 255
Ch26	2 bytes	0 - 255
Ch27	2 bytes	0 - 255
Ch28	2 bytes	0 - 255
Ch29	2 bytes	0 - 255
Ch30	2 bytes	0 - 255
Ch31	2 bytes	0 - 255
Ch32	2 bytes	0 - 255
Ch33	2 bytes	0 - 255
Ch34	2 bytes	0 - 255
Ch35	2 bytes	0 - 255
Ch36	2 bytes	0 - 255
Ch37	2 bytes	0 - 255
Ch38	2 bytes	0 - 255
Ch39	2 bytes	0 - 255

Mask bit 1	1 bit	0 – 1
Mask bit 2	1 bit	0 - 1
Mask bit 3	1 bit	0 - 1
Mask bit 4	1 bit	0 - 1
Mask bit 5	1 bit	0 - 1
Mask bit 6	1 bit	0 - 1
Mask bit 7	1 bit	0 - 1
Mask bit 8	1 bit	0 - 1
Mask bit 9	1 bit	0 - 1
Mask bit 10	1 bit	0 - 1
Spare	53 bit	x



Ch40	2 bytes	0 - 255
Ch41	2 bytes	0 - 255
Ch42	2 bytes	0 - 255
Ch43	2 bytes	0 - 255
Mask bit 0	1 bit	0 - 1
Mask bit 1	1 bit	0 - 1
Mask bit 2	1 bit	0 - 1
Mask bit 3	1 bit	0 - 1
Mask bit 4	1 bit	0 - 1
Mask bit 5	1 bit	0 - 1
Mask bit 6	1 bit	0 - 1
Mask bit 7	1 bit	0 - 1
Mask bit 8	1 bit	0 - 1
Mask bit 9	1 bit	0 - 1
Mask bit 10	1 bit	0 - 1
Mask bit 11	1 bit	0 - 1
Mask bit 12	1 bit	0 - 1
Mask bit 13	1 bit	0 - 1
Mask bit 14	1 bit	0 - 1
Mask bit 15	1 bit	0 - 1
Mask bit 16	1 bit	0 - 1
Mask bit 17	1 bit	0 - 1
Mask bit 18	1 bit	0 - 1
Mask bit 19	1 bit	0 - 1
Mask bit 20	1 bit	0 - 1
Mask bit 21	1 bit	0 - 1
Mask bit 22	1 bit	0 - 1



Mask bit 23	1 bit	<i>0 - 1</i>
Mask bit 24	1 bit	<i>0 - 1</i>
Mask bit 25	1 bit	<i>0 - 1</i>
Mask bit 26	1 bit	<i>0 - 1</i>
Mask bit 27	1 bit	<i>0 - 1</i>
Mask bit 28	1 bit	<i>0 - 1</i>
Mask bit 29	1 bit	<i>0 - 1</i>
Mask bit 30	1 bit	<i>0 - 1</i>
Mask bit 31	1 bit	<i>0 - 1</i>
Mask bit 32	1 bit	<i>0 - 1</i>
Mask bit 33	1 bit	<i>0 - 1</i>
Mask bit 34	1 bit	<i>0 - 1</i>
Mask bit 35	1 bit	<i>0 - 1</i>
Mask bit 36	1 bit	<i>0 - 1</i>
Mask bit 37	1 bit	<i>0 - 1</i>
Mask bit 38	1 bit	<i>0 - 1</i>
Mask bit 39	1 bit	<i>0 - 1</i>
Mask bit 40	1 bit	<i>0 - 1</i>
Mask bit 41	1 bit	<i>0 - 1</i>
Mask bit 42	1 bit	<i>0 - 1</i>
Mask bit 43	1 bit	<i>0 - 1</i>
Spare	20 bit	<i>X</i>

13.2.9 SCIENCE ACTIVATION

In this paragraph the science activation procedure is described as reported in the tables below.

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Topic	Description	Note
Purpose	To switch on the Radiometer Chains and the REBA science processing in the nominal conditions.	PFLC SSA
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	2 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA on, connected and synchronized REBA and DAE powered on. REBA initialized and DAE connection to the REBA DPU established.	
Initial satellite state	LFI unknown state: intermediate between DAE Set-up and Normal or Extended Science Mode (DAE is on but DC-DC converters are off and Science is not produced)	see Table 13.2-13, Table 13.2-15
End satellite state	LFI in Normal or Extended Science Mode	
Reference procedures	1. Science activation	see Table 13.2-34
Procedure predecessors		
Contingency procedures		

Table 13.2-33 Summary of the Science activation procedure

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1						
2						



3	SPU connect to DAE	SPU connect to DAE TC(8,4)	LC055320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
4	Start REBA science processing	Start science processing TC(8,1)	LC007320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
5	Start DAE science sequencer. From this moment onward, science TM (21,x) is produced	Start DAE science sequencer TC(8,4)	LC065320	Receive Packets ID 120011342 and 120017342 In the packet 120102369 the parameters LM411328 = 27h In the packet 120202369 the parameters LM576350 = 0003h LM586350 = 0 LM587350 = 2FFFh LM588350 = 0		If TC failure see Note ⁽⁰⁾
6	Verify telemetry	Planck REBA LFI HK TM(3,25)		Receive Packets ID parameters LM596350=15 LM597350=5h LM598350=1h LM560350=FFh LM561350=FFh LM562350=FFh LM563350=FFh LM564350=FFh LM565350=F0h LM570350=80h LM571350=00h LM572350=00h LM573350=00h LM574350=00h LM575350=00h LM587350= 2FFFh	120202369 with Calibration Switch Time Submode A Submode B SPU Det Mask A0 SPU Det Mask A1 SPU Det Mask A2 SPU Det Mask A3 SPU Det Mask A4 SPU Det Mask A5 SPU Det Mask B0 SPU Det Mask B1 SPU Det Mask B2 SPU Det Mask B3 SPU Det Mask B4 SPU Det Mask B5 SPU 1355 Status	



				LM586350=0h	SPU SMCS errors		
				LM588350=0h	SPU Comm Error		

Table 13.2-34 Science activation

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.

13.2.10 CHANGE SCIENCE PROCESSING MODES

In this paragraph the procedure to change the science processing mode is described as reported in the tables below.

Topic	Description	Note
Purpose	To define the processing mode (A and B) of the scientific data of LFI (see § 15.1.3).	PFLCSSX
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	2 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA on, connected and synchronized REBA and DAE powered on. REBA initialized and DAE connection to the REBA DPU established.	
Initial satellite state	LFI Normal or Extended Science Mode	see Table 13.2-15 and Table 13.2-18



End satellite state	LFI Normal or Extended Science Mode Note that during this procedures the LFI goes in an unknown state since science processing is stopped	
Reference procedures	1. Change Science processing modes	see Table 13.2-36
Procedure predecessors		
Contingency procedures		

Table 13.2-35 Summary of the procedure to change the science processing mode

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
0	Stop DAE science sequencer.	Stop DAE science sequencer TC(8,4)	LC066320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
1	Stop science processing. From this moment onward, science TM (21,x) is not produced anymore.	Stop science processing TC(8,2)	LC018320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
2	Verify science processing is stopped	REBA HK TM(3,25)		Receive packet ID 120202369 parameter LM576350 bit 15 = 0		
3	Set Science Processing type. Accordingly each RCA will belong to processing mode A and/or B (see § 15.1.3).	Set Science Processing TC(8,4)	LC076320 parameters LP166320 (mode A) and LP167320 (mode B) = TBD (*), parameter from LP116320 to LP119320 = TBD bit mask of the channels to be	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾



			processed in mode A and parameter from LP120320 to LP123320 = TBD bit mask of the channels to be processed in mode B. All these parameters through TPF.			
4	Start REBA science processing	Start science processing TC(8,1)	LC007320	Receive Packets ID 120011342 and 120017342 In the packet 120202369 the parameters LM576350 BIT 15 = 1		If TC failure see Note ⁽⁰⁾
5	Start DAE science sequencer. From this moment onward, science TM (21,x) is produced	Start DAE science sequencer TC(8,4)	LC065320	Receive Packets ID 120011342 and 120017342 In the packet 120102369 the parameters LM411328 = 27h In the packet 120202369 the parameters LM576350 = 0003h LM586350 = 0 LM587350 = 2FFFh LM588350 = 0		If TC failure see Note ⁽⁰⁾

Table 13.2-36 Change science processing mode

(*) Refer to section 15.1.3 for the description of the science processing types.



Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1.

13.2.11 SCIENCE DE-ACTIVATION

In this paragraph the science de-activation procedure is described as reported in the tables below.

Topic	Description	Note
Purpose	To switch off the Radiometer Chains and the REBA science processing.	PFLCSSD Step 1 to 3
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	2 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA on, connected and synchronized REBA and DAE powered on. REBA initialized and DAE connection to the REBA DPU established.	
Initial satellite state	LFI Normal or Extended Science Mode	see Table 13.2-14, Table 13.2-16
End satellite state	LFI unknown state: intermediate between Normal or Extended Science and DAE Set-up Mode (DC-DC are still on but science is not running)	
Reference procedures	1. Science de-activation	see Table 13.2-38



Procedure predecessors		
Contingency procedures		

Table 13.2-37 Summary of the Science de-activation procedure

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the arrival of science packets or science processing activation	Diagnostic and Nominal Data Science Report TM(21,x), REBA HK TM(3,25)		Receive packet ID (120011369 AND/OR 120012369 AND/OR 120211369 AND/OR 120213369) OR 120202369, parameter LM576350 bit 15 = 1		
2	Verify Telemetry	REBA HK TM(3,25)		Receive packet ID 120202369 and save the values of the following SPU parameters: LM560350 Det Mask A0 LM561350 Det Mask A1 LM562350 Det Mask A2 LM563350 Det Mask A3 LM564350 Det Mask A4 LM565350 Det Mask A5 LM570350 Det Mask B0 LM571350 Det Mask B1 LM572350 Det Mask B2 LM573350 Det Mask B3 LM574350 Det Mask B4 LM575350 Det Mask B5 Use these values (merged two by two, pay attention in merging 00h values)		



				to fill the parameters requested by next TC (step 3)		
3	Disable the channels which are enabled	Disable Channels TC(8.4)	LC078320	LP116320 Use A0A1 LP117320 Use A2A3 LP118320 Use A4A5 LP119320 00 00h LP120320 Use B0B1 LP121320 Use B2B3 LP122320 Use B4B5 LP123320 00 00h		
4	Verify Telemetry	REBA HK TM(3,25)		Receive packet ID 120202369 and verify the values of the following SPU parameters: LM560350 Det Mask A0 LM561350 Det Mask A1 LM562350 Det Mask A2 LM563350 Det Mask A3 LM564350 Det Mask A4 LM565350 Det Mask A5 LM570350 Det Mask B0 LM571350 Det Mask B1 LM572350 Det Mask B2 LM573350 Det Mask B3 LM574350 Det Mask B4 LM575350 Det Mask B5		
5	Stop DAE science sequencer.	Stop DAE science sequencer TC(8,4)	LC066320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
6	Stop science processing. From this moment onward,	Stop science processing TC(8,2)	LC018320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾



	science TM (21,x) is not produced anymore.					
7	Verify science processing is stopped	REBA HK TM(3,25)		Receive packet ID 120202369 parameter LM576350 bit 15 = 0 and verify TM(21,x) is no more arriving		
8	Enable again the channels which were enabled	Enable a new Channel TC(8.4)	LC077320	LP116320 Use A0A1 LP117320 Use A2A3 LP118320 Use A4A5 LP119320 00 00h LP120320 Use B0B1 LP121320 Use B2B3 LP122320 Use B4B5 LP123320 00 00h		
9	Verify Telemetry	REBA HK TM(3,25)		Receive packet ID 120202369 and verify the values of the following SPU parameters: LM560350 Det Mask A0 LM561350 Det Mask A1 LM562350 Det Mask A2 LM563350 Det Mask A3 LM564350 Det Mask A4 LM565350 Det Mask A5 LM570350 Det Mask B0 LM571350 Det Mask B1 LM572350 Det Mask B2 LM573350 Det Mask B3 LM574350 Det Mask B4 LM575350 Det Mask B5		

Table 13.2-38 Science de-activation



Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1.

13.2.12 DEFINITION OF THE SCIENCE PROCESSING PARAMETER

The procedures to define the science processing parameters are described in the tables below.

Topic	Description	Note
Purpose	To initialize and adjust the processing parameters of the scientific data of LFI.	PFLCSGP, PFLCSOP
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA DPU established and synchronized.	
Initial satellite state	LFI Normal and Extended Science Mode	see Table 13.2-13, Table 13.2-15
End satellite state	LFI Normal and Extended Science Mode	
Reference procedures	1. Definition of the science processing parameter	Table 13.2-40
Procedure predecessors		
Contingency procedures		



Table 13.2-39 Summary of the procedures to define the processing parameters

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Set Science Processing parameters. The values of the parameters will be passed by using the TPF files. See § 15.1.2 for a description of the parameters.					
1.1	Set GMF 1	Set parameters GMFs TC(8,4)	LC071320 parameter LP170320 = 83h, LP168320 = CEFh (GMF1) parameters LP068320 to LP111320 (*)	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
1.2	Set GMF 2	Set parameters GMFs TC(8,4)	LC071320 parameter LP170320 = 8Ah, LP168320 = CF0h (GMF2) parameters LP068320 to LP111320 (*)	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
1.3	Set Offset Adjust	Set parameters Offset TC(8,4)	LC071320 parameter LP170320 = 81h, LP168320 = D03h (offset adjust) parameters	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾



1.4	Set Second quantisation	Set parameters ReQuant TC(8,4)	LP068320 to LP111320 (*) LC071320 parameter LP170320 = 82h, LP168320 = CF9h (re-quant) parameters LP068320 to LP111320 (*)	Receive Packets ID 120011342 and 120017342	If TC failure see Note ⁽⁰⁾
2	Verify Science Processing parameters				
2.1	Verify the values of GMF1 and GMF2	Get parameters N- average and GMFs TC(14,1)	LC150320 parameter LP162320 = 1h LP164320 = 3h LP165320 = 1Ah LP163320 = 853h	Receive Packets ID 120011342, 120017342 and 122131350 (check the content of updated values of GMF1 and 2 (**) see § 11.1.8.21, LM301550 to LM344350 for GMF1, LM351550 to LM394350 for GMF2)	
2.2	Verify the values of the offset and second quantization	Get parameters Offsets and ReQuants TC(14,1)	LC150320 parameter LP162320 = 1h LP164320 = 3h LP165320 = 1Ah LP163320 = 852h	Receive Packets ID 120011342, 120017342 and 122130350 (check the content of updated values of offset and re- quant (**) see § 11.1.8.20)	

Table 13.2-40 Definition of the science processing parameters



Note (*): Fill all the remaining parameters of the command with the corresponding values of the selection mask (LP112320, LP113320, LP114320 and LP115320, set to FFFFh if change is required on all RCAs) and the corresponding item

Note (**): This information is not periodically reported but has to be dumped only upon dedicated request

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.

Note 1:

Depending on the Activity ID and SID, configuration values and configuration mask may refer to detectors or horns. If they refer to detectors the 44 parameter values of the list and the 44 bits of configuration mask are used; if they refer to horns only 11 values of the list and 11 bits of configuration mask are used leaving the rest as spare.

For a detailed explanation of how masks should be filled, refer to [AN1], “Appendix B – SCOS 2K MASK PARAMETERS”.

That is,

Configuration mask definition

Bit 0 (MSB) to Bit 63 (LSB) defines the detector or horn affected by the TC. This depends on the Activity ID and SID.

- If they refer to configuration of detectors (SIDs 3311, 3312, 3321, 3331):

Bit (i) = 1, for i=0 to 43, sets a value for detector i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 43, means detector i is not affected by the TC.

Bit (i), for i=44 to 63 spare (not used, set to zero)

- If they refer to configuration of horns (SIDs 3391):

Bit (i) = 1, for i=0 to 10, sets a value for horn i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 10, means horn i is not affected by the TC.



Bit (i), for i=11 to 63 spare (not used, set to zero)

Note 2:

a) Detector mask definition

Bit 0 (MSB) to Bit 63 (LSB) defines the detector affected by the TC.

Bit (i) = 1, for i=0 to 43, sets a value for detector i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 43, means detector i is not affected by the TC.

Bit (i), for i=44 to 63 spare (not used, set to zero)

b) Horn mask definition

Bit 0 (MSB) to Bit 15 (LSB) defines the horn affected by the TC.

Bit (i) = 1, for i=0 to 10, sets a value for horn i, the value is the ith value of the parameter list.

Bit (i) = 0, for i=0 to 10, means radiometer i is not affected by the TC.

Bit (i), for i=11 to 15 spare (not used, set to zero)

The structure of the data field of packet is given in the following tables for the three corresponding cases: detectors and RCAs.

Application Data for Detectors		
DATA	SIZE	COMMENTS
Function ID	1 byte	26h
Activity ID	1 byte	81h, 82h, 83h
SID	2 bytes	3311, 3312, 3321, 3331
Ch0	4 bytes	
Ch1	4 bytes	
Ch2	4 bytes	
Ch3	4 bytes	

Application Data for RCAs		
DATA	SIZE	COMMENTS
Function ID	1 byte	26h
Activity ID	1 byte	84h
SID	2 bytes	3391
RCA0	2 bytes	0 – 65535
RCA1	2 bytes	0 – 65535
RCA2	2 bytes	0 – 65535
RCA3	2 bytes	0 – 65535



Ch4	4 bytes	
Ch5	4 bytes	
Ch6	4 bytes	
Ch7	4 bytes	
Ch8	4 bytes	
Ch9	4 bytes	
Ch10	4 bytes	
Ch11	4 bytes	
Ch12	4 bytes	
Ch13	4 bytes	
Ch14	4 bytes	
Ch15	4 bytes	
Ch16	4 bytes	
Ch17	4 bytes	
Ch18	4 bytes	
Ch19	4 bytes	
Ch20	4 bytes	
Ch21	4 bytes	
Ch22	4 bytes	
Ch23	4 bytes	
Ch24	4 bytes	
Ch25	4 bytes	
Ch26	4 bytes	
Ch27	4 bytes	
Ch28	4 bytes	
Ch29	4 bytes	
Ch30	4 bytes	

RCA4	2 bytes	<i>0 – 65535</i>
RCA5	2 bytes	<i>0 – 65535</i>
RCA6	2 bytes	<i>0 – 65535</i>
RCA7	2 bytes	<i>0 – 65535</i>
RCA8	2 bytes	<i>0 – 65535</i>
RCA9	2 bytes	<i>0 – 65535</i>
RCA10	2 bytes	<i>0 – 65535</i>
Mask bit 0	1 bit	<i>0 - 1</i>
Mask bit 1	1 bit	<i>0 - 1</i>
Mask bit 2	1 bit	<i>0 - 1</i>
Mask bit 3	1 bit	<i>0 - 1</i>
Mask bit 4	1 bit	<i>0 - 1</i>
Mask bit 5	1 bit	<i>0 - 1</i>
Mask bit 6	1 bit	<i>0 - 1</i>
Mask bit 7	1 bit	<i>0 - 1</i>
Mask bit 8	1 bit	<i>0 - 1</i>
Mask bit 9	1 bit	<i>0 - 1</i>
Mask bit 10	1 bit	<i>0 - 1</i>
Spare	5 bit	<i>x</i>



Ch31	4 bytes	
Ch32	4 bytes	
Ch33	4 bytes	
Ch34	4 bytes	
Ch35	4 bytes	
Ch36	4 bytes	
Ch37	4 bytes	
Ch38	4 bytes	
Ch39	4 bytes	
Ch40	4 bytes	
Ch41	4 bytes	
Ch42	4 bytes	
Ch43	4 bytes	
Mask bit 0	1 bit	0 - 1
Mask bit 1	1 bit	0 - 1
Mask bit 2	1 bit	0 - 1
Mask bit 3	1 bit	0 - 1
Mask bit 4	1 bit	0 - 1
Mask bit 5	1 bit	0 - 1
Mask bit 6	1 bit	0 - 1
Mask bit 7	1 bit	0 - 1
Mask bit 8	1 bit	0 - 1
Mask bit 9	1 bit	0 - 1
Mask bit 10	1 bit	0 - 1
Mask bit 11	1 bit	0 - 1
Mask bit 12	1 bit	0 - 1
Mask bit 13	1 bit	0 - 1



Mask bit 14	1 bit	<i>0 - 1</i>
Mask bit 15	1 bit	<i>0 - 1</i>
Mask bit 16	1 bit	<i>0 - 1</i>
Mask bit 17	1 bit	<i>0 - 1</i>
Mask bit 18	1 bit	<i>0 - 1</i>
Mask bit 19	1 bit	<i>0 - 1</i>
Mask bit 20	1 bit	<i>0 - 1</i>
Mask bit 21	1 bit	<i>0 - 1</i>
Mask bit 22	1 bit	<i>0 - 1</i>
Mask bit 23	1 bit	<i>0 - 1</i>
Mask bit 24	1 bit	<i>0 - 1</i>
Mask bit 25	1 bit	<i>0 - 1</i>
Mask bit 26	1 bit	<i>0 - 1</i>
Mask bit 27	1 bit	<i>0 - 1</i>
Mask bit 28	1 bit	<i>0 - 1</i>
Mask bit 29	1 bit	<i>0 - 1</i>
Mask bit 30	1 bit	<i>0 - 1</i>
Mask bit 31	1 bit	<i>0 - 1</i>
Mask bit 32	1 bit	<i>0 - 1</i>
Mask bit 33	1 bit	<i>0 - 1</i>
Mask bit 34	1 bit	<i>0 - 1</i>
Mask bit 35	1 bit	<i>0 - 1</i>
Mask bit 36	1 bit	<i>0 - 1</i>
Mask bit 37	1 bit	<i>0 - 1</i>
Mask bit 38	1 bit	<i>0 - 1</i>
Mask bit 39	1 bit	<i>0 - 1</i>
Mask bit 40	1 bit	<i>0 - 1</i>



Mask bit 41	1 bit	0 - 1
Mask bit 42	1 bit	0 - 1
Mask bit 43	1 bit	0 - 1
Spare	20 bit	<i>x</i>

13.2.13 STARTING THE MONITORING FUNCTIONS

The procedure to start the monitoring functions is described in the tables below.

Topic	Description	Note
Purpose	To initialize and adjust the monitoring functions of the LFI. See § 9.2.3 for a description of LFI monitoring functions.	PFLCSMA
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA established and synchronized.	
Initial satellite state	LFI Normal and Extended Science Mode	see Table 13.2-13, Table 13.2-15
End satellite state	LFI Normal or Extended Science Mode	



Reference procedures	1. Starting the monitoring functions	see Table 13.2-42
Procedure predecessors		
Contingency procedures	Note that some monitoring functions are automatically enabled. If this is the case, the corresponding check will fail (see step 1) and it is not necessary to enable the corresponding function being already enabled.	

Table 13.2-41 Summary of the procedure to start the monitoring functions

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the status of monitoring functions, respectively the monitoring of the SPU CPU, FPU temperature and TM rate (boolean parameters 0=disabled)	REBA HK TM(3,25)		In the packet 120202369 the parameters LM528340 = 0, LM527340 = 0, LM526340 = 0	4 s	
2	Enable the monitoring on the SPU-CPU load	Start SPU CPU monitoring TC(8,1)	LC003320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
2a	Verify the status of monitoring functions	REBA HK TM(3,25)		In the packet 120202369 the parameters LM528340=1h SPU CPU Monitoring LM543340=00F1h DPU Task Status LM532340=0h SPU CPU Monitoring LM529340=0h Monitor error = 0		
3	Enable the monitoring on the science telemetry rate	Start Science TM rate monitoring TC(8,1)	LC008320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
3a	Verify the status of monitoring functions	REBA HK TM(3,25)		In the packet 120202369 the parameter LM543340=00F5h DPU Task Status	4 s	
3b	Verify the status of	REBA HK		Rec In the packet 120202369 the		



	monitoring functions	TM(3,25)		parameter LM529340=0h Monitor error bit#5 = 0 LM534340=003Ch TM Rate monitor period set to 60 Min LM535340=0030h TM expected set to 48kbps LM537340=0168h TM rate Tau Value set to 360 Min		
4	Enable the monitoring on the FPU temperature	Start FPU temperature monitoring TC(8,1)	LC006320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
4a	Verify the status of monitoring functions	REBA HK TM(3,25)		In the packet 120202369 the parameters LM527340=1h FPU Temperature Monitoring LM543340=00F7h DPU Task Status	4 s	

Table 13.2-42 Starting the monitoring functions

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.

13.2.14 VERIFYING THE MONITORING FUNCTIONS

The procedure to verify the monitoring functions is described in the tables below.

Topic	Description	Note
Purpose	To verify the monitoring functions of the LFI. See § 9.2.3 for a description of LFI monitoring functions.	PFLCSMX



Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA established and synchronized.	
Initial satellite state	LFI Normal and Extended Science Mode	see Table 13.2-13, Table 13.2-15
End satellite state	LFI Normal or Extended Science Mode	
Reference procedures	1. Verifying the monitoring functions	see Table 13.2-44
Procedure predecessors		
Contingency procedures		

Table 13.2-43 Summary of the procedure to verify the monitoring functions

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the status of monitoring functions (monitoring functions are already started, boolean parameters 1=enabled)	REBA HK TM(3,25)		In the packet 120202369 the parameters LM528340 = 1 and LM527340 = 1	4 s	
2	Verify the SPU-CPU out of limit counter. See § 9.2.3.1	REBA HK TM(3,25)		In the packet 120202369 the parameters LM532340 = 0,	20 s	



3	Reset the SPU-CPU out of limit counter	Reset SPU-CPU counter TC(8,4)	LC057320	LM529340 bit 3 and 7=0 Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
4	Verify the SPU-CPU out of limit counter	REBA HK TM(3,25)		In the packet 120202369 the parameters LM532340 = Ah		
5	Verify the FPU temperature threshold. See § 9.2.3.3	REBA HK TM(3,25)		In the packet 120202369 the parameters LM533340 = FFFFh, LM529340 bit 2 and 6=0	4 s	
6	Reset the FPU over-temperature counter	Reset FPU out of limit counters TC(8,4)	LC070320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
7	Change the FPU temperature threshold	Set FPU temperature limits TC(8,4)	LC069320 parameter LP173320 = TBD (hexadecimal value, not calibrated, see Note (2))	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
8	Verify the FPU temperature threshold	REBA HK TM(3,25)		In the packet 120202369 the parameters LM533340 = TBD (see step 7)	4 s	
9	Re-set the FPU temperature threshold setting again the default value this had before step 7.	Set FPU temperature limits TC(8,4)	LC069320 parameter LP173320 = TBD (hexadecimal value, not calibrated)	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
10	Verify the science telemetry rate	REBA HK TM(3,25)		In the packet 120202369 the parameters	4 s	



	parameters. See § 9.2.3.2.			LM529340 bit 5 = 0, LM534340 = 3Ch (sampling period), LM535340 = 30h (maximum telemetry rate in kbps), LM537340 = 168h (time constant), LM542340 = 0 (table step)		
11	Verify the step table.	Get TM rate step table TC(14,1)	LC150320 parameters LP162320 = 1h, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 2C0h	Receive Packets ID 120011342 and 120017342 and 120704340 (containing the step table)		
12	Change the time constant value. Default is 360 s (168h)	Set TM rate Tau TC(8,4)	LC086320 parameter LP175320 = TBD	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
13	Change the sampling period. Default is 60 s (3Ch). min is 60 s, max is 6 hrs	Set TM rate period TC(8,4)	LC085320 parameter LP176320 = TBD	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
14	Reset TM packet counter	Reset Science TM counter TC(8,4)	LC084320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
15	Change the step table. Values are between 0 to 43, representing the Detector ID to be set/unset. See Note ⁽¹⁾	Set TM rate steps table TC(8,4)	LC082320 parameter LP201320 to LP376320 = TBD ⁽¹⁾ (176 byte)	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
16	Verify the science telemetry rate parameters	REBA HK TM(3,25)		In the packet 12020369 the parameters LM529340 bit 5 = 0,	4 s	



				LM534340 = TBD step 13 (sampling period), LM535340 = 48 ** (maximum telemetry rate in kbps), LM537340 = TBD step 12 (time constant), LM542340 = 0 (table step)		
17	Verify the step table	Get TM rate step table TC(14,1)	LC150320 parameters LP162320 = 1h, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 2C0h	Receive Packets ID 120011342 and 120017342 and 120704340 (containing the step table) as for step 15		

Table 13.2-44 Verifying the monitoring functions (in normal science mode this parameter is set to 30h (48 kbps) going from the DAE Set-up directly to the extended science mode, this parameter is set to TBD, TM > 48 kbps)**

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.

Note (1) Values are between 0 to 43, representing the Detector ID to be set/unset in processing groups A and B (see Table 15.1 3 Identification matrix for the detectors). A value equal to 0xFF means no detector is to be set/unset.

Note (2) The temperature limit in K is indicative and could be set from manual stack in case of different need using the calibration curve number 104, 106, 109, 110, 111, 113 and 114 in LFI Database (caf.tab): the value 0h corresponds to the maximum temperature threshold (90 K) while 1AA0h to about 25 K.



13.2.15 ENABLING THE AUTONOMOUS FUNCTIONS

The procedure to enable the autonomous functions is described in the tables below.

Topic	Description	Note
Purpose	To initialize and adjust the autonomous functions of the LFI. See § 9.2.3 for a description of LFI autonomous functions.	PFLCSAA
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA established and synchronized.	
Initial satellite state	LFI Normal and Extended Science Mode	see Table 13.2-13, Table 13.2-15
End satellite state	LFI Normal or Extended Science Mode	
Reference procedures	1. Enabling the autonomous functions	see Table 13.2-46
Procedure predecessors		
Contingency procedures	Note that some autonomous functions are automatically enabled (FEU switch off and TM flow control). If this is the case, the corresponding check will fail (see step 1) and it is not necessary to enable	



the corresponding function being already enabled.

Table 13.2-45 Summary of procedure to enable the autonomous functions

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the status of autonomous functions, respectively the AF corresponding to the 1355 link, to the FEU switch off and to the TM flow control (boolean parameters, 0=disabled).	REBA HK TM(3,25)		In the packet 120202369 the parameters LM519340 = 0, LM520340 = 0, LM521340 = 0	4 s	
2	Enable the autonomous functions	Enable AF stop det proc TC(8,4) Enable AF switch off FEU TC(8,4) Enable AF restart 1355 all comm TC(8,4)	LC043320 (telemetry flow control), LC045320 (switch off of FEU), LC048320 (1355 link)	Receive Packets ID 120011342 and 120017342 for each of the commands		If TC failure see Note ⁽⁰⁾
3	Verify the status of autonomous functions	REBA HK TM(3,25)		In the packet 120202369 the parameters LM519340 = 1, LM520340 = 1, LM521340 = 1	4 s	

Table 13.2-46 Enabling the autonomous functions

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.



13.2.16 TESTING THE AUTONOMOUS FUNCTIONS

The procedure to test the autonomous functions is described in the tables below.

Topic	Description	Note
Purpose	To test the autonomous functions of the LFI.	PFLCSAX
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA established and synchronized.	
Initial satellite state	LFI Normal and Extended Science Mode	see Table 13.2-13, Table 13.2-15
End satellite state	LFI Normal or Extended Science Mode	
Reference procedures	1. Testing the autonomous functions	see Table 13.2-48
Procedure predecessors		
Contingency procedures		

Table 13.2-47 Summary of the procedure to test the autonomous functions

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the status of	REBA	HK	In the packet 120202369	4 s	



	autonomous functions respectively the AF corresponding to the 1355 link, to the FEU switch off and to the TM flow control (boolean parameters, 1=enabled).	TM(3,25)		the parameters LM519340 = 1, LM520340 = 1, LM521340 = 1		
2	Verify FEU is active, respectively the DC-DC converters 1 to 4 are enabled	DAE slow HK TM(3,25)		In the packet 120101369 the parameters LM001332 = 1, LM002332 = 1, LM003323 = 1, LM004332 = 1	64 s	
3	Activate the FEU switch off autonomous function and switch off the FEU	Activate AF switch off FEU TC(8,4)	LC067320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
4	Verify FEU is not active, respectively the DC-DC converters 1 to 4 are now disabled	DAE slow HK TM(3,25)		In the packet 120101369 the parameters LM001332 = 0, LM002332 = 0, LM003323 = 0, LM004332 = 0	64 s	
5	Verify the status of the detectors. Six 8-bit parameters to verify the status of each detector. See Appendix B for the definition and correspondance parameter vs detector channel.	REBA HK TM(3,25)		In the packet 120202369 the parameters LM560350 = FFh, LM561350 = FFh, LM562350 = FFh, LM563350 = FFh, LM564350 = FFh, LM565350 = F0h	4 s	Use the RCA activation procedure (Par. 13.2.6, Table 13.2-28)



6	Activate the telemetry flow control autonomous function by using the two parameters step (LP145320, corresponding to the row number of step table) and activity (LP146320, indicating the moving direction, up=0 / down=1). See Note ⁽¹⁾	Activate AF Enabl disabl sc det processing TC(8,4)	LC081320 parameters LP145320=TBD LP146320=TBD ⁽¹⁾	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
7	Verify the status of the detectors	REBA HK TM(3,25)		In the packet 120202369 the parameters LM560350 = TBD, LM561350 = TBD, LM562350 = TBD, LM563350 = TBD, LM564350 = TBD, LM565350 = TBD (see parameter as set in step 6)	4 s	
8	Verify one of the three DPU (LM552340) and one of the three SPU (LM587350) 1355 links are disconnected	REBA HK TM(3,25)		In the packet 120202369 the parameters LM552340 bit 6 or 11 or 15 = 0, or LM587350 bit 6 or 11 or 15 = 0	4 s	
9	Reset DPU SMCS	Reset DPU SMCS TC(8,4)	LC039320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
10	Activate restart of the 1355 link control		LC091320	Receive Packets ID 120011342 and		If TC failure see Note ⁽⁰⁾



11	Verify the three DPU (LM552340) and three SPU (LM587350) 1355 links are connected	REBA TM(3,25)	HK	120017342	In the packet 120202369 the parameters LM552340 bit 6, 11 and 15 = 1, LM587350 bit 6, 11 and 15 = 1	4 s

Table 13.2-48 Testing the autonomous functions

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.

Note (1) See 9.2.3.2 for details. As an example:

- If Action = down and Step = 1, it shall send to SPU_ASW the command “Stop Calibration Channel Switching”.
- If Action = up and Step = 2, it shall send to SPU_ASW the command “Start Calibration Channel Switching”.
- If Action = down and $2 \leq \text{Step} \leq N$, it shall get the current status of both processing groups A and B and it shall send to SPU_ASW the following 3 commands:
 - SPU Command “Stop Science processing”.
 - SPU Command “Set science processing types” with the following parameters for both processing groups A and B:
 - A Type = current type A and Detector Mask = Current Detector Mask A minus those detectors specified in Step of TM_RATE_STEPS Table.
 - B: Type = 3 and Detectors Mask = Current Detector Mask B plus those detectors removed from A.
 - SPU Command “Start Science Processing”.
- If Action = up and $3 \leq \text{Step} \leq N + 1$, it shall get the current status of both processing groups A and B and it shall send to SPU_ASW the following 3 commands:
 - SPU Command “Stop Science processing”.
 - SPU Command “Set science processing types” with the following parameters for both processing groups A and B:
 - A: Type = current type in status and Detector Mask = Current Detector Mask A plus those detectors of Step –1 which are currently enabled in Detector B.



B: Type = 3 and Detectors Mask = Current Detector Mask B minus those detectors of Step –1.

SPU Command “Start Science Processing”.

- For any other combination of parameters Step and Action the autonomous function shall do nothing going directly to the next sentence.
- Generate an Event report (5,1) SID=5110 reporting success/failure of the execution of the autonomous function.

13.2.17 SETTING THE TELEMETRY RATE

The procedures to set the telemetry rate (that include the procedures to go from the DAE Set-up to the Normal Science or the Extended Science^(**) mode and from the Normal Science to the Extended Science^(**) mode and viceversa) are described in the tables below.

Topic	Description	Note
Purpose	To go in the Planck LFI Nominal or Extended Science Mode or to pass from Nominal to Extended or viceversa.	PFLCSNN step 2, 3
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability. The ground equipment should guarantee a suitable TM packet rate	The maximum TM packet rate supported by LFI is 20 TM packet/s
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite. The satellite should guarantee a suitable TM packet rate.	The maximum TM packet rate supported by LFI is 20 TM packet/s
LFI instrument pre-requisites	REBA powered on, ASW initialized and	



	synchronized.	
Initial satellite state	- LFI DAE Set-up Mode - LFI Normal or Extended Science Mode	see Table 13.2-13, Table 13.2-15 see Table 13.2-17, Table 13.2-18
End satellite state	- LFI DAE Set-up - LFI Extended or Normal Science Mode	
Reference procedures	1. Setting the telemetry rate	see Table 13.2-50
Procedure predecessors		
Contingency procedures		

Table 13.2-49 Summary of the procedures to set the telemetry rate

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
0	Check the value of the maximum allowed TM rate parameter, this is 48 kbps for Nominal, > 48 kbps for Extended Science mode	REBA HK TM(3,25)		In the packet 120202369 the parameter LM535340 = 30h (for Nominal Science, corresponding to a maximum telemetry rate of 48 kbps, otherwise should be > 48) (**)		
1	Set the maximum allowed TM rate in the required mode	Set the expected TM rate parameter TC(8,4)	LC083320 parameter LP174320 = TBD maximum TM rate (48 for Normal Science, > 48 for Extended Science(**))	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾



2	Check the TM rate parameter set in step 1	REBA TM(3,25)	HK		In the packet 120202369 the parameter LM535340=TBD (as set in step 1)	4 s	

Table 13.2-50 Setting the telemetry rate

Note ():** these procedures are the ones required to go to the nominal LFI telemetry rate (corresponding to the Normal Science Mode, see Paragraph 13.2.1.7 or 13.2.1.9 and Table 13.2-15 or Table 13.2-17). If the LFI is required to go to the Extended Science Mode (see Paragraph 13.2.1.5 or 13.2.1.10 and Table 13.2-13 or Table 13.2-18), the procedures are the same but the values to be set are those corresponding to the extended science mode (TBD, TM > 48 kbps).

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.

13.2.18 AUTONOMOUS FUNCTIONS DISABLING

The autonomous functions disabling procedure is described in the tables below.

Topic	Description	Note
Purpose	To disable the autonomous functions of the LFI.	PFLCSAD
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	



LFI instrument pre-requisites	Monitoring and autonomous functions activated.	
Initial satellite state	LFI Normal or Extended Science Mode	see Table 13.2-14, Table 13.2-16
End satellite state	LFI Normal or Extended Science Mode	
Reference procedures	1. Disabling the autonomous functions	see Table 13.2-52
Procedure predecessors		
Contingency procedures		

Table 13.2-51 Summary of the autonomous functions disabling procedures

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the status of autonomous functions respectively the AF corresponding to the 1355 link, to the FEU switch off and to the TM flow control (boolean parameters, 1=enabled).	REBA HK TM(3,25)		In the packet 120202369 the parameters LM519340 = 1, LM520340 = 1, LM521340 = 1	4 s	
2	Disable the autonomous functions	Disable AF stop det proc TC(8,4) Disable AF switch off FEU TC(8,4) Disable AF restart 1355 all comm TC(8,4)	LC044320 (telemetry flow control), LC046320 (switch off of FEU), LC049320 (1355 link)	Receive Packets ID 120011342 and 120017342 for each of the commands		If TC failure see Note ⁽⁰⁾
3	Verify the status of autonomous functions	REBA HK TM(3,25)		In the packet 120202369 the parameters LM519340 = 0, LM520340 = 0,	4 s	



LM521340 = 0

Table 13.2-52 Disabling the autonomous functions

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.

13.2.19 MONITORING FUNCTIONS DISABLING

The monitoring functions disabling procedure is described in the tables below.

Topic	Description	Note
Purpose	To disable the monitoring functions of the LFI.	PFLCSMD
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	Monitoring and autonomous functions activated.	
Initial satellite state	LFI Normal or Extended Science Mode	see Table 13.2-14, Table 13.2-16
End satellite state	LFI Normal or Extended Science Mode	
Reference procedures	1. Disabling the monitoring functions	see Table 13.2-54
Procedure predecessors		



Contingency procedures

Table 13.2-53 Summary of the monitoring functions disabling procedures

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the status of monitoring functions, respectively the monitoring of the SPU CPU, FPU temperature and TM rate (boolean parameters 1=enabled)	REBA HK TM(3,25)		In the packet 120202369 the parameters LM528340 = 1, LM527340 = 1	4 s	
2	Disable the monitoring on the SPU-CPU load	Stop SPU CPU monitoring TC(8,2)	LC015320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
3	Disable the monitoring on the FPU temperature	Stop FPU temperature monitoring TC(8,2)	LC017320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
4	Disable the monitoring on the science telemetry rate	Stop Science TM rate monitoring TC(8,2)	LC019320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
5	Verify the status of monitoring functions	REBA HK TM(3,25)		In the packet 120202369 the parameters LM528340 = 0, LM527340 = 0, LM526340 = 0	4 s	

Table 13.2-54 Disabling the monitoring functions

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.



13.2.20 EVENT PACKETS ENABLING

The procedure to enable the event packets is described in the tables below.

Topic	Description	Note
Purpose	To enable the events packets TM(5,x). For details on events packets structure, see § 11.3.	PFLCSEA
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Nominal Mode of the Satellite. Satellite is spinning.	
LFI instrument pre-requisites	REBA and RAA powered on	
Initial satellite state	LFI DAE Set-Up Mode	
End satellite state	LFI DAE Set-Up Mode	
Reference procedures	1. Event packets enabling	see Table 13.2-56
Procedure predecessors		
Contingency procedures		

Table 13.2-55 Summary of the procedures to enable the event packets

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Event packet activation to allow the generation of TM(5,x) produced as a result of an anomalous	TC(14,1)	LC150320, parameters LP162320 = 3	Receive Packets ID 120011342, 120017342		If TC failure see Note ⁽⁰⁾



	behaviour of the LFI instrument. Respectively TM(5,1), TM(5,2) and TM(5,4) are enabled.		LP164320 = 5, LP165320 = 1, LP163320 = 0 LP164320 = 5, LP165320 = 2, LP163320 = 0 LP164320 = 5, LP165320 = 4, LP163320 = 0			
2	Report Enabled Packets	TC(14,3)	LC217320	Receive Packets ID 120011342, 120017342 and verify in the TM packet 120144340 the presence of all the enabled event TM packets.		If TC failure see Note ⁽⁰⁾

Table 13.2-56 Event packets enabling

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1.

13.2.21 SCIENCE DC-DC SWITCH OFF

The Science DC-DC Switch Off procedure is described in the tables below.

Topic	Description	Note
Purpose	To Switch OFF the Science DC-DC convertes.	PFLC SSD Step 4, 5



Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is on.	
Initial satellite state	LFI unknown state: intermediate between Normal or Extended Science and DAE Set-up Mode (Science is already de-activated)	see Table 13.2-12
End satellite state	LFI DAE Set-up Mode	
Reference procedures	1. Science DC-DC Switch Off	see Table 13.2-60
Procedure predecessors		
Contingency procedures		

Table 13.2-57 Summary of the Science DC-DC switch off procedure

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
0	Inizialization		Table 13.2-65	Reset all the RCAs parameters to zero		
1	Science DC-DC set-up in order to switch off the 4 power group, 1 to 4, according to the order in table in § 6.2.1.3.4.1.	Science DC-DC set-up TC(8,4)	LC132320 LP063320 = 0 LP064320 = 0 LP065320 = 0 LP066320 = 0 LP112320 = F000h	Receive Packets ID 120011342 and 120017342 In the packet 120102369 the parameters LM421332 = 0, LM422332 = 0, LM423332 = 0,	4 s	If TC failure see Note ⁽⁰⁾



				LM424332 = 0		

Table 13.2-58 Science DC-DC switch off

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1.

13.2.22 RAA OFF CHECK

The RAA Off Check procedure is described in the tables below.

Topic	Description	Note
Purpose	To verify the RAA is OFF.	PFLNSSF Step 3
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA is on.	
Initial satellite state	LFI DAE Set-up Mode	see Table 13.2-12
End satellite state	LFI Standby Mode	
Reference procedures	1. RAA off check	see Table 13.2-60
Procedure predecessors		
Contingency procedures		

Table 13.2-59 Summary of the RAA OFF check procedure



STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Check the RAA is Off	REBA TM(3,25)	HK	In the packet 120202369 the parameter LM202342 = 5h	4 s	

Table 13.2-60 RAA off check

13.2.23 REBA AND RAA POWER ON/OFF BY SATELLITE

The REBA and the RAA must be powered ON and OFF by the satellite. The corresponding procedures are therefore defined by the satellites itself. The requirements are briefly described in the table below for the four procedures corresponding to the following steps:

- REBA POWER ON
- REBA POWER OFF
- RAA POWER ON
- RAA POWER OFF

Topic	Description	Note
Purpose	To power ON / OFF the REBA and the RAA.	PFLN SON Step 7, PFLN SOF Step 4, PFLN SDN Step 2, PFLN SSF Step 2
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	



Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites – REBA POWER ON – REBA POWER OFF – RAA POWER ON – RAA POWER OFF	- The REBA and RAA are powered off - The REBA is powered on, the RAA is powered off - The RAA is powered off, the REBA is powered on and ASW initialized - The RAA is powered on, the REBA is powered on	
Initial satellite state – REBA POWER ON – REBA POWER OFF – RAA POWER ON – RAA POWER OFF	- LFI OFF Mode - LFI Standby Mode - LFI Standby Mode - LFI DAE Set-up Mode	see Table 13.2-9 see Table 13.2-10 see Table 13.2-11 see Table 13.2-12
End satellite state – REBA POWER ON – REBA POWER OFF – RAA POWER ON – RAA POWER OFF	- LFI Standby Mode - LFI OFF Mode - LFI DAE Set-up Mode - LFI Standby Mode	
Reference procedures	1. REBA POWER ON 2. REBA POWER OFF 3. RAA POWER ON 4. RAA POWER OFF	LFI REBA LCL Power ON LFI REBA LCL Power OFF LFI RAA LCL Power ON LFI RAA LCL Power OFF
Procedure predecessors		
Contingency procedures		

Table 13.2-61 Summary of the REBA and RAA power ON/OFF procedure



13.2.24 RESETTING THE TELEMETRY COUNTER

The procedure to reset the telemetry counter that should be implemented every DTCP is described in the tables below.

Topic	Description	Note
Purpose	To reset the TM rate counter.	PFLCRTA
Constraints on use	Procedure to be applied during the visibility period (DTCP) every DTCP when in science mode	
Time criticality	No criticalities	
Expected duration	1 minutes	Less than 1 min
Ground Equipment pre-requisites	LFI HK decoding capability. The ground equipment should guarantee a suitable TM packet rate	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite. The satellite should guarantee a suitable TM packet rate.	
LFI instrument pre-requisites	REBA powered on, ASW initialized and synchronized.	
Initial satellite state	- LFI Normal or Extended Science Mode	see Table 13.2-17, Table 13.2-18
End satellite state	- LFI Extended or Normal Science Mode	
Reference procedures	1. Resetting the telemetry counter	see Table 13.2-63
Procedure predecessors		
Contingency procedures		

Table 13.2-62 Summary of the procedures to reset the telemetry counter



STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Check the value of the telemetry counter	REBA HK TM(3,25)		In the packet 120202369 AND110369, take note of the value of parameter LM536340		
2	Reset the TM counter	Reset the TM rate counter TC(8,4)	LC084320			If TC failure see Note ⁽⁰⁾
3	Check the TM counter has been resetted	REBA HK TM(3,25)		In the packet 120202369 AND110369, check value of parameter LM536340 is < 100 or less than value in step 1	4 s	

Table 13.2-63 Resetting the telemetry counter

13.2.25 INIZIALIZATION

The procedure to initialize the power supplies is described in the tables below. It should be applied every time a power supply is switched on.

Topic	Description	Note
Purpose	To initialize the power supplies	
Constraints on use	Procedure to be applied during the visibility period (DTCP)	
Time criticality	No criticalities	
Expected duration	1 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability. The ground equipment should guarantee a suitable	



	TM packet rate	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite. The satellite should guarantee a suitable TM packet rate.	
LFI instrument pre-requisites	REBA powered on, ASW initialized and synchronized.	
Initial satellite state	- LFI DAE Set Up - Normal or Extended Science Mode	see Table 13.2-12 see Table 13.2-17, Table 13.2-18
End satellite state	- LFI Extended or Normal Science Mode	
Reference procedures	1. Inizialization	see Table 13.2-65
Procedure predecessors		
Contingency procedures		

Table 13.2-64 Summary of the procedures to initialize the power supplies

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Configure the RCA parameters. At the first switch on, the values are the ones that put zero currents on the FPU ("Zero Biases conditions"). A corresponding TPF file (containing the values of all the parameters) will be produced.					If TC failure see Note ⁽⁰⁾



1.1	Configure Offset that is the offset circuitry of DAE before ADC converter	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C23h (Offset) (*)	Receive Packets ID 120011342 and 120017342		
1.2	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM101326 to LM144326		
1.3	Configure Gain that is the gain circuitry of DAE before ADC converter	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C22h (Gain) (*)	Receive Packets ID 120011342 and 120017342		
1.4	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM001326 to LM044326		
1.5	Configure Vgate1 that is the gate voltage of the first amplifier stage in each FEM	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C1Dh (Vgate1) (*)	Receive Packets ID 120011342 and 120017342		
1.6	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah,	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID		



			LP163320 = 44Dh	121101369 parameters from LM001322 to LM044322		
1.7	Configure Vgate2 that is the gate voltage of the second amplifier stage in each FEM	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C1Eh (Vgate2) (*)	Receive Packets ID 120011342 and 120017342		
1.8	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM101322 to LM144322		
1.9	Configure Voltage drain of each amplifier of the FEMs	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C1Fh (Drain) (*)	Receive Packets ID 120011342 and 120017342		
1.10	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM201322 to LM244322		
1.11	Configure Iswitch1 that is the current that drives the first diode of each phase shifter	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C20h (Iswitch1) (*)	Receive Packets ID 120011342 and 120017342		
1.12	Verify the configuration	Get DAE actual configuration	LC150320 parameter	Receive Packets ID 120011342, 120017342		



		TC(14,1)	LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM151322 to LM194322		
1.13	Configure Iswitch2 that is the current that drives the second diode of each phase shifter	Configure DAE TC(8,4)	LC121320 parameter LP158320 = C21h (Iswitch2) (*)	Receive Packets ID 120011342 and 120017342		
1.14	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM401322 to LM444322		
1.15	Configure Pol A-C that sets the polarization status A-C phase shifters	Configure DAE TC(8,4)	LC128320 parameter LP159320 = C26h (Pol A-C) (*)	Receive Packets ID 120011342 and 120017342		
1.16	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM301322 to LM311322		
1.17	Configure Pol B-D that sets the polarization status B-D phase	Configure DAE TC(8,4)	LC128320 parameter LP159320 = C27h	Receive Packets ID 120011342 and 120017342		



	shifters		(Pol B-D) (*)			
1.18	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM321322 to LM331322		
1.19	Configure En/Dis A-C that sets 4 kHz switching of the A-C phase shifters	Configure DAE TC(8,4)	LC128320 parameter LP159320 = C24h (En/Dis A-C) (*)	Receive Packets ID 120011342 and 120017342		
1.20	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM251322 to LM261322		
1.21	Configure En/Dis B-D that sets 4 kHz switching of the B-D phase shifters	Configure DAE TC(8,4)	LC128320 parameter LP159320 = C25h (En/Dis B-D) (*)	Receive Packets ID 120011342 and 120017342		
1.22	Verify the configuration	Get DAE actual configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 44Dh	Receive Packets ID 120011342, 120017342 and check the correctness of the uploaded parameters in packet ID 121101369 parameters from LM451322 to LM461322		



Table 13.2-65 Initialization

(*) Fill all the remaining parameters of the command with the corresponding values of the selection mask and the corresponding item in the corresponding TPF with “zero biases conditions”, see also § 13.2.6.

13.2.26 SCIENCE DC-DC CONVERTERS SWITCH ON

In this paragraph the procedures to switch on a single power group or all together are described as reported in the tables below.

Topic	Description	Note
Purpose	To set the RCA settings stored in the REBA.	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA DPU established and synchronized.	
Initial satellite state	- LFI Normal or Extended Science Mode - LFI DAE Set Up	see Table 13.2-13, Table 13.2-15 see Table 13.2-12



End satellite state	- LFI Normal or Extended Science Mode - RCA de-activation	
Reference procedures	1. Science DC-DC switch on	see Table 13.2-67
Procedure predecessors		
Contingency procedures		

Table 13.2-66 Summary of the procedures to switch on science DC/DC converters

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVER Y
1	Verify the Science DC-DC is off. Every parameter corresponds to a power supply group according to the order in table in § 6.2.1.3.4.1 and tables below	DAE fast HK TM(3,25)		In the packet 120102369 the parameters LM421332 = 0 or LM422332 = 0 or LM423332 = 0 or LM424332 = 0	4 s	
2	Science DC-DC set-up	Science DC-DC set-up TC(8,4)	LC132320 LP063320 = X1 LP064320 = X2 LP065320 = X3 LP066320 = X4 LP112320 = Yh	Receive Packets ID 120011342 and 120017342 In the packet 120102369 the parameters LM421332 = X1 LM422332 = X2 LM423332 = X3 LM424332 = X4	4 s	If TC failure see Note ⁽⁰⁾
3	Inizialization procedure: configure the RCA parameters of		see Table 13.2-65			



all the RCAs belonging to the power group that has been just switched on. The values are the ones that put zero currents on the FPU ("Zero Biases conditions").						

Table 13.2-67 Science DC-DC Switch on

	TC & TM parameter	DC/DC #1	DC/DC #2	DC/DC #3	DC/DC #4	All DC/DC
Parameter to load in TC (8,4)	LP063320	X1=1h	X1=0h	X1=0h	X1=0h	X1=1h
	LP064320	X2=0h	X2=1h	X2=0h	X2=0h	X2=1h
	LP065320	X3=0h	X3=0h	X3=1h	X3=0h	X3=1h
	LP066320	X4=0h	X4=0h	X4=0h	X4=1h	X4=1h
	LP112320	Y=8	Y=4	Y=2	Y=1	Y=F
Parameter obtained from telemetry (120102369)	LM421332	X1=0h	X1=0h	X1=0h	X1=0h	X1=1h
	LM422332	X2=1h	X2=1h	X2=0h	X2=0h	X2=1h
	LM423332	X3=0h	X3=0h	X3=1h	X3=0h	X3=1h
	LM424332	X4=0h	X4=0h	X4=0h	X4=1h	X4=1h

Warning: The DC/DC converters do not follow the same order of the power groups so the following table must be taken in mind before applying the right values in the LP parameters.

DC/DC converters	Power Group	RCA	Reference LP	Reference LM
#2	#1	RCA 18 RCA 26	LP064320	LM422332
#1	#2	RCA 19-20 RCA 28	LP063320	LM421332



#3	#3	RCA 21-22 RCA 24 RCA 27	LP065320	LM423332
#4	#4	RCA 23 RCA 25	LP066320	LM424332

13.2.27 SPU CONNECTION

In this paragraph the procedures to connect the SPU to DAE are described as reported in the tables below.

Topic	Description	Note
Purpose	To connect the SPU to DAE	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA DPU established and synchronized.	
Initial satellite state	LFI DAE Set Up	see Table 13.2-12
End satellite state	LFI DAE Set Up	see Table 13.2-12
Reference procedures	1. DPU connection to DAE	see Table 13.2-69
Procedure predecessors		



Contingency procedures

Table 13.2-68 Summary of the procedures to connect the SPU to the DAE

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	SPU connect to DAE	TC(8,4)	LC055320	Receive Packets ID 120011342 and 120017342	4 s	
2	Verify the SPU status	REBA HK TM(3,25)		LM558350=00 00h SPU task error LM586350=00 00h SMSC Errors LM587350=2F7Fh 1355 Link Status LM588350=00 00h 1355 Link errors		

Table 13.2-69 SPU connection to DAE

13.2.28 DEFINITION OF THE N_AVE SCIENCE PROCESSING PARAMETER

The procedures to define the science processing parameters are described in the tables below.

Topic	Description	Note
Purpose	To initialize and adjust the N_ave processing parameters of the scientific data of LFI.	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of	



	the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA DPU established and synchronized.	
Initial satellite state	LFI Normal and Extended Science Mode	see Table 13.2-13, Table 13.2-15
End satellite state	LFI Normal and Extended Science Mode	
Reference procedures	1. Definition of the N _{ave} science processing parameter	Table 13.2-71
Procedure predecessors		
Contingency procedures		

Table 13.2-70 Summary of the procedures to define the N_{Ave} science processing parameters

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Set Science Processing parameters. The values of the parameters will be passed by using the TPF files. See § 15.1.2 for a description of the parameters. Set N average	Set parameter N-average TC(8,4)	LC075320 parameters LP049320 to LP059320 (*)	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
2	Verify the values of N average	Get parameters N-average TC(14,1)	LC150320 parameter LP162320 = 1h LP164320 = 3h LP165320 = 1Ah LP163320 = 853h	Receive Packets ID 120011342, 120017342 and 122131350 (check the content of updated values of N average (**) see § 11.1.8.21, LM401350 to		



				LM411350		

Table 13.2-71 Definition of the N_{Ave} science processing parameters

Note (*): Fill all the remaining parameters of the command with the corresponding values of the selection mask (LP061320=FFFFh if set for all RCAs) and the corresponding item

Note (**): This information is not periodically reported but has to be dumped only upon dedicated request

Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1, otherwise the recovery action depends of the type of the failure, see high level recovery procedure in § 13.3.1.

Note 1:

Depending on the Activity ID and SID, configuration values and configuration mask may refer to detectors or horns. If they refer to detectors the 44 parameter values of the list and the 44 bits of configuration mask are used; if they refer to horns only 11 values of the list and 11 bits of configuration mask are used leaving the rest as spare.

For a detailed explanation of how masks should be filled, refer to [AN1], “Appendix B – SCOS 2K MASK PARAMETERS”.

13.2.29 SCRUB REBA MEMORIES

The procedures to scrub REBA memories are described in the tables below.

Topic	Description	Note
Purpose	To scrub REBA memories	
Constraints on use	Procedure to be applied during the visibility period	



	(DTCP).	
Time criticality	No criticalities	
Expected duration	15 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA DPU established and synchronized.	
Initial satellite state	LFI Normal and Extended Science Mode	see Table 13.2-13, Table 13.2-15
End satellite state	LFI Normal and Extended Science Mode	
Reference procedures	1. Scrub REBA memories	See Table 13.2-73
Procedure predecessors		
Contingency procedures		

Table 13.2-72 Summary of the procedures to define the processing parameters

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Start the scrub of DPU memories	Perform DPU memory scrubbing TC(8,4)	LC047320	Receive Packets ID 120011342 and 120017342		
2	Verify the status of parameters DPU DSP HW error	REBA ASW HK TM(3,25)		Receive Packets ID 120099320 with parameters LM500340 = 1000h DPU CPU Load LM543340 = 01F0h DPU Task Status LM543340 = 01F0h DPU Task Errors		
3	Start the scrub of SPU memories		LC056320	Receive Packets ID 120011342 and 120017342		



4	Verify the status of parameters DPU DSP HW error	REBA ASW HK TM(3,25)		Receive Packets ID 120099320 with parameters LM557350 = 1000h SPU CPU Load LM576350 = 000Ah SPU Task Status LM580350 = 00h SPU Task Errors		
5	Verify the status of parameters DPU DSP HW error	REBA ASW HK TM(3,25)		Receive Packets ID 120099320 with parameters LM500340<1000 DPU CPU load LM543340=00F0h DPU task status LM548340=00h DPU HW errors LM557350<100 SPU CPU Load LM576350=00 02h SPU Task Status LM580350=00h SPU Task Errors		

Table 13.2-73 Scrub REBA memories

13.2.30 UPDATE ALL DEFAULT RCA SETTINGS

In this paragraph the procedure to update all together the default RCA settings is described as reported in the tables below.

Topic	Description	Note
Purpose	To update all together the default RCA settings stored in the REBA.	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of	



	the Satellite.	
LFI instrument pre-requisites	REBA and RAA powered on. REBA initialized and synchronized, RAA connection to the REBA DPU established and synchronized.	
Initial satellite state	LFI Normal or Extended Science	see recovery action TBW
End satellite state	LFI Normal or Extended Science	
Reference procedures	1. Update all the default RCA settings	see Table 13.2-75
Procedure predecessors		
Contingency procedures		

Table 13.2-74 Summary of the procedures to update all the default RCA settings

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify the RCA parameters	Get DAE default configuration TC(14,1)	LC150320 LP162320=1h LP164320=3h LP165320=1Ah LP163320=44Dh	Receive Packets ID and 120011342, 120017342		
2	Configure all the default RCA parameters. This sets the dae default configuration	Save DAE actual configuration as default TC(8,4)	LC060320	Receive Packets ID and 120011342, 120017342		
3	Verify the RCA parameters	Get DAE default configuration TC(14,1)	LC150320 parameter LP162320 = 1, LP164320 = 3h, LP165320 = 1Ah, LP163320 = 457h	Receive Packets ID and 120011342, and 120017342, in the packet ID 121111369 the corresponding parameters according to step 1		



Table 13.2-75 Update all the default RCA settings

13.2.31 SET SCIENCE PROCESSING MODES

In this paragraph the procedure to set the science processing mode is described as reported in the tables below.

Topic	Description	Note
Purpose	To set the processing mode (A and B) of the scientific data of LFI (see § 15.1.3).	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	2 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA on, connected and synchronized REBA and DAE powered on. REBA initialized and DAE connection to the REBA DPU established.	
Initial satellite state	LFI Stand-by, Normal or Extended Science Mode	see Table 13.2-11, Table 13.2-15 and Table 13.2-18
End satellite state	LFI Stand-by, Normal or Extended Science Mode Note that during this procedures the LFI goes in an unknown state since science processing is stopped	
Reference procedures	1. Set Science processing modes	see Table 13.2-77
Procedure predecessors		



Contingency procedures

Table 13.2-76 Summary of the procedure to set the science processing mode

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify science processing is stopped	REBA HK TM(3,25)		Receive packet ID 120202369 parameter LM576350 bit 15 = 0		
2	Set Science Processing type. Accordingly each RCA will belong to processing mode A and/or B (see § 15.1.3).	Set Science Processing TC(8,4)	LC076320 parameters LP166320 (mode A) and LP167320 (mode B) = TBD (*), parameter from LP116320 to LP119320 = TBD bit mask of the channels to be processed in mode A and parameter from LP120320 to LP123320 = TBD bit mask of the channels to be processed in mode B. All these parameters through TPF.	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾

Table 13.2-77 Set science processing mode

(*) Refer to section 15.1.3 for the description of the science processing types.



Note (0) In case of TC acceptance failure, see Par. 13.3.3, item # 1.

13.2.32 SET DEFAULT DAE CONFIGURATION

In this paragraph the procedure to set the default DAE configuration is described as reported in the tables below.

Topic	Description	Note
Purpose	To set the default DAE configuration	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	2 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	REBA and RAA on, connected and synchronized REBA and DAE powered on. REBA initialized and DAE connection to the REBA DPU established.	
Initial satellite state	Normal or Extended Science Mode	see Table 13.2-15 and Table 13.2-18
End satellite state	Normal or Extended Science Mode Note that during this procedures the LFI goes in an unknown state since science processing is stopped	
Reference procedures	1. Set default DAE configuration	see Table 13.2-81
Procedure predecessors		



Contingency procedures		

Table 13.2-78 Summary of the procedure to set the default DAE configuration

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Configure DAE as default	Configure DAE by default TC(8,4)	LC059320	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾
2	Verify the RCA parameters	Get DAE default configuration TC(14,1)	LC150320 LP162320=1h LP164320=3h LP165320=1Ah LP163320=44Dh	Receive Packets ID 120011342 and 120017342		If TC failure see Note ⁽⁰⁾

Table 13.2-79 Set the default DAE configuration

13.2.33 REBA TM DIAGNOSTIC

In this paragraph the procedure to verify the REBA TM diagnostic is described as reported in the tables below.

Topic	Description	Note
Purpose	To verify the REBA TM diagnostic	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	10 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of	



LFI instrument pre-requisites	the Satellite. REBA and RAA on, connected and synchronized REBA and DAE powered on. REBA initialized and DAE connection to the REBA DPU established.	
Initial satellite state	LFI Normal or Extended Science Mode	see Table 13.2-15 and Table 13.2-18
End satellite state	LFI Normal or Extended Science Mode Note that during this procedures the LFI goes in an unknown state since science processing is stopped	
Reference procedures	1. REBA TM diagnostic	see Table 13.2-81
Procedure predecessors		
Contingency procedures		

Table 13.2-80 Summary of the procedure to verify REBA TM diagnostic

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Start of REBA diagnostic TM(3,26)	Enable REBA HK transmission TC(14,1)	TM LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=12Ch	Acknowledge by 120011342, 120017342 and 120300369 (TM (3,26) "REBA Diagnostic HK")		
2	Stop REBA HK TM(3,25)	Disable REBA HK transmission TC(14,2)	TM LC182320 parameter LP162320=1h LP164320=3h LP165320=19h LP163320=CAh	Acknowledge by 120011342, 120017342		
3	Verify start of REBA diagnostic	REBA Diagnostic HK TM (3,26)		Receive pkt ID 120300369 with parameters LM101340>0 Science packet generated LM102340>0 HK packet generated		



				LM105340=0	Science Packet Lost		
				LM106340=0	Not Science Packet lost		
				LM118340>0	DPU to SPU HK packets		
				LM120340>0	DPU to SPU Science Packets		
4	Start of REBA diagnostic HK TM(3,26)	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=12Dh	Acknowledge by 120011342, 120017342 and 120301350 (TM (3,26) "Compression Factor HK Packet format")			
5	Stop Compression Factor HK Packet format TM(3,26)	Disable transmission TC(14,2) TM	LC182320 parameter LP162320=1h LP164320=3h LP165320=1ah LP163320=12Dh	Acknowledge by 120011342, 120017342			
6	Check the arrival of Compression Factor HK Packet structure	Compression Factors Periodical TM (3,26)		Receive pkt 120301350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8			
7	Produce one non periodical compression packet diagnostic packet TM(3,26)	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=515h	Acknowledge by 120011342, 120017342 and 121301350 (TM (3,26) "Non periodical compression packet diagnostic packet")			
8	Check the arrival of non-periodical compression packet diagnostic packet TM(3,26)	Non periodical compression packet diagnostic packet TM (3,26)		Receive pkt 121301350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8			
9	Start SPU maximum memory occupancy dignostic packets TM(3,26)	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=12Eh	Acknowledge by 120011342, 120017342 and 120302350 (TM (3,26) "SPU maximum memory occupancy dignostic packets")			



10	Stop SPU maximum memory occupancy diagnostic packets TM(3,26)		LC182320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=12Eh	Acknowledge by 120011342, 120017342		
11	Check the arrival of SPU maximum memory occupancy diagnostic packet	SPU maximum memory occupancy diagnostic packets TM (3,26)		Receive pkt 120302350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
12	Produce one non periodical SPU maximum memory occupancy diagnostic packets TM(3,26)	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=516h	Acknowledge by 120011342, 120017342 and 121302350 (TM (3,26) "Non periodical SPU maximum memory occupancy diagnostic packets")		
13	Check the arrival of SPU Max Mem Occu Format Non Per packet	Non periodical SPU maximum memory occupancy diagnostic packets TM (3,26)		Receive pkt 121302350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
14	Start periodical SPU Current Memory Consumption TM(3,26)	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=12Fh	Acknowledge by 120011342, 120017342 and 120303350 (TM (3,26) "SPU Current Memory Periodical")		
15	Stop periodical SPU Current Memory Periodical TM(3,26)	Disable TM transmission TC(14,2)	LC182320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=12Fh	Acknowledge by 120011342, 120017342		
16	Check the arrival of SPU Current Memory Periodical packet	SPU Current Memory Periodical TM (3,26)		Receive pkt 120303350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		



17	Produce one non periodical SPU Current Memory Occ. Format TM(3,26)	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=517h	Acknowledge by 120011342, 120017342 and 121303350 (TM (3,26) "Non periodical SPU Current Memory Occ. Format")		
18	Check the arrival of Non periodical SPU Current Memory Occ. Format packet	Non periodical SPU Current Memory Occ. Format TM (3,26)		Receive pkt 121303350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
19	Start periodical SPU CPU Consumption TM(3,26)	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=130h	Acknowledge by 120011342, 120017342 and 120304350 (TM (3,26) "SPU CPU Consumption Periodical")		
20	Stop SPU CPU Consumption Periodical TM(3,26)	Disable transmission TC(14,2) TM	LC182320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=130h	Acknowledge by 120011342, 120017342		
21	Check the arrival of SPU CPU Consumption Periodical packet	SPU CPU Consumption Periodical TM (3,26)		Receive pkt 120304350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
22	Produce one non periodical SPU CPU Consump Format TM(3,26)	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=518h	Acknowledge by 120011342, 120017342 and 121304350 (TM (3,26) "SPU CPU Consump Format Non Per")		
23	Check the arrival of SPU CPU Consump Format Non Per packet	SPU CPU Consump Format Non Per TM (3,26)		Receive pkt 121304350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		



24	Produce one DAE actual configuration packet TM(3,26)	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=44Dh	Acknowledge by 120011342, 120017342 and 121101369 (TM (3,26) "DAE actual configuration packet")		
25	Check the arrival of DAE actual configuration packet	DAE actual configuration packet TM (3,26)		Receive pkt 121101369. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
26	Produce one DAE default configuration packet TM(3,26)	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=457h	Acknowledge by 120011342, 120017342 and 121111369 (TM (3,26) "DAE default configuration packet")		
27	Check the arrival of DAE default configuration packet	DAE default configuration packet TM (3,26)		Receive pkt 121111369. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
28	Produce one DPU HW register and EDAC failure diagnostic packet	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=7E5h	Acknowledge by 120011342, 120017342 and 122021340 (TM (3,26) "DPU HW register and EDAC failure diagnostic packet")		
29	Check the arrival of DPU HW register and EDAC failure diagnostic packet	DPU HW register and EDAC failure diagnostic packet TM (3,26)		Receive pkt 122021340. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
30	Produce one SPU HW register and EDAC failure diagnostic packet	Enable transmission TC(14,1) TM	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=849h	Acknowledge by 120011342, 120017342 and 122121350 (TM (3,26) "SPU HW register and EDAC failure diagnostic packet")		



31	Check the arrival of SPU HW register and EDAC failure diagnostic packet	SPU HW register and EDAC failure diagnostic packet TM (3,26)		Receive pkt 122121350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
32	Produce one DPU 1355 link error diagnostic packet	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=7E6h	Acknowledge by 120011342, 120017342 and 122022340 (TM (3,26) "Produce one DPU 1355 link error diagnostic packet")		
33	Check the arrival of Produce one DPU 1355 link error diagnostic packet	Produce one DPU 1355 link error diagnostic packet TM (3,26)		Receive pkt 122022340. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
34	Produce one SPU 1355 link error diagnostic packet	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=84Ah	Acknowledge by 120011342, 120017342 and 122122350 (TM (3,26) "Produce one SPU 1355 link error diagnostic packet")		
35	Check the arrival of Produce one SPU 1355 link error diagnostic packet	Produce one SPU 1355 link error diagnostic packet TM (3,26)		Receive pkt 122122350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
36	Produce one DAE SMCS1 registers diagnostic packet	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=7EDh	Acknowledge by 120011342, 120017342 and 122029328 (TM (3,26) "Produce one DAE SMCS1 registers diagnostic packet")		



37	Check the arrival of Produce one DAE SMCS1 registers diagnostic packet	Produce one DAE SMCS1 registers diagnostic packet TM (3,26)		Receive pkt 122029328. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
38	Produce one DAE SMCS1 GPIO diagnostic packet	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=833h	Acknowledge by 120011342, 120017342 and 122099328 (TM (3,26) "Produce one DAE SMCS1 GPIO diagnostic packet")		
39	Check the arrival of Produce one DAE SMCS1 GPIO diagnostic packet	Produce one DAE SMCS1 GPIO diagnostic packet TM (3,26)		Receive pkt 122099328. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
40	Produce one DAE SMCS2 registers diagnostic packet	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=851h	Acknowledge by 120011342, 120017342 and 122129328 (TM (3,26) "Produce one DAE SMCS2 registers diagnostic packet")		
41	Check the arrival of Produce one DAE SMCS2 registers diagnostic packet	Produce one DAE SMCS2 registers diagnostic packet TM (3,26)		Receive pkt 122129328. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
42	Produce one GMFs adn N-Averaging diagnostic packet	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=853h	Acknowledge by 120011342, 120017342 and 122131350 (TM (3,26) "Produce one GMFs adn N-Averaging diagnostic packet")		



43	Check the arrival of Produce one GMFs adn N-Averaging diagnostic packet	Produce one GMFs adn N-Averaging diagnostic packet TM (3,26)		Receive pkt 122131350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
44	Produce one Offset and Re-quant diagnostic packet	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=852h	Acknowledge by 120011342, 120017342 and 122130350 (TM (3,26) "Produce one Offset and Re-quant diagnostic packet")		
45	Check the arrival of Produce one Offset and Re-quant diagnostic packet	Produce one Offset and Re-quant diagnostic packet TM (3,26)		Receive pkt 122130350. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		
46	Produce one TM rate steps table diagnostic packet	Enable TM transmission TC(14,1)	LC150320 parameter LP162320=1h LP164320=3h LP165320=1Ah LP163320=2C0h	Acknowledge by 120011342, 120017342 and 120704340 (TM (3,26) "Produce one TM rate steps table diagnostic packet")		
47	Check the arrival of Produce one TM rate steps table diagnostic packet	Produce one TM rate steps table diagnostic packet TM (3,26)		Receive pkt 120704340. Ask Operator to save raw telemetry and check consistency of TM packet structure as in §11.1.8		

Table 13.2-81 REBA TM diagnostic

13.3 INSTRUMENT OPERATIONS PROCEDURES FOR CONTINGENCY RECOVERY OPERATIONS

The table below reports a high level list of contingency procedures to be applied when a problem occurs during a Transition between two LFI Nominal Operating modes described in Paragraph 13.2 (for more details refer to Table 13.2-8). This list is then described in more details in the following Table 13.3-2 and in paragraph 13.3.1 where each sub-section is dealing with one of these high level contingency problems. In each of



these sections a brief description of the problem that has occurred is given and where possible, a recovery solution is provided and a reference to low level contingency actions (§ 13.3.3, applicable instead for single TC failure) is given.

Note that, as described in detail in § 11.1.4, if a single command has failed, a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8) is produced. These packets contain an error code that gives indications on the reason of the failure (see also [AN3] ADDENDUM TM_1_2 and [AN5] ADDENDUM TM_1_8). The contingency procedure to be applied depends on this information and is detailed in § 13.3.2.

Note also that according to the type of failure, case by case, it could be required to understand the reason why a whole procedure or a single command has failed and apply the correct contingency action to recover the failure accordingly.

Operating Mode Transition	Nominal Procedure Name	Contingency Procedure	Procedure List Item (see Table 13.3-2)
OFF to Standby	REBA Power On by the Satellite	Up to S/C ^(*) , Power on Retry, Switch to redundant	1, 2
	REBA ASW Init	Power on Retry, Switch to redundant, In case of :ASW corrupted, HW error	1, 2 3, 4
	REBA Synchronization	Time shift, Auto synch, REBA not responding	5, 6, 22
	Event Packet Enabling		
Standby to OFF	REBA Power Off by the Satellite	Up to S/C ^(*)	
Standby to DAE Set-up	RAA Power On by the Satellite	Up to S/C ^(*)	
	RAA On Check and Connection to REBA RAA Synchronization	Wrong 1355, Bad DAE HK Time shift	7, 8 9
DAE Set-up to Standby	RAA Power Off by the Satellite RAA Off Check	Up to S/C ^(*) Don't believe HK	



DAE Set-up to Normal Science	Setting the Telemetry Rate	Different data rate	
	Science Activation	DAE part, REBA part, SPU to DAE connection	16, 17, 23
	RCA Activation	REBA part, DAE part, Bad HK, cryo harness...	10, 11, 12
	Definition of the Science Processing Parameters	Science processing calculations	14
Normal Science to DAE Set-up	Starting of the Monitoring Functions	Bad HK	18
	Disabling the Monitoring Functions	Bad HK	
	RCA De-activation	REBA part, DAE part, Bad HK, cryo harness...	
	Science De-activation	Bad HK	
Extended Science to Normal Science	Science DC-DC switch off	TBD	
	Setting the Telemetry Rate	Bad HK	
Normal Science to Extended Science	Setting the Telemetry Rate	Bad HK	
Additional procedures	Enabling the Autonomous Functions	Bad HK	18
	Verification of the Monitoring Functions	Bad HK	18
	Testing the Autonomous Functions	FP Temp, Bad HK, Wrong 1355	19, 10, 21
	Disabling the Autonomous Functions	Retry, Bad HK	

Table 13.3-1 LFI nominal operating modes and corresponding high level list of contingency procedure. The last column refers to Table 13.3-2.

Note (*): the REBA and RAA power ON/OFF procedures, described in § 13.2.23 and Table 13.2-61, do not depend on the LFI and are operated directly by the satellite thus also the corresponding contingency procedures, at least as a first step, depend only on the satellite.

According to the type of contingency, an event report TM(5,x) will be produced by the LFI.

Events of type 1 TM(5,1), event reports (see description in § 11.3.1), are managed autonomously by the instrument and do not require an action from ground.



Events of type 2 TM(5,2), exeptional reports (see description in § 11.3.2), are managed by the spacecraft. There is just one type of exeptional report in the LFI related to a possible problem on DPU-DAE link: the CDMU switches off the DAE to put the instrument in a safe mode because this kind of problem can affect the communications. Due to the switch off of the DAE, the focal plane thermal stability is not maintained any more and the normal status of the LFI should be recovered as soon as possible. A description of this kind of reports and possible recovery actions is given in § 13.3.4.

Events of type 4 TM(5,4), alarm reports (see description in § 11.3.3) can derive from event reports and should be managed directly from ground. A description of this kind of reports and possible recovery actions is given in § 13.3.5.

Additional contingency procedures which already happened in the past, are detailed in § 13.3.6 and 13.4.

13.3.1 HIGH LEVEL CONTINGENCY PROCEDURES

The following is a high level list of contingency procedures.

#	Operation	Contingency procedure name	Reference
1	REBA Power on retry	REBA power cycle	Par. 13.3.1.1
2	Switch to redundant	Pass to the redundant REBA	Par. 13.3.1.2
3	REBA HW error recovery	In case of HW error detected at REBA switch on	Par. 13.3.1.3
4	ASW integrity management	In case of ASW wrong checksum in EEPROM	Par. 13.3.1.4
5	REBA autosynch	REBA Failed synchronisation OBT drift	Par. 13.3.1.5
6	REBA time setting	REBA Failed synchronisation OBT shift	Par. 13.3.1.6
7	RAA HK link recovery	Failed connection between REBA DPU and DAE	Par. 13.3.1.7
8	DAE On detection error	Failure in the HK chain for DAE On detection	Par. 13.3.1.8
9	RAA time setting	RAA Failed synchronisation OBT shift	Par. 13.3.1.9



10	Wrong LFI configuration	The REBA doesn't execute the setting commands	Par. 13.3.1.10
11	See N. 7	The DAE doesn't receive the set value	
12	DAE command link verification	The echo of the setting is wrong	Par. 13.3.1.11
13	RCA verification	Wrong effect in the RCA output	Par. 13.3.1.12
14	See dedicated chapter	Need for recomputation of parameters	
15	Science power supply recovery	Science DC/DC converter failure	Par. 13.3.1.12
16	DAE processing recovery	Science sequencer failure	Par. 13.3.1.13
17	REBA SPU recovery	REBA science processing failure	Par. 13.3.1.14
18	Monitoring and Autonomous function recovery	Wrong report on monitoring and autonomous functions	Par. 13.3.1.15
19	FPU temperature recovery	Failure in FP temperature	Par. 13.3.1.16
20	See N 18	Wrong report of Science TM volume	
21	1355 link recovery	1355 link non recoverable failure	Par. 13.3.1.17
22	REBA recovery from not responding to TC	REBA does not respond to a command	Par. 13.3.1.18
23	DPU-SPU reconnection	SPU fails connection to DAE	Par. 13.3.1.19

Table 13.3-2 Contingency procedures list

In the following paragraphs the corresponding procedures to be applied are described.

13.3.1.1 REBA POWER ON RETRY

If the procedure to switch on the REBA by the satellite, described in Table 13.2-61 Summary of the REBA and RAA power ON/OFF procedure, failed while LFI is in the transition phase from OFF to Standby Mode (see § 13.2.1.1 and Table 13.2-9), or the REBA has switched off during this operation, or a failure appears when applying the REBA ASW INIT procedure (see Table 13-14, step 1 or 2), the REBA needs to be switch on again by the satellite. This corresponds to apply again the procedure "1.REBA POWER ON" described in Table 13.2-61 and then restart eventually the REBA ASW INIT procedure. In case of a REBA ASW INIT failure, the REBA should be first switched OFF ("2.REBA POWER OFF" described in Table 13.2-61).



13.3.1.2 SWITCH TO REDUNDANT

If the procedure to switch on the REBA by the satellite failed while LFI is in the transition phase from OFF to Standby Mode or the REBA has switched off during this operation, or a failure appears when applying the REBA ASW INIT procedure, and the contingency procedure described in the previous paragraph 13.3.1.1 has failed, it turns out to be necessary to switch to the redundant REBA. This corresponds to apply again the procedure “1.REBA POWER ON” described in Table 13.2-61 Summary of the REBA and RAA power ON/OFF procedure on the redundant unit as described in the table below and then restart eventually the REBA ASW INIT procedure.

The system should switch to the redundant REBA that must be powered ON by the satellite. The redundant REBA is switched on by the corresponding dedicated LCL protected line. The corresponding procedure is therefore defined by the satellites itself.

Topic	Description	Note
Purpose	To switch to redundant REBA and power it ON	
Constraints on use	Procedure to be applied during the visibility period (DTCP).	
Time criticality	No criticalities	
Expected duration	5 minutes	TBC
Ground Equipment pre-requisites	LFI HK decoding capability.	
Satellite pre-requisites	Earth Acquisition, Sun Acquisition, Nominal Mode of the Satellite.	
LFI instrument pre-requisites	The REBA and RAA are powered off	
Initial satellite state	LFI OFF Mode	see Table 13.2-9
End satellite state	LFI Standby Mode	
Reference procedures	1. REDUNDANT REBA POWER ON	LFI redundant REBA LCL Power ON
Procedure predecessors		
Contingency procedures		



Table 13.3-3 Summary of the redundant REBA power ON procedure

13.3.1.3 REBA HW ERROR RECOVERY

While LFI is in the transition phase from OFF to Standby Mode (see § 13.2.1.1 and Table 13.2-9) and switches on the REBA, when applying the REBA ASW INIT procedure (see Table 13.2-20), a HW error can be detected (step 7).

Refer to the corresponding low level procedure, paragraph 13.3.3, item 9 HW error, to recover from this problem.

13.3.1.4 ASW INTEGRITY MANAGEMENT

While LFI is in the transition phase from OFF to Standby Mode (see § 13.2.1.1 and Table 13.2-9) and switch on the REBA, when applying the REBA ASW INIT procedure (see Table 13.2-20), an ASW wrong checksum error in EEPROM can occur while checking the EEPROM content (step 4 and 11).

Refer to the corresponding low level procedure, paragraph 13.3.3, item 17 Memory scrub, to recover from this problem.

13.3.1.5 REBA AUTOSYNCH

While LFI is in the transition phase from OFF to Standby Mode (see § 13.2.1.1 and Table 13.2-9) and switch on the REBA, when applying the REBA SYNCHRONIZATION procedure (see Table 13.2-22), the REBA synchronisation can fail due to an OBT drift.

This should be identified by a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8), error code 0027, see the corresponding action in Table 13.3-6 and § 13.3.3.

13.3.1.6 REBA TIME SETTING

While LFI is in the transition phase from OFF to Standby Mode (see § 13.2.1.1 and Table 13.2-9) and switch on the REBA, when applying the REBA SYNCHRONIZATION procedure (see Table 13.2-22), the REBA synchronisation can fail due to an OBT shift.



This should be identified by a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8), error code 0027, see the corresponding action in Table 13.3-6 and § 13.3.3.

13.3.1.7 RAA HK LINK RECOVERY

While LFI is in the transition phase from Standby to DAE Set-up Mode (see § 13.2.1.3 and Table 13.2-11) and switch on the RAA, when applying the RAA On Check and Connection to the REBA procedure (see Table 13.2-24), a failed connection between REBA DPU and DAE can occur.

The DAE doesn't receive the set value.

This should be identified by a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8), error code 002A or 002B, see the corresponding action in Table 13.3-6 and § 13.3.3.

13.3.1.8 DAE ON DETECTION ERROR

While LFI is in the transition phase from Standby to DAE Set-up (see § 13.2.1.3 and Table 13.2-11) and switch on the RAA, when applying the RAA On Check and Connection to the REBA procedure (see Table 13.2-24), a failure in the HK chain for DAE On detection can occur.

13.3.1.9 RAA TIME SETTING

While LFI is in the transition phase from Standby to DAE Set-up Mode (see § 13.2.1.3 and Table 13.2-11), when applying the RAA Synchronization procedure (see Table 13.2-26), a RAA failed synchronisation OBT shift can occur.

This should be identified by a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8), error code 0032, 0033 or 0034, see the corresponding action in Table 13.3-6 and § 13.3.3.

13.3.1.10 WRONG LFI CONFIGURATION

While LFI is in the transition phase from DAE Set-up to Normal or Extended Science Mode (see § 13.2.1.5 and 13.2.1.7, Table 13.2-13 and Table 13.2-15), when applying the RCA Activation procedure (see Table 13.2-28), the REBA doesn't execute the setting commands.



This should be identified by a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8), error code 002A or 002B, see the corresponding action in Table 13.3-6 and § 13.3.3.

13.3.1.11 DAE COMMAND LINK VERIFICATION

While LFI is in the transition phase from DAE Set-up to Normal or Extended Science Mode (see § 13.2.1.5 and 13.2.1.7, Table 13.2-13 and Table 13.2-15), when applying the RCA Activation procedure (see Table 13.2-28), the echo of the setting is wrong.
This should be identified by looking at the upoloaded parameters in the corresponding packet ID as described in the corresponding procedure step.

13.3.1.12 RCA VERIFICATION

Wrong effect in the RCA output.

The following cases are identified:

- Recomputation of parameters is needed, see dedicated chapter “Need for recomputation of parameters” (TBW);
- Science power supply recovery;
- Science DC/DC converter failure.

13.3.1.13 DAE PROCESSING RECOVERY

While LFI is in the transition phase from DAE Set-up to Normal or Extended Science Mode (see § 13.2.1.5 and 13.2.1.7, Table 13.2-13 and Table 13.2-15), when applying the Science Activation procedure (see Table 13.2-34), a science sequencer failure can occur.

This should be identified by a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8), error code 0096, 0097 or 0098, see the corresponding action in Table 13.3-6 and § 13.3.3.

13.3.1.14 REBA SPU RECOVERY

While LFI is in the transition phase from DAE Set-up to Normal or Extended Science Mode (see § 13.2.1.5 and 13.2.1.7, Table 13.2-13 and Table 13.2-15), when applying the Science Activation procedure (see Table 13.2-34), a REBA science processing failure can occur.



This should be identified by a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8), error code 008B or 0095, see the corresponding action in Table 13.3-6 and § 13.3.3.

13.3.1.15 MONITORING AND AUTONOMOUS FUNCTION RECOVERY

While LFI is in the transition phase from DAE Set-up to Normal or Extended Science Mode (see § 13.2.1.5 and 13.2.1.7, Table 13.2-13 and Table 13.2-15), when applying the Starting and Verification of the Monitoring Functions or Enabling and Testing the Autonomous Functions procedures (see Table 13.2-42, Table 13.2-44, Table 13.2-46 and Table 13.2-48), a wrong report on monitoring and autonomous functions and/or a wrong report of Science TM volume can occur.

This should be identified by a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8), error code 0022, 0023, 0024 or 0037, see the corresponding actions in Table 13.3-6 and § 13.3.3.

13.3.1.16 FPU TEMPERATURE RECOVERY

While LFI is in the transition phase from DAE Set-up to Normal or Extended Science Mode (see § 13.2.1.5 and 13.2.1.7, Table 13.2-13 and Table 13.2-15), when applying the Testing the Autonomous Functions procedure (see Table 13.2-48), a failure in FP temperature can occur.

This should be identified by a corresponding “acceptance report failure” – TM(1,2) or “execution report failure” – TM(1,8), error code 002F, see the corresponding actions in Table 13.3-6 and § 13.3.3.

13.3.1.17 1355 LINK RECOVERY

While LFI is in the transition phase from DAE Set-up to Normal or Extended Science Mode (see § 13.2.1.5 and 13.2.1.7, Table 13.2-13 and Table 13.2-15), when applying the Testing the Autonomous Functions procedure (see Table 13.2-48), a 1355 link non recoverable failure can occur.

13.3.1.18 REBA RECOVERY FROM NOT RESPONDING

The REBA can fail in responding to a TC during each transition phase or whenever sending a TC to the LFI.



If the REBA is not responding to a telecommand, first wait 30 s to leave time for resolving possible delays in the TC dispatching pipeline. It has to be checked the right TC has been sent and if the acknowledgment has been required.

In case no TM(1,x) is received check whether the REBA is delivering other kind of TM packets (notice that HK packets have the precedence over the Science packets).

- In case HK packets are delivered: send a Test Connection TC LC216320 and check the availability of the TC loop
 - If the Test Connection is successful then retry with the originally unanswered TC
 - If the Test Connection is failed then reset the TC queue by sending TC LC035320 if ASW is running, otherwise LC032320 for SUSW. Then retry with the originally unanswered TC. See § 13.3, point 5, Table 13.3-7 and Table 13.3-8.
- In case HK packets are not delivered: check the CDMU to REBA communication at bus level and then by sending a Test Connection TC LC216320. See § 13.3, point 6, Table 13.3-9 and Table 13.3-10.
 - If the Test Connection is successful then dump DPU DRAM (see Table 13.1-2, step 1.1 and 1.2) address 0000 0000 to 0000 001D (with OBSM tool or by direct TC and corresponding procedure, see §13.1.1.1) and investigate possible problem sources. Then reset the REBA by sending TC LC001320 and verify SUSW HK telemetry is produced after 10 s.
 - If this is successful, dump again DPU DRAM (see Table 13.1-2, step 1.1 and 1.2) address 0000 0000 to 0000 001D (with OBSM tool or by direct TC and corresponding procedure, see §13.1.1.1).
 - If this fails, send a low level command that writes (anything) at the subaddress 28 of the REBA 1553 interface. This will re-start the machine as it was submitted to a power cycle. Dump DPU DRAM (see Table 13.1-2, step 1.1 and 1.2) address 0000 0000 to 0000 001D (with OBSM tool or by direct TC and corresponding procedure, see §13.1.1.1) and verify SUSW HK telemetry is produced after 10 s. Investigation is now required to understand the reasons of the failure.
 - If the Test Connection fails, send a low level command that writes (anything) at the subaddress 28 of the REBA 1553 interface. This will re-start the machine as it was submitted to a power cycle. Dump DPU DRAM (see Table 13.1-2, step 1.1 and 1.2) address 0000 0000 to 0000 001D (with OBSM tool or by direct TC and corresponding procedure, see §13.1.1.1) and verify SUSW HK telemetry is produced after 10 s. Investigation is now required to understand the reasons of the failure.

If none of this is successful, power cycle the REBA (see procedure § 13.2.23, Table 13.2-61: step 2 and then 1).



If a successful action is achieved, then put LFI to the same mode it was before the failure (see § 13.2.1 and Figure 13-1 LFI transition procedures):

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	LFI to standby		See § 13.2.1.1, Table 13.2-20 and Table 13.2-22	LFI in Stand-by mode: parameter LM202342=101b		
2	LFI to DAE Set-up		See § 13.2.1.3	LFI in DAE Set-up mode: parameter LM202342=1100b		
3	LFI to Normal Science		See § 13.2.1.7	LFI in Normal Science mode: parameter LM202342=10100b		
4	LFI to Extended Science		See § 13.2.1.10	LFI in Extended Science mode: parameter LM202342=11100b		

Table 13.3-4 Put the LFI in the original mode it was before the contingency. The first step is to put the LFI in stand-by, then in DAE set-up and to Normal (or Extended) Science Mode, stop at the correct step according to the original mode

Try to resend the TC a second time, if this fails again, additional investigation has to be performed and possibly work around solutions should be found.

13.3.1.19 DPU-SPU RECONNECTION

If during the procedure Science activation the DPU fails the connection to the SPU (see procedure in Table 13.2-34), it is necessary to apply the contingency procedure to reconnect the DPU to the SPU. The procedure consists in reported in the following table. It consists in the reset of the three SMCS chips (step 1) and then in bring the LFI in the original mode when the contingency appears.



STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Reset of the three SMCS chips		Table 13.2-24 RAA On check and connection to REBA	Receive Packets ID 120011342 and 120017342	4 s	
2	Verify the DPU status	REBA HK TM(3,25)		In packet 120202369 LM543340=00F0h DPU Task Status LM546340=0000h DPU HK errors LM551340=0000h DPU 1355 SMCS LM552340=6FF7h DPU 1355 Status		
3	Verify the DPU status	LFI DAE Fast HK Format TM(3,25)		In packet 120102369 LM101332=30°C±10 Service DC/DC temperature LM102332=30°C±10 Science 1 temperature LM105332=5V±10% Service V out LM107332=0.47A±10% Service Primary current LM108332=30°C±10 Science 2 temperature LM111332=30°C±10 Science 3 temperature LM114332=30°C±10 Science 4 temperature LM207332=30°C±10 Left Bem Temperature LM209332=30°C±10 Left Fem temperature LM211332=30°C±10 Left DAQ temperature LM307332=30°C±10 Right Bem Temperature LM309332=30°C±10 Right Fem temperature LM311332=30°C±10 Right DAQ temperature LM401328=0h PING Status LM402328=0h PONG Status LM411328=02h GPIO-1 Status LM413328=02h GPIO-1 Status LM421332=0h Science DC/DC 1 status LM422332=0h Science DC/DC 2 status LM423332=0h Science DC/DC 3 status LM424332=0h Science DC/DC 4 status		
4	RAA		Table 13.2-25	RAA synchronized		



	synchronization		Summary of the RAA synchronization procedure			
5	Set TM rate		Table 13.2-50 Setting the telemetry rate			
6	Enabling event packets TM(5,x)		Table 13.2-56 Event packets enabling			
7	Change processing type		Table 13.2-36 Change science processing mode, step 3			
8	Define the science processing parameters		Table 13.2-40 Definition of the science processing parameters, step 1.1 (processing type 1) and step 1.1 to 1.5 (type 5) and corresponding checks			
8	SPU connection, REBA and DAE science sequencer		Table 13.2-34 Science activation, step 3 to 5			

Table 13.3-5 DPU-SPU reconnection



13.3.2 TELECOMMAND ACCEPTANCE TM(1,2) AND EXECUTION TM(1,8) FAILURE

Below the table with a detailed description of the error codes contained in TM(1,2) and in TM(1,8) and the corresponding recovery actions.

Error code (Hex)	Description	Parameters (PTC,PFC) <range>	Recovery action	Item # (see § 13.3.3)
0000	Illegal APID	- 0000h (MSB) -Received Packet ID field (2,16)	• Re-send TC • TC Routing error • Check DB	• 1 • 2 • 3
0001	Incomplete or invalid length or total packet size doesn't match the message size returned by the transfer layer	- 0000h (MSB) -Received length field (3,12)	• Re-send TC • Check DB	• 1 • 3
0002	Incorrect checksum	- 0000h (MSB) -Received checksum field (2,16)	• Re-send TC	• 1
0003	Illegal packet type	- 0000 00h (MSB) -Received packet type (2,8)	• Re-send TC • Check DB	• 1 • 3
0004	Illegal packet sub-type	- 0000 00h (MSB) -Received packet sub-type (2,8)	• Re-send TC • Check DB	• 1 • 3
0005	Illegal or inconsistent application data (used only by DPU SUSW, not used by DPU ASW)	-0000 0000h	• Re-send TC • TC Routing error • Check DB	• 1 • 2 • 3
0010	TC rejected: Command queue overflow	-0000 0000h	• Wait and re-send TC • Clear hanged queue • Reset hanged REBA	• 4 • 5 • 6
0012	DPU Invalid memory ID	- 0000 00h (MSB) -Received memory ID (2,8)	• TC correctness • Re-send TC • REBA SW bug • HW error	• 7 • 1 • 8 • 9
0013	DPU Invalid address field	- 00h (MSB) -Received address (2,8) + (2,16)	• TC correctness • Re-send TC • REBA SW bug	• 7 • 1 • 8



			• HW error	• 9
0014	DPU Invalid data length in SAUs	- 0000h (MSB) -Received data length (3,12)	• TC correctness • Re-send TC • REBA SW bug • HW error	• 7 • 1 • 8 • 9
0015	DPU Invalid checksum (checksum received does not correspond to the Data Field in Load)	- 0000h (MSB) -Received checksum (2,16)	• TC correctness • Re-send TC • REBA SW bug	• 7 • 1 • 8
0017	DPU Invalid activity ID field	- 0000 00h (MSB) -Received activity ID (2,8)	• TC correctness • Re-send TC • REBA SW bug	• 7 • 1 • 8
0018	DPU Invalid SID field for Service 8	- 0000h (MSB) -Received SID (2,8)	• TC correctness • Re-send TC • REBA SW bug	• 7 • 1 • 8
0019	DPU Invalid function ID field	- 0000 00h (MSB) -Received function ID (2,8)	• Procedure correctness • TC correctness • Re-send TC • REBA SW bug	• 10 • 7 • 1 • 8
001A	Invalid parameter N in service 14,1	- 0000h (MSB) -Received N (3,12)	• TC correctness • Re-send TC • REBA SW bug	• 7 • 1 • 8
001B	DPU Invalid checksum after re-reads memory area in Load command	- 0000h (MSB) -Calculated checksum (2,16)	• TC correctness • Dump loaded memory • Re-send TC • Check memory health • REBA SW bug	• 7 • 11 • 1 • 12 • 8
001C	Illegal packet type for Service 14	- 0000 00h (MSB) -Received packet type (2,8)	• TC correctness • Re-send TC • REBA SW bug	• 7 • 1 • 8
001D	Illegal packet sub-type for Service 14	- 0000 00h (MSB) -Received packet sub-type (2,8)	• TC correctness • Re-send TC	• 7 • 1



			• REBA SW bug • TC correctness • Re-send TC • REBA SW bug	• 8 • 7 • 1 • 8
001E	DPU Invalid SID field for Service 14	-Received Type (2,8) -Received subtype (2,8) -Received SID (2,16)	• TC correctness • Re-send TC • REBA SW bug	• 7 • 1 • 8
001F	Type-subtype-SID already enabled (for Service 14)	-Received Type (2,8) -Received subtype (2,8) -Received SID (2,16)	• Procedure correctness • TC correctness • Re-send TC • REBA SW bug	• 10 • 7 • 1 • 8
0020	Type-subtype-SID already disabled (for Service 14)	-Received Type (2,8) -Received subtype (2,8) -Received SID (2,16)	• Procedure correctness • TC correctness • Re-send TC • REBA SW bug	• 10 • 7 • 1 • 8
0022	Invalid TM rate parameter (for “Set expected TM rate parameter”)	- 0000 00h (MSB) -Received TM rate (3,12)	• TC correctness • Re-send TC • Procedure correctness • REBA SW bug	• 7 • 1 • 10 • 8
0023	Invalid Tau value (for “Set Tau” command)	-Received Tau value (5,1)	• TC correctness • Re-send TC • REBA SW bug	• 7 • 1 • 8
0024	Invalid CF threshold value	-Received value (5,1)	• Check DB • TC correctness • REBA SW bug	• 3 • 7 • 8
0025	Function ID already “stopped”	- 0000 00h (MSB) -Received function ID (2,8)	• Procedure correctness • TC correctness • Re-send TC • REBA SW bug	• 10 • 7 • 1 • 8
0026	Function ID already “running”	- 0000 00h (MSB) -Received function ID (2,8)	• Procedure correctness • TC correctness • Re-send TC • REBA SW bug	• 10 • 7 • 1 • 8
0027	REBA OBT synchronisation/verification error	- 0000h (MSB)	• TC Routing error	• 2



		Error type: (2,16) - 91h sema. Timeout - 92h sync TC sequence error - 93h autosync enabled	• TC correctness If the synchronisation fails: • Re-send TC • Procedure correctness Else if the verification fails • Time shift check • REBA SW bug • HW error	• 7 • 1 • 10 • 13 • 8 • 9
0028	DPU-SPU not connected (Details on each link status shall be available in the LFI HK)	-0000 0000h	• Procedure correctness • SMCS re-connection • TC correctness • REBA SW bug • HW error	• 10 • 14 • 7 • 8 • 9
0029	DPU-SPU communication error	- 0000h (MSB) Error type: (2,16) - 01h SPU access timeout - 02h SPU conn. timeout - 05h TX timeout - 06h ACK timeout - 07h SPU communication status access timeout	• Re-send TC • REBA SW bug • HW error	• 1 • 8 • 9
002A	DPU-DAE not connected (Details on each link status shall be available in the LFI HK)	-0000 0000h	• Procedure correctness • SMCS re-connection • TC correctness • REBA SW bug • HW error	• 10 • 14 • 7 • 8 • 9
002B	DPU-DAE communication error	- 0000h (MSB) Error type: (2,16) - 11h DAE access timeout - 12h DAE link2 conn. timeout	• Re-send TC • SMCS re-connection • REBA SW bug • HW error	• 1 • 14 • 8 • 9



		- 13h DAE link 3 conn. timeout - 14h DAE communication status timeout - 15h WD TX-C timeout - 16h WD TX-N timeout - 17h RD TX-C timeout - 18h RD RX-N timeout - 19h WG TX-C timeout - 1Ah WG RX-C timeout - 1Bh WG TX-C timeout - 1Ch RR TX-C timeout - 1Dh RR RX-C timeout - 1Eh WR TX-C timeout		
002C	TC synchronisation is in process (for “Enable autosynch”)	-0000 0000h	• Procedure correctness • TC correctness • TC Routing error • REBA SW bug	• 10 • 7 • 2 • 8
002D	SPU Ack/Nack not valid	- 0000h (MSB) - SPU Ack/Nack (2,16)	• Re-send TC • REBA SW bug • HW error	• 1 • 8 • 9
002E	Invalid size in SPU Dump packet	- 0000h (MSB) - SPU dump size (2,16)	• TC correctness • Re-send TC • REBA SW bug • HW error	• 7 • 1 • 8 • 9
002F	DAE HK acquisition stopped (for “start FPT monitoring”)	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0030	SPU runs SUSW (for “Start CPU monitoring” and “Start	-0000 0000h	• Procedure correctness	• 10



	CF monitoring")		• Unexpected reset • TC correctness • REBA SW bug	• 15 • 7 • 8
0031	Internal data access timeout (for "Get" and "Reset" commands)	- 0000h (MSB) - Resource ID: (2,16) - 81h RES_DIAG_BUFF	• Re-send TC • REBA SW bug • HW error	• 1 • 8 • 9
0032	DAE OBT synchronisation/verification is not performed: 1Hz signal timeout	- 0000h (MSB) - "first"/"second" signal (2,16)	• Re-send TC • REBA SW bug • HW error	• 1 • 8 • 9
0033	DAE OBT synchronisation/verification is not performed: DAE communication error	- Step (1-3) (2,16) <1..3> - Error type: (2,16) - 11h DAE access timeout - 15h WD TX-C timeout - 16h WD TX-N timeout - 17h RD TX-C timeout - 18h RD RX-N timeout - 19h WG TX-C timeout - 1Ah WG RX-C timeout - 1Bh WG TX-C timeout	• SMCS re-connection • Re-send TC • REBA SW bug • HW error	• 14 • 1 • 8 • 9
0034	DAE OBT is not correct in DAE verification	- REBA OBT (9,17) - DAE OBT (9,17)	• Procedure correctness • REBA SW bug • HW error	• 10 • 8 • 9
0035	Autosync is already enabled (for "Enable autosync")	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0036	Autosync is already disabled (for "Disable autosync")	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0037	AF is already enabled (for "Enable AF")	-0000 0000h	• Procedure correctness	• 10



			• TC correctness • REBA SW bug	• 7 • 8
0038	AF is already disabled (for “Disable AF”)	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
003A	Invalid command for SPU running application	-0000 0000h	• Procedure correctness • TC correctness • Unexpected reset • REBA SW bug	• 10 • 7 • 15 • 8
003D	Not enough memory to allocate TM packet	-0000 0000h	• TM data production • Procedure correctness • TC correctness • REBA SW bug	• 16 • 10 • 7 • 8
003E	Invalid checksum for DAE configuration in EEPROM	-0000 0000h	• Memory scrub • REBA SW bug • HW error	• 17 • 8 • 9
003F	DPU LLSWDRV returns error	-driver function ID	• REBA SW bug • HW error	• 8 • 9
0040	Error checking functions of SPU or DAE for function status report	-0000 0000h	• REBA SW bug	• 8
0041	SPU invalid command ID	- 0000h (MSB) -Wrong command ID (2,16)	• Check DB • TC correctness • REBA SW bug	• 3 • 7 • 8
0042	SPU Invalid memory ID	- 0000 00h (MSB) -Received memory ID (2,8)	• Procedure correctness • TC correctness • Unexpected reset • REBA SW bug • HW error	• 10 • 7 • 15 • 8 • 9
0043	SPU Invalid address field	- 00h (MSB) -Received address (2,8) + (2,16)	• TC correctness • Unexpected reset • REBA SW bug	• 7 • 15 • 8



			• HW error	• 9
0044	SPU Invalid Data length in SAUs	- 0000h (MSB) -Received Data Length (3,12)	• Procedure correctness • TC correctness • REBA SW bug • HW error	• 10 • 7 • 8 • 9
0045	SPU Invalid checksum (checksum received does not correspond to the Data field in Load)	- 0000h (MSB) -Received checksum (2,16)	• TC correctness • Re-send TC • REBA SW bug • HW error	• 7 • 1 • 8 • 9
0047	SPU Invalid activity ID field	- 0000h (MSB) -Received activity ID (2,16)	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0048	SPU Invalid SID field	- 0000h (MSB) -Received SID (2,16)	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0049	SPU Invalid Parameter field	-Received invalid parameter in SID	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
004A	SPU could not perform command	-0000 0000h	• Procedure correctness • TC correctness • Unexpected reset • REBA SW bug • HW error	• 10 • 7 • 15 • 8 • 9
004B	SPU invalid checksum after re-reads memory area in Load command	- 0000h (MSB) -Calculated checksum (2,16)	• TC correctness • Memory scrub • REBA SW bug • HW error	• 7 • 17 • 8 • 9
0071	SPU invalid command ID	- 0000h (MSB) -Wrong command ID (2,16)	• Check DB • TC correctness • REBA SW bug	• 3 • 7 • 8
0072	SPU Invalid memory ID	- 0000 00h (MSB)	• Procedure correctness	• 10



		-Received memory ID (2,8)	• TC correctness • Unexpected reset • REBA SW bug • HW error	• 7 • 15 • 8 • 9
0073	SPU Invalid address field	- 00h (MSB) -Received address (2,8) + (2,16)	• TC correctness • Unexpected reset • REBA SW bug • HW error	• 7 • 15 • 8 • 9
0074	SPU Invalid Data length in SAUs	- 0000h (MSB) -Received Data Length (3,12)	• Procedure correctness • TC correctness • REBA SW bug • HW error	• 10 • 7 • 8 • 9
0077	SPU Invalid activity ID field	- 0000h (MSB) -Received activity ID (2,16)	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0078	SPU Invalid SID field (for “startfunc” commands)	- 0000h (MSB) -Received SID (2,16)	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
007E	Invalid SID (applicable to “Get” commands only)	- 0000h (MSB) -Received SID (2,16)	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0082	Invalid GMF value	-Received value (5,1)	• TC correctness • REBA SW bug	• 7 • 8
0083	Invalid ReQuant value	-Received value (5,1)	• TC correctness • REBA SW bug	• 7 • 8
0084	Invalid nAverage value (applicable to “Set nAverage” only)	-Radiometer ID (2,16) -Wrong nAverage (3,12)	• TC correctness • REBA SW bug	• 7 • 8
0085	Cannot update nAverage value for a horn under processing (applicable to “Set nAverage” only)	- 0000h (MSB) -Radiometer ID (2,16)	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0086	Invalid processing type for mode A or B (applicable to	-Sub-mode (A or B) (2,16) <0..1>	• TC correctness	• 7



	'Set science processing types' only)	-Received sub-mode (2,16) <0..6>	• REBA SW bug	• 8
0089	Memory allocation failure (applicable to 'Enable a channels' and 'Set science processing types' only)	-Sub-mode (2,16) <0..1> -Detector ID (2,16)	• REBA SW bug 8	• 8
008A	Cannot change science mode configuration while science processing is running (applicable to 'Set science processing types' only)	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
008B	Science processing is already running (applicable to 'Start Science processing' only)	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
008C	Science processing is already stopped (applicable to 'Stop Science processing' only)	-0000 0000h	• Procedure correctness • TC correctness • Unexpected reset • REBA SW bug	• 10 • 7 • 15 • 8
008D	SPU-DAE connection failure (applicable to 'get DAE SMCS-2 registers' and 'SPU connect to DAE' only) (Details on each link status shall be available in the REBA HK TM.)	-0000 0000h	• Procedure correctness • TC correctness • Unexpected reset • REBA SW bug • HW error	• 10 • 7 • 15 • 8 • 9
008E	Calibration channel switching is already running (applicable to "Start Calibration channel switching" only)	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
008F	Calibration channel switching is already stopped (applicable to "Stop Calibration channel switching" only)	-0000 0000h	• Procedure correctness • TC correctness • Unexpected reset • REBA SW bug	• 10 • 7 • 15 • 8
0091	Calibration channel switching cannot be started while Science processing is not started (applicable to "Start calibration channel switching" only)	-0000 0000h	• Procedure correctness • TC correctness • Unexpected reset • REBA SW bug	• 10 • 7 • 15 • 8
0092	Calibration switching period is wrong (for "Set switching period" and "Start Calibration channel	- 0000h (MSB) -Received switching period (3,12)	• TC correctness • REBA SW bug	• 7 • 8



	switching" only)			
0093	Science verification is already enabled (for "Enable Science verification")	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0094	Science verification is already disabled (for "Disable Science verification")	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug	• 10 • 7 • 8
0095	Science processing status access time out	-0000 0000h	• REBA SW bug • HW error	• 8 • 9
0096	SPU-DAE communication status access timeout	-0000 0000h	• REBA SW bug • HW error	• 8 • 9
0097	SPU-DAE access time out	-0000 0000h	• REBA SW bug • HW error	• 8 • 9
0098	SPU-DAE is not connected	-0000 0000h	• Procedure correctness • TC correctness • Unexpected reset • REBA SW bug • HW error	• 10 • 7 • 15 • 8 • 9
0099	Science configuration timeout	-0000 0000h	• REBA SW bug • HW error	• 8 • 9
009A	Science detector already enabled	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug • HW error	• 10 • 7 • 8 • 9
009B	Science detector already disabled	-0000 0000h	• Procedure correctness • TC correctness • Unexpected reset • REBA SW bug • HW error	• 10 • 7 • 15 • 8 • 9
009E	Received command length does not correspond to command type	-Received command length (3,12)	• Check DB • TC correctness	• 3 • 7



		-Expected command length (3,12)	• TC Routing error • REBA SW bug • HW error	• 2 • 8 • 9
009F	SPU LLSWDRV returns error	-Driver function ID	• REBA SW bug • HW error	• 8 • 9
00D0	TC rejected: Command queue overflow (DPU_SUSW)	-0000 0000h	• Procedure correctness • REBA SW bug • HW error	• 10 • 8 • 9
00DA	Could not perform command (DPU SUSW)	-0000 0000h	• Procedure correctness • TC correctness • REBA SW bug • HW error	• 10 • 7 • 8 • 9
00DB	Invalid checksum after re-reading memory area (DPU_SUSW)	- 0000h (MSB) -Invalid checksum calculated (2,16)	• TC correctness • REBA SW bug • HW error	• 7 • 8 • 9

Table 13.3-6 TM(1,2) and TM(1,8) Error Code and corresponding contingency actions

13.3.3 LOW LEVEL CONTINGENCY ACTIONS

1. Re-send TC

The rationale behind is that there is a remote chance that the TC is rejected because of unknown corruption of the TC or a problem in the SW that has to execute it.

Before trying something more invasive re-sending the TC could easily solve the problem.



2. TC routing error

The rationale for this action is that the CDMU has sent to LFI a command that was originally foreseen for another item thus it carries some wrong indications on the APID.

Check the path of the TC routed from the MOC to LFI.

3. Check DB

This action is called when there is the suspect that the TC or its parameters are wrongly defined in the DB.

Verify with the original documentation that the DB is in line with the definition of the TC interpreted by the OBSW.

4. Wait and re-send TC

This action is called when the TC could be rejected because of a transitory problem that doesn't require any other intervention than leave to the machine the time to get autonomously out from the failure situation.

Re-schedule the command 10 seconds after it was released before.

5. Clear hanged queue

It is assumed that the TC queue is hanged or is not cleared by the OBSW.

In case the SUSW is running send the command LC032320 without parameters:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify SUSW is running and the arrival of	REBA SUSW HK TM(3,25), SID=201		Receive packets ID 120201342 once per	Less than 30 s	



	corresponding Telemetry Packets			second		
2	Clear DPU TCS queue queue	PERFORM ACTIVITY FUNCTION TC(8,4)	LC032320	Receive Packets ID 120011342, and 120017342		

Table 13.3-7 Clear hanged queue (SUSW)

In case the ASW is running, check LM501340: if the value is 400h, this confirms the queue is full and send the command LC035320 without parameters:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify ASW is running and the status of parameter Software ID	Verify REBA HK TM(3,25)		Acknowledgement by Telemetry Packets ID 120202369 parameter LM206342 = 0202h	No delay	
2	Verify the TC queue is full	Verify REBA HK TM(3,25)		Acknowledgement by Telemetry Packets 120202369 parameter LM501340 = 400h		
3	Clear DPU TCS queue	PERFORM ACTIVITY FUNCTION TC(8,4)	LC035320	Receive Packets ID 120011342, and 120017342		

Table 13.3-8 Clear hanged queue (ASW)

These commands should overcome any other queued or executing TC and clear the TC queue.

6. Reset hanged REBA

In case the SW is hanged this condition should be trapped by the internal watchdog and restart the REBA from the Startup SW. In case the REBA is not completely hanged (and reset the watchdog) but doesn't respond, it could be useful to reset the unit.



In case the SUSW is running send the command LC033320 without parameters:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify SUSW is running and the arrival of corresponding Telemetry Packets	REBA SUSW HK TM(3,25), SID=201		Receive packets ID 120201342 once per second	Less than 30 s	
2	High level SW reset DPU	PERFORM ACTIVITY FUNCTION TC(8,4)	LC033320	Receive Packets ID 120011342, and 120017342		
3	Put the LFI in the original mode		See § 13.2.1 and Figure 13-1 LFI transition procedures	The LFI is now in an intermediate mode between Off and Stand-by. The first step is to put the LFI in stand-by, then in DAE set-up and to Normal (or Extended) Science Mode, according to the original mode when the contingency appeared.		
3.1	LFI to standby		See § 13.2.1.1, Table 13.2-20, step 7 (included) onward and Table 13.2-22	LFI in Stand-by mode: parameter LM202342=101b		
3.2	LFI to DAE Set-up		See § 13.2.1.3	LFI in DAE Set-up mode: parameter LM202342=1100b		
3.3	LFI to Normal Science		See § 13.2.1.7	LFI in Normal Science mode: parameter LM202342=10100b		
3.4	LFI to Extended Science		See § 13.2.1.10	LFI in Extended Science		



				mode: parameter LM202342=11100b		

Table 13.3-9 Reset hanged REBA (SUSW)

In case the ASW is running send the command LC001320 without parameters:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify ASW is running and the status of parameter Software ID	Verify REBA HK TM(3,25)		Acknowledgement by Telemetry Packets ID 120202369 parameter LM206342 = 0202h	No delay	
2	Start DPU SUSW	START FUNCTION TC(8,1)	LC001320	Receive Packets ID 120011342, and 120017342		
3	Put the LFI in the original mode		See § 13.2.1 and Figure 13-1 LFI transition procedures	The LFI is now in an intermediate mode between Off and Stand-by. The first step is to put the LFI in stand-by, then in DAE set-up and to Normal (or Extended) Science Mode, according to the original mode when the contingency appeared.		
3.1	LFI to standby		See § 13.2.1.1, Table 13.2-20, step 7 (included) onward and Table 13.2-22	LFI in Stand-by mode: parameter LM202342=101b		



3.2	LFI to DAE Set-up		See § 13.2.1.3	LFI in DAE Set-up mode: parameter LM202342=1100b		
3.3	LFI to Normal Science		See § 13.2.1.7	LFI in Normal Science mode: parameter LM202342=10100b		
3.4	LFI to Extended Science		See § 13.2.1.10	LFI in Extended Science mode: parameter LM202342=11100b		

Table 13.3-10 Reset hanged REBA (ASW)

If this doesn't work send a low level command that writes (anything) at the subaddress 28 of the REBA 1553 interface. This will re-start the machine as it was submitted to a power cycle.

After this operation, the LFI should be recovered up to the Mode before the failure.

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	LFI to standby		See § 13.2.1.1, Table 13.2-20 and Table 13.2-22	LFI in Stand-by mode: parameter LM202342=101b		
2	LFI to DAE Set-up		See § 13.2.1.3	LFI in DAE Set-up mode: parameter LM202342=1100b		
3	LFI to Normal Science		See § 13.2.1.7	LFI in Normal Science mode: parameter LM202342=10100b		
4	LFI to Extended Science		See § 13.2.1.10	LFI in Extended Science mode: parameter LM202342=11100b		



Table 13.3-11 Put the LFI in the original mode it was before the contingency. The first step is to put the LFI in stand-by, then in DAE set-up and to Normal (or Extended) Science Mode, stop at the correct step according to the original mode

Investigation on the causes is requested.

7. TC correctness

This action is often performed as a first check in case the TC is rejected. The aim is to verify that the parameters used into the TC are correct (e.g the ID of the memory to dump).

Open the echo of the rejected TC and check that the parameters of the command are the correct ones for the specific application.

8. REBA SW bug

When several trials are done the remaining possibility is that the SW has a bug.

How to cope with this bug shall be defined case by case because a new delivery will be required. The image of the new on-board software will be produced and a consequence a software patch operation should be implemented by using OBSM.

An example of patch of EEPROM is given in Table 13.1-2, step 3, here the correct regiorn of EEPROM should be patched, see § 10.3 and 10.3.1.4. Before the patch, the LFI fall back procedure should be applied up to step:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	LFI to DAE Set-up		See § 13.2.1.8	LFI in Stand-by mode: parameter LM202342=101b		
2	LFI to standby		See § 13.2.1.4	LFI in DAE Set-up mode: parameter LM202342=1100b		
3	Reset the REBA: start DPU SUSW	START FUNCTION	LC001320	Receive Packets ID 120011342, and 120017342		



		TC(8,1)				
4	REBA communication and hardware self check		See Table 13.2-20 REBA ASW Init, step 1 to 3			
5	Patch EEPROM		See example in Table 13.1-2, step 3			

Table 13.3-12 Switch off the LFI up to Stand-by before patching EEPROM

After this operation, the LFI should be recovered up to the Mode before the failure.

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	LFI to standby		See § 13.2.1.1, Table 13.2-20 step 4 (included) onward and Table 13.2-22	LFI in Stand-by mode: parameter LM202342=101b		
2	LFI to DAE Set-up		See § 13.2.1.3	LFI in DAE Set-up mode: parameter LM202342=1100b		
3	LFI to Normal Science		See § 13.2.1.7	LFI in Normal Science mode: parameter LM202342=10100b		
4	LFI to Extended Science		See § 13.2.1.10	LFI in Extended Science mode: parameter LM202342=11100b		

Table 13.3-13 Put the LFI is the original mode it was before the contingency. The first step is to put the LFI in stand-by, then in DAE set-up and to Normal (or Extended) Science Mode, stop at the correct step according to the original mode

9. HW error



When several trials are done the remaining possibility is that the HW failed.

How to cope with this failure shall be defined case by case. Operation work around solutions should be identified.

10. Procedure correctness

This action is called to check that the applied procedure is correctly implemented.

11. Dump loaded memory

It is assumed that there was a trouble in the patch of a memory location due to unknown causes. Check the entity of the failure and the effect of the load memory command dumping the dump memory locations for comparison.

12. Check memory health

Verify the health of the memories to look for possible weak or failed locations.

The operations to be performed should follow the following order:

- Scrub memory: See paragraph 13.2.29, Table 13.2-73;
- If scrub is not successful, this means that there is a damaged area in the memory that should be avoided. According to the type of memory, a software patch could be required. An image of the new software will be produced that should be uploaded by using OBSM;
- If scrub is successful, dump the memory and patch the dump result with the same contents by using OBSM (see par. 13.1.1.1, 13.1.1.2 and 13.1.1.3 for corresponding patch and dump activities);
- If this last operation does not work, this means that an hardware error has happened. Ad hoc investigation is required.

Note that not all the memories can be scrubbed, patched or dump, see details in par. 10.3.

13. Time shift check



A failure in the synchronisation could be due to an actual time shift between the satellite OBT and the instrument OBT.

Do not re-synchronise the instrument!

Evaluate the actual time difference and the trend of shift along the mission.

The evaluation of the successive activities will depend on the results of this action.

14. SMCS re-connection

If for any reason the SMCS reconnection autonomous function doesn't work it is possible to manually re-connect the broken link.

Send the command LC039320 without parameters to reset the SMCS chip then send the commands for reset the SMCS chips on the other side of the broken link then reconnect the relevant links:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Reset SMCS ships and reconnect DPU to SPU		See § 13.2.4 and Table 13.2-24, step 2 to 5	The link is working again as expected		

15. Unexpected reset

An unexpected reset due to the intervention of internal watchdog had happened.

Analyse the status of the instrument at the time of the reset to evaluate the ultimate cause.

Further activity is depending on the condition in which the error happened.

See also contingency explained in paragraph 13.3.1.18 that can be applicable also in this case.

16. TM data production

The production of TM data is so large that the REBA cannot route all of the packets into the S/C 1553 data Bus.



Check the actual rate of polling from the CDMS to the instrument (13 pkts/s). Then verify in the REBA HK whether the TM packets actually delivered are compatible with those declared to be generated.

Check the processing type of the Science data and verify that what is detected is not due to a peak of TM generation (statistics of the compressor)

17. Memory scrub

A checksum is failed. This could be due to a soft error in the memory

Re-send the command that generated the checksum error (the reading of a single wrong bit should be corrected by the EDAC) or run the memory scrub task (See paragraph 13.2.29, Table 13.2-73) for regenerating all the memories.

13.3.4 EVENT REPORTS: EXEPTIONAL REPORT TM(5,2)

After an exceptional report the LFI will be set “Stand-by”Mode. To recover the LFI, the first action is to restart from this point to switch On the LFI, from Stand-by to Normal Science, see Table 13.2-8 and § 13.2.1.4, up to the original mode it was before the failure:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	LFI to DAE Set-up		See § 13.2.1.3	LFI in DAE Set-up mode: parameter LM202342=1100b		
2	LFI to Normal Science		See § 13.2.1.7	LFI in Normal Science mode: parameter LM202342=10100b		
3	LFI to Extended Science		See § 13.2.1.10	LFI in Extended Science mode: parameter LM202342=11100b		



Table 13.3-14 Put the LFI in the original mode it was before the contingency. The first step is to put the LFI in DAE set-up, then to Normal (or Extended) Science Mode, stop at the correct step according to the original mode

If this operation does not solve the problem, the LFI should be switched off (see Table 13.2-8 and § 13.2.1.2) and on again from the very beginning (see Table 13.2-8 and § 13.2.1.1, 13.2.1.3 and 13.2.1.7).

If this operation does not solve the problem, probably this error means that a serious problem on the REBA appeared and it will be difficult to recover from it even from ground and thus the redundant REBA should instead be used. Only when the problem is understood and solved, a new LFI Instrument Commanding Request will be implemented (probably switching OFF the LFI and switching to the redundant REBA).

13.3.5 EVENT REPORTS: ERROR ALARM REPORT TM(5,4)

Four Error Alarm Event reports TM(5,4) (which should be managed by the ground support) could be produced by the LFI. For each of the four error alarm reports (5,4), below a short explanation and the LFI status.

All of them are events for which an automatic procedure to recover was not possible and an intervention from ground is required. In the paragraphs below, a first explanation of the problem that could have occurred is given and possible solutions are proposed. Nevertheless the final intervention could depend on the type of original failure which happened.

13.3.5.1 LFI: TM(5,4) EDAC DOUBLE ERROR – APID 1536, ID 5003, SPID 125003369

When a double EDAC error appears (a single error is automatically managed by the LFI 5,1 5002) on DPU and/or SPU, the REBA is put in a safe mode, Stand-by (SUSW only).

The IOT will try to understand the problem but in the meanwhile the LFI should be recovered to its original status, possibly back to the Normal Science Mode (again from "start up ASW" on).



The procedure to be followed is:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Verify SUSW is running and the arrival of corresponding Telemetry Packets	REBA SUSW HK TM(3,25), SID=201		Receive packets ID 120201342 once per second	Less than 30 s	
2	Put the LFI in the original mode		See § 13.2.1 and Figure 13-1 LFI transition procedures	The LFI is now in an intermediate mode between Off and Stand-by. The first step is to put the LFI in stand-by, then in DAE set-up and to Normal (or Extended) Science Mode, according to the original mode when the contingency appeared.		
2.1	LFI to standby		See § 13.2.1.1, Table 13.2-20, step 6 (included) onward and Table 13.2-22	LFI in Stand-by mode: parameter LM202342=101b		
2.2	LFI to DAE Set-up		See § 13.2.1.3	LFI in DAE Set-up mode: parameter LM202342=1100b		
2.3	LFI to Normal Science		See § 13.2.1.7	LFI in Normal Science mode: parameter LM202342=10100b		
2.4	LFI to Extended Science		See § 13.2.1.10	LFI in Extended Science mode: parameter LM202342=11100b		

Table 13.3-15 Recovery from EDAC double error



Note that if in this situation the REBA is not responding, before applying this procedure, the REBA should be reset (see par. 13.3.3 item 6. “Reset hanged REBA”).

13.3.5.2 LFI: TM(5,4) SMCS HW COMMUNICATION ERROR – APID 1536, ID 5031, SPID 125531369

If this type of (5,4) appears, it means that the attempts to re-establish the link between the SPU and the DAE or between the SPU and the DPU (see the corresponding autonomous function and service 5,1 5031) failed. Probably this error means that a serious problem on the REBA appeared and it will be difficult to recover from it even from ground and thus the redundant REBA should instead be used.

The status of the LFI is not automatically changed to maintain the thermal stability (only if a problem on DPU-DAE link the CDMU switches off the DAE to put the instrument in a safe mode because this kind of problem can affect the communications, service 5,2). LFI is of course losing science.

Only when the problem is understood and solved, a new LFI Instrument Commanding Request will be implemented (probably switching to the redundant REBA). This means that the LFI should be switched off and then on again with Redundant REBA (see paragraphs 13.2.1.8, 13.2.1.4, 13.2.1.2 and 13.2.1.1, 13.2.1.3, 13.2.1.7).

13.3.5.3 LFI: TM(5,4) SPU CPU WORKLOAD EXCEEDS ALLOWED LIMIT – APID 1536, ID 5102, SPID 125102340

There is an overload of the CPU of the SPU. The LFI does not change its status, it keeps staying in Normal Science (or in the original status) but the alarm is meant to inform the LFI IOT that something abnormal is causing an overload on the science processor and probably a consequent loss of Science TM.

The reasons which can cause this problem can be very different (data are not behaving as expected but also the compressor itself does not behave as expected). It is not a question of safety of the instrument or of the S/C but this can cause a loss of scientific data and thus should be recovered as soon as possible.

Only when the problem is understood and solved, a new LFI Instrument Commanding Request will be implemented probably acting on the science processing parameters.



13.3.5.4 LFI: TM(5,4) FP TEMPERATURE EXCEEDS ALLOWED LIMIT– APID 1536, ID 5103, SPID 125103340

When the FPU temperature increases above the threshold (set at 25 K by default but the value can be changed by TC) or better when 4 out of 7 temperature sensors measure this high temperature for more than 10 s consecutive, Science DC-DC converters are automatically switched off and the LFI goes to DAE set-up Mode.

The IOT will try to understand the problem but note that this could not depend on the LFI.

Only when the problem is understood and solved, a new LFI Instrument Commanding Request will be implemented to recover the LFI back to the Normal Science Mode:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Check the LFI is in DAE Set-up			Verify LM202342=1100b		
2	Science DC-DC converters switch on		See § 13.2.26	Power groups are on		
3	Science activation		See § 13.2.9, Table 13.2-34	SPU connect to DAE and science is activated		
4	Set default DAE configuration		See § 13.2.32, Table 13.2-79	Sconfigure DAE as default saved in EEPROM		
5	Check the LFI is in Normal Science			Verify LM202342=10100b		

13.3.6 ADDITIONAL CONTINGENCY PROCEDURES

13.3.6.1 SPU CONNECTION TO DAE

While putting LFI in normal science mode, when trying to perform the SPU connection to DAE (LC055320, see SCIENCE ACTIVATION, par. 13.2.9), during ground tests it happened that the REBA was no more producing any TM.



The solution is to apply the reset of the three SMCS chips. As a consequence some procedures to restart the DAE and the connections should be applied again and then the original configuration should be restored. The test sequence that should be applied if this problem appears is the following:

STEP #	DESCRIPTION	TYPE	ACTION	EXPECTED RESULT	DELAY	RECOVERY
1	Reset SMCS ships and go to DAE set-up mode		See § 13.2.4 and Table 13.2-24, § 13.2.5	LFI in DAE Set-up mode: parameter LM202342=1100b		
2	LFI to Normal Science		See § 13.2.1.7, up to “science Activation”	LFI in Normal Science mode: parameter LM202342=10100b		

Table 13.3-16 Recovery action for SPU connection to DAE failure

If this contingency action has not the expected result and do not solve the problem, the final contingency action is to switch off the LFI completely (up to OFF state) and back ON.

13.4 SPECIAL REMARKS

13.4.1 RCA 28 PHASE SWITCH STATUS

Due to a peculiarity of RCA 28, its phase switch polarization A/C shall be always set to zero and switching never enabled.



13.4.2 DAE OFFSET RANGES

For all the RCAs, the DAE offset shall never be programmed in the range between 0 and 50 due to high temperature sensitivity in that range.

The DAE offset applied to Sky and Ref samples appears to be different in some offset values ranges. These ranges are narrow and shall be avoided during the observation. The identification of the ranges can be done in flight during the CPV phase acquiring data at different DAE offset steps.

13.4.3 RCA 28 SOFT SWITCH ON PROCEDURE

In order to avoid RCA 28 saturation at the FEM power on, a “soft” switch on procedure has been identified and successfully performed during the LFI FM Test Campaign. In particular, this procedure sets V_{gate1} , V_{gate2} and V_{drain} biases so that the RCA 28 LNAs are switched on at different steps:

Step #	V_{gate1}		V_{gate2}		V_{drain}	
	M1	M2	M1	M2	M1	M2
1	$0.3 V_{G1\_nom}$	0	V_{G2_nom}	V_{G2_nom}	0	V_{d_nom}
2	$0.3 V_{G1\_nom}$	0	V_{G2_nom}	V_{G2_nom}	V_{d_nom}	V_{d_nom}
3	$0.3 V_{G1\_nom}$	$0.3 V_{G1\_nom}$	V_{G2_nom}	V_{G2_nom}	V_{d_nom}	V_{d_nom}
4	V_{G1_nom}	V_{G1_nom}	V_{G2_nom}	V_{G2_nom}	V_{d_nom}	V_{d_nom}

	Name of Procedure	Reference	Note
1	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.10	RCA 28 is biased with values given in step 1 of table above
2	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.6	RCA 28 is biased with values given in step 2 of table above
3	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.6	RCA 28 is biased with values given in step 3 of table above
4	Configure RCA Parameters	Table 13.2-28, step 2.1 to 2.6	RCA 28 is biased with values given in step 4 of table above

Note that I1 and I2 are set at their nominal values directly on step 1.



14 INSTRUMENT BUDGETS

14.1 LFI POWER BUDGET

14.1.1 ON SVM

See Paragraph 6.1.9.1 for a detailed description and for the table reporting on SVM heat dissipation.

14.1.2 ON PLANCK PAYLOAD MODULE (PPLM)

See Paragraph 6.1.9.2 for a detailed description and for the table reporting on PPLM heat dissipation.

14.1.3 INSTRUMENT OPERATING MODES

See Paragraph 8.1 for a detailed description.

14.1.4 SUPPLY VOLTAGES

See Paragraph 6.1.9.3 for a detailed description and for the table reporting on supply voltages.

14.1.4.1 SUBSYSTEM POWER BUDGETS

<i>Ass.y</i>	<i>Sub-Ass.y</i>	<i>#</i>	<i>Unit [W]</i>	<i>Est. [W]</i>	<i>Cont. [%]</i>	<i>Total [W]</i>
FEM's				0,056	0%	0,056
	30 GHz	2		0,123	0%	0,123
	44 GHz	3		0,150	0%	0,150
	70 GHz	6		4.633	5%	4.865

DAE				31.986	5%	33.585
	DAE BEU Box			9.900	5%	10.395
	Lx BEM Tray Box			2.306	5%	2.421
	Rx BEM Tray Box			0.200	20%	0.240
	Lx FEM Tray Box			2.880	5%	3.024
	Rx FEM Tray Box			2.400	20%	2.880
	Power Box			12.400	5%	13.020
BEM's				13.284	5%	13.948



	30 GHz	2		4.914	5%	5.160
	44 GHz	3		4.633	5%	4.865
	70 GHz	6		3,737	5%	3.924

				22.700	5%	23.835
REBA Nom.				22.700	5%	23.835
REBA Red.				0.000	0%	0.000

14.2 LFI DATA BUDGET

TM packets (Bytes)

Maximum packet length	1024

TM Budget (kbps)	53.5
Present TM load (kbps)	44.710
Min. packet budget (pkt/s)	6.531
Actual packet budget needs (pkt/s)	5.427

Science data (Bytes)

Average length of pkts (%)	100
Radiometer compression packet rate (pkt/s)	4.8486
Science packet budget (pkt/s)	12
Packeting overhead (%)	4.297
Packeting overhead (kbps)	1.707
Gross Science telemetry (kbps)	42.286

Housekeeping (3,25)

Average length of pkts (%)	61.43
Packet frequency (pkt/s)	0.5781
HK packet budget (pkt/s)	1
Packeting overhead (%)	3.555
Packeting overhead (kbps)	0.168
Gross HK Budget (kbps)	2.4248

14.3 LFI MASS BUDGET

The maximum allocated mass for the Planck Instruments is 445 kg.

This total mass is distributed to the two Planck instruments and the sorption cooler with the following allocations:

- LFI: 89 kg



- HFI: 244 kg
- Sorption cooler: 112 kg.

The present distribution of the instrument and cooler mass to the different interfaces in the system is as given in Table 14.3-1.

Interface	Max. allocated Mass [kg]	Remarks
Planck Telescope Structure	62	HFI/LFI merged FPU, incl. HFI JFET
PPLM and SVM Warm Units	383	
Total	445	

Table 14.3-1 Distribution of Planck Instrument Mass

14.3.1 SIZES AND MASS PROPERTIES

Paragraph 6.1.5, Table 6.2-4 and

LFI MASS BUDGET						BUDGET				
Project Code	WBS Code	Sub System	Unit	Ass.y	Sub-Ass.y	#	Unit [kg]	Est. [kg]	Cont. [%]	Total [kg]
PLBEU	===	BEU						25.542	1%	25.834
	PLAE0		DAE					23.130	1%	23.361
	PLAEA				DAE BEU Box			6.830	1%	6.898
	PLAEB				Lx BEM Tray Box			6.040	1%	6.100
	PLAEC				Lx FEM Tray Box					
	PLAED				Rx BEM Tray Box			5.750	1%	5.808
	PLAEE				Rx FEM Tray Box					
	PLAEF				Power Box			4.510	1%	4.555
	===		BEM's					2,412	3%	2,473
	PLAAD				30 GHz	2		0,624	1%	0,630
	PLABD				44 GHz	3		0,864	1%	0.873
	PLACD				70 GHz	6		0,924	5%	0.970

Table 6.2-5 give a detailed description of the mass and size properties. The total LFI mass is 89.9 kg. With a total mass allocation of 89 kg, the current overall negative margin for LFI is 1%.

14.3.2 SUBSYSTEM MASS BUDGETS

LFI MASS BUDGET						BUDGET				
Project Code	WBS Code	Sub System	Unit	Ass.y	Sub-Ass.y	#	Unit [kg]	Est. [kg]	Cont. [%]	Total [kg]
PLRAA	PLA00	RAA						77.900	2%	79.647
PLFEU	===	FEU						22. 935	1%	23.185
	PLAGA				FE Structure + Bipodes + FEU internal wiring			17.680	1%	17.857
	PLAGA/A + PLAGA/B + PLAHC				Main Frame			17.680	1%	17.857
					FEED HORN + OMTs			2.825	1%	2.853
	PLAAA+PLAAB				30 GHz	2		0.842	1%	0.850
	PLABA+PLABB				44 GHz	3		0.908	1%	0.917
	PLACA+PLACB				70 GHz	6		1.750	1%	1.086
	===				FEM's			2.478	2%	2.561



	PLAAC	30 GHz	2	0.405	0.810	1%	0.818
	PLABC	44 GHz	3	0.386	1.110	1%	1.121
	PLACC	70 GHz	6	0.085	0.510	5%	0.536
PLBEU	===	BEU			25.542	1%	25.834
	PLAE0	DAE			23.130	1%	23.361
	PLAEA	DAE BEU Box			6.830	1%	6.898
	PLAEB	Lx BEM Tray Box			6.040	1%	6.100
	PLAEC	Lx FEM Tray Box					
	PLAED	Rx BEM Tray Box			5.750	1%	5.808
	PLAEE	Rx FEM Tray Box					
	PLAEF	Power Box			4.510	1%	4.555
	===	BEM's			2,412	3%	2,473
	PLAAD	30 GHz	2		0,624	1%	0,630
	PLABD	44 GHz	3		0,864	1%	0,873
	PLACD	70 GHz	6		0,924	5%	0,970
PLWG	===	WG (Including support structure)			23.005	5%	24.146
	PLAGC	WG Structure			15.940	6%	16.940
		Upper			6.600	1%	6.666
		Lower (including thermal shields)			9.430	10%	10.274
	===	WGs			7.065	2%	7.206
	PLAAE	30 GHz	8		1.750	2%	1.785
	PLABE	44 GHz	12		2.505	2%	2.555
	PLACE	70 GHz	24		2.810	2%	2.866
	PLAH0	RAA HARNESS			5.491	1%	5.546
	PLAHA	BEU Internal harness			4.489	1%	4.534
	PLAHA/A	Power Box to BEU Box harness			0,729	1%	0,736
	PLAHA/B	Power Box to Lateral Trays harness			2,811	1%	2,839
	PLAHA/C	DAE BEU Box to Lateral Trays harness			0.949	1%	0.958
	PLAHB	DAE - FEU Cryo-harness	14		1,002	1%	1,012
PL4K	PLAF0	4K Load			0,927	1%	0,936
PLREB	PLB00	REBA			8.480	1%	8.565
PLREN	PLBAA	REBA Nom.			4.240	1%	4.282
PLRER	PLBAB	REBA Red.			4.240	1%	4.282
PLIH	PLE00	SYSTEM HARNESS			3,495	1%	3,530
	PLEA0	REBA to BEU harness			3,495	1%	3,530
		TOTAL			89.875	2%	91.742

14.4 LFI THERMAL BUDGET

In this section we present the current LFI heat load budget at the various relevant cold stages, i.e. the 20 K FPU and the three V-grooves at 140 K, 100 K and 50 K.

In order to decrease the overall power budget in Planck, it has been proposed to lower the input power requirement for the JPL-provided sorption cooler (from 520 to 420 W), while simultaneously lowering the cooling power requirement (to about 900 mW at 60K). Nominally, considering a 50 K environment in this configuration the allocated thermal loads are 1280 mW at 20K, 610 mW at VG1, 560 mW at VG2, 5370 mW at VG3.

Table 14.4-1 – FPU heat load budget for a 50 K environment



	50K Environment		
	Current Value [mW]	Requested Margin [mW]	Total [mW]
HEMTs	346	0	346
WGs	160	48	208
WGs Upper Support Structure	6	2	8
WGs Bottom Support Structure (TBC)	14	3	17
Harness	37	11	48
Radiant	8	4	12
Struts	37	8	45
Thermal Switch (60-20K)	4	2	6
Redundant Cooler pipes	1.2	0.3	2
Nom. SCE-SCC Cables (TBC)	5	TBC	5
Red. SCE-SCC Cables (TBC)	5	TBC	5
TOTALS	625	78	702

Table 14.4-2 – FPU heat load budget for a 60K environment

	60K Environment		
	Current Value [mW]	Requested Margin [mW]	Total [mW]
HEMTs	346	0	346
WGs	221	0	221
WGs Upper Support Structure	6	0	6
WGs Bottom Support Structure (TBC)	16	0	16
Harness	43	0	43
Radiant	17	0	17
Struts	50	0	50
Thermal Switch (60-20K)	4	0	4
Redundant Cooler pipes	1.6	0	2
Nom. SCE-SCC Cables (TBC)	5	0	5
Red. SCE-SCC Cables (TBC)	5	0	5
TOTALS	715	0	715

In Table 14.4-3 we report the nominal LFI heat load budgets at the three V-grooves. These values have been calculated assuming 12 RCAs at 100 GHz (to be modified) and with a waveguide thickness reduced to 0.127 mm in the section between the warm and intermediate V-grooves. Furthermore the heat loads have to be estimated at FIXED boundary Nominal temperatures as indicated in the table.

Table 14.4-3 – Nominal heat load budgets at three the V-grooves (no margins)

Cold V-groove 49 K [mW]	Intermediate V-groove 98 K[mW]	Warm V- groove 150 K [mW]



Waveguides			
Conductive	487	434	4121
Radiative	9	146	540
Total Waveguides	496	580	4661
Harness			
Conductive	138	0	281
Radiative	-0.5	2	4
Total harness	137.5	2	285
Waveguide support			
Conductive	25	94	6
Radiative	TBD	TBD	TBD
Total WG support	25	94	6
TOTAL	658.5	676	4952

14.4.1 SUBSYSTEM THERMAL PROPERTIES

14.4.1.1 4K THERMAL PROPERTIES

The thermal model should rely on a good knowledge of the fundamental properties of the system: unfortunately the thermal properties (e.g. conductivity and heat capacity) of Eccosorb at cryogenic temperatures are not well known. The heat capacity is the parameter which gives the most important information in a transient process, indicating how fast the system is to react to thermal stresses, while the conductivity indicates the thermal resistance of the material. A test activity on CR-110 and CR-117 thermal properties is in progress at IASF-BO.

Test strategy is based on the analysis of heat transmission along a bar of ECCOSORB linked to a thermal boundary on one side, heating the opposite side and monitoring temperature with sensors at regular length intervals.

The goal of tests is to estimate thermal conductivity analysing the final steady state and specific heat using transient data, by means of a thermal analysis software.

Data analysis is currently going on and preliminary results show good agreement with literature data as far as conductivity regards. We report in figure some results, in terms of temperature measured at different quotes along the bar. Points with error bars are experimental data, while the solid curves shows temperature behaviour in presence of best fit thermal parameters (conductivity and specific heat).

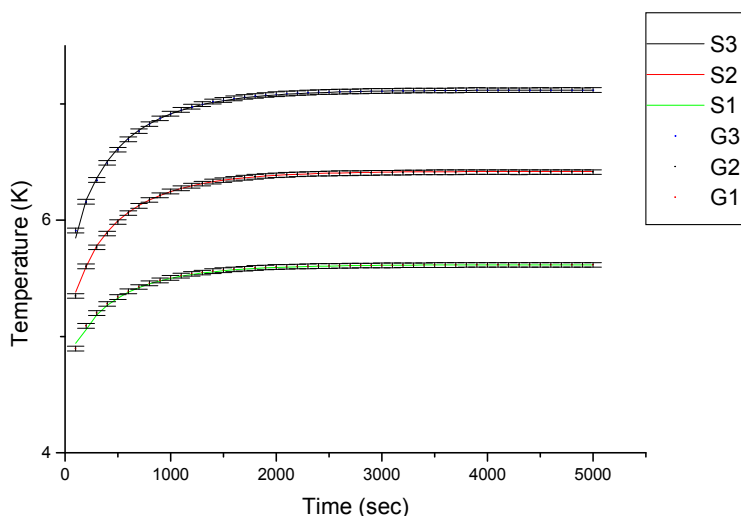


Figure 14-1: Test data for ECCOSORB CR-110 in one of the run at IASF-BO

Preliminary data for a CR-110 bar are reported in Figure 14-1 as an example. Preliminary analysis show agreement with the poor data available in the literature (Peterson & Richards) and reported in Table 14.4-4 and Table 14.4-5.

Property	4 K	300 K	Reference
Density	1.6 g/cc	1.6 g/cc	Emerson & Cummings
Heat capacity	$10^4 \mu\text{J/g-K}$		Peterson & Richards '84
Attenuation (18 GHz)			
CR-110		6.6 dB/cm	Emerson & Cummings
CR-117		119 dB/cm	Emerson & Cummings

Table 14.4-4 Eccosorb CR/MF series properties

Property	4 K	300 K	Reference
Density	1.6 g/cc	1.6 g/cc	Emerson & Cummings
Heat capacity	$10^4 \mu\text{J/g-K}$		Peterson & Richards '84
Thermal Conductivity	0.8 mW / cm-K		Peterson & Richards '84
Boundary resistance	5 mm equiv.		Peterson & Richards '84
CTE		$3 \times 10^{-5} / ^\circ\text{C}$	Emerson & Cummings
30 GHz absorption	.8 cm^{-1}	1.2 cm^{-1}	Hemmati et al. '85
30 GHz reflectivity	.13		Hemmati et al. '85

Table 14.4-5 Eccosorb CR-110 properties



Power load on the HFI is calculated considering the surface of all the loads (A_1) and the aluminium MS, surrounded by the 20 K environment (A_2). Assuming an environment with a “general” emissivity $\varepsilon_2 \sim 0.05$ and considering Eccosorb as a perfect black body ($\varepsilon_1 = 1$) we can write:

$$P = \sigma A_1 \mathfrak{T}_{12} (T_2^4 - T_1^4) \quad (14.4-1)$$

where

$$A_1 \mathfrak{T}_{12} = \frac{1 - \varepsilon_1}{\varepsilon_1 A_1} + \frac{1}{A_1} + \frac{1 - \varepsilon_2}{\varepsilon_2 A_2} \quad (14.4-2)$$

which indicates the exposition of the body surface relative to the environment. If, in first approximation, we consider $A_2 \gg A_1$ (the load is a small object in an large environment) the radiative power reduces to

$$P = \sigma A_1 \varepsilon_1 (T_2^4 - T_1^4) \quad (14.4-3)$$

Repeating the same calculation for the two aluminium supporting rings, in the case of not very polished metal (for example $\varepsilon_3 = 0.1$) we obtain, including margins in the size and emissivity of the loads, the values summarized in the following Table.

Table 14.4-6 – Estimated radiative input on the load

	Material	Surface	Rad. Power (μW)	Total Power (μW)
	Eccosorb	0.0124	112	
	Aluminum	0.01	10	
total				122

Assuming for simplicity Aluminium as a perfect conductor and neglecting the Eccosorb thermal resistance, all the power absorbed by the load is transmitted to the HFI 4 K shield by conduction: even in this case the total value, including full margins, is less than 0.3 mW, well below the requirement imposed by the HFI thermal load (1mW).

14.4.1.2 THERMAL PROPERTIES OF THE WGS

The conductive and radiative heat loads have been calculated for all the waveguides. A thermal model of the waveguides has been setup. This model has been developed in the following way:

1. Use the WGs detailed geometrical model (made by ESARAD)
2. Estimate the GR factors between WGs and PPLM model
3. Estimate the thermal loads as follow:
 - a. Develop a conductive model of the WGs
 - b. Consider the radiative coupling between WGs and PPLM estimated in point 2.
 - c. Consider conductive links between WGs and boundary VGs (No conductive links between PPLM nodes are considered)
 - d. Fix all the PPLM temperatures (values decided from ALCATEL)



- e. Estimate both conductive heat loads between WGs $\leftrightarrow$ VGs and radiative heat loads between WGs and PPLM boundary nodes

The 92 waveguides has been considered as a single equivalent bundle for the copper part. Single waveguides have been considered at 30, 44 and 70 GHz for the Stainless Steel section.

This model does not take into account the possible temperature variations of the V-grooves, when connected to the waveguides. Then, as requested by ALCATEL, the V-grooves have been considered as a boundary values at fixed temperature.

The resulting values, compared with the ALCATEL requirements, are reported in Table 14.4-7.

Table 14.4-7 – Heat load for the LFI waveguides. The radiative value is due to the radiation inside the WGs.

Stage	Heat Load (mW)			
	Conductive	Radiative	Total	Allocated
20 K stage (FPU)	125	29	154	–
49 K stage (VG3)	527	10	537	510
98 K stage (VG2)	783	121	904	500
149 K stage (VG1)	4014	510	4524	4640

14.4.2 THERMAL INTERFACES

See Paragraph 6.1.7 for the relevant information on the instrument temperatures.

14.4.2.1 INSIDE CRYOSTAT

NA

14.4.2.2 OUTSIDE CRYOSTAT

NA

14.4.2.3 ON SVM

See Paragraph 6.1.7.1 for the relevant information.

14.4.2.4 ON PLANCK P/L MODULE (PPLM)

See Paragraph 6.1.7.2 for the relevant information.

14.4.2.5 TEMPERATURE CHANNELS

See Paragraph 6.1.7.3 for the relevant information.



14.5 ERROR AND ALIGNEMENT

TBW

14.6 TIMING

The distribution of the unique on-board time maintained by the spacecraft (CDMS) to the instrument is required in order to time-tag accurately the instrument data.

The signal received from the CDMS to synchronise the on board time in instrument with respect to that of the spacecraft has a maximum absolute error less than $\pm 250 \mu\text{s}$.

14.6.1 SPECIAL SIGNALS: ON BOARD CLOCK SYNCHRONISATION SIGNAL

It is required by the instrument to receive from the spacecraft (CDMS) the on board spacecraft clock at a frequency of 131.072 KHz to allow the instrument to generate its internal clocks. This same clock shall be distributed from the CDMS to be used in the time tagging via hardware of the star reference event. The long term frequency stability of this clock shall be no worse than 1×10^{-6} over a period of 30 days. The short term frequency stability of this clock shall be no worse than 1×10^{-6} over a period of 100 seconds.

LFI requires four On Board Clock (OBC) synchronisation signals. They are allocated thus: one OBC synchronisation signal to the nominal REBA

- one OBC synchronisation signal to the redundant REBA
- one OBC synchronisation signal to the nominal DAE interface
- one OBC synchronisation signal to the redundant DAE interface

A cross coupling between nominal and redundant clock generators is performed on the S/C side to ensure that the redundancy of the signal is assured.



15 INSTRUMENT SCIENCE DATA DEFINITION

15.1 SCIENCE TELEMETRY

15.1.1 FILLING OF SCIENCE TM ALLOCATION

All the science data flow coming from the foreseen on-board data processing (see RD20) can be summarised in the following tables.

	30 Ghz	44 GHz	70 GHz	Total
Detectors chains	8	12	24	44
Radiometers	4	6	12	
Horns	2	3	6	
Sampling frequency (Hz)	8192	8192	8192	
Angular resolution (arcmin)	33	23	14	
View to spin axis angle (°)				85
Pixels per circle	652	936	1537	3125
Bins per pixel	3	3	3	
Bin size (arcmin)	11	7,67	4,67	
Bins per circle	1956	2807	4611	9374
Pixel crossing time (ms)	92,02	64,13	39,04	
Bin crossing time (ms)	30,67	21,38	13,01	
Samples per bin	126	88	53	
Data words per bin (word)	2	2	2	
Averaging samples per bin	63	44	27	
Detectors data rate (word/s)	65	94	154	5333
Total frequency data rate (kbps)	8.35	17.96	59.02	85.33

Table 15.1-1 Data generation general assumptions

Now we have to consider that each TM packet has a maximum of 1006 octets available for the scientific data because 1024 octets must comprise the packet header and the SID.

Among these 1006 octets only 26 are used for the tertiary header and the SID. Doing so only 980 octets are available for the actual (compressed) scientific data.

Now assuming that an on-board compression is performed with a factor 2.4 the results concerning the data rates are the following

30 Ghz	44 GHz	70 GHz	Total



Total samples (word/s)	65	94	154	
Compression factor	2.4	2.4	2.4	
Compressed samples	27	39	64	
Science data available (word)	490	490	490	
Time per packet (s)	18.035	12.570	7.651	
Corresponding sky arc (°)	108	75	46	
Packet frequency (Hz)	0.444	0.955	3.137	4.535
Net Data volume (word/s)	217.352	467.778	1536.986	2222.116
Net Data volume (kbps)	3.478	7.484	24.592	35.554

Table 15.1-2 Data processing and compression results

This result refers to the net science telemetry rate that LFI sends to ground. If we add the overhead due to the packet header (protocol) and the tertiary header we obtain a gross science telemetry rate of 37.150 kbps.

This number should be added to the data coming from the calibration channel (uncompressed) sent to ground in parallel. This channel has a worst case gross data production of 5.140 kbps for a total science data of 42.286 kbps (see Paragraph 14.2).

15.1.2 BUILDING OF SCIENCE TM PACKETS

For LFI there have been selected 3 of the 4 possible science Telemetry packets (see the Addenda "Provided Services" [AN20]).

TM(21,1)	Nominal Science Data Packets
TM(21,2)	All other possible science data packets
TM(21,3)	Calibration Science Data Packets

The data inside the packets have the same structure for both the services. This is practical, considering also that we could have channels producing science and diagnostic packets independently at the same time.

The structure concept is the following: we introduce, at the beginning of the data field, after the SID, a 24 bytes "Tertiary Header" to include all the information needed to the chunk of data.

The tertiary header overall structure is:

"TERTIARY HEADER" first part					
Horn ID (RCA)	Radio meter	Detector	Processing type	Phase switch	Packet counter
6 bits	1 bit	1 bits	8 bits	2 bits	14 bits



Detector ID	Processing Info

"TERTIARY HEADER" second part		
Processing status	Uncompressed samples	N average
4 bits	12 bits	16 bits

"TERTIARY HEADER" third part			
GMF 1	GMF 2	Offset Adjust	Second quantisation
32 bits	32 bits	32 bits	32 bits

The meaning of the various fields are reported hereafter.

Horn ID (RCA): identifies the whole chain related to a single horn (i.e. the chains formed by two radiometers), inside a certain Frequency.

Horn ID on the FPU	Frequency	Horn ID in the Tertiary header
28	30 GHz	0001 10
27	30 GHz	0000 00
26	44 GHz	0010 10
25	44 GHz	0001 01
24	44 GHz	0000 01
23	70 GHz	0001 00
22	70 GHz	0000 11
21	70 GHz	0000 10
20	70 GHz	0001 11
19	70 GHz	0010 00
18	70 GHz	0010 01

Radiometer: identifies one of the two radiometers related to a certain Horn ID (RCA).

	Radiometer 0	Radiometer 1
Bits	0	1

Detector: identifies one of the two channels related to a certain radiometer.

	Detector 0	Detector 1
Bits	0	1



The Data Source address is therefore composed putting the together these three fields that allows to identify the downloaded item according to the following tables.

Detector ID	Frequency	RCA #	Radiometer	Detector
0x00	30 GHz	27	0	0
0x01			0	1
0x02			1	0
0x03			1	1
0x04	44 GHz	24	0	0
0x05			0	1
0x06			1	0
0x07			1	1
0x08	70 GHz	21	0	0
0x09			0	1
0x0A			1	0
0x0B			1	1
0x0C	70 GHz	22	0	0
0x0D			0	1
0x0E			1	0
0x0F			1	1
0x10	70 GHz	23	0	0
0x11			0	1
0x12			1	0
0x13			1	1
0x14	44 GHz	25	0	0
0x15			0	1
0x16			1	0
0x17			1	1
0x18	30 GHz	28	0	0
0x19			0	1
0x1A			1	0
0x1B			1	1
0x1C	70 GHz	20	0	0
0x1D			0	1
0x1E			1	0
0x1F			1	1
0x20	70 GHz	19	0	0
0x21			0	1
0x22			1	0
0x23			1	1
0x24	44 GHz	18	0	0
0x25			0	1
0x26			1	0
0x27			1	1



0x28	44 GHz	26	0	0
0x29			0	1
0x2A			1	0
0x2B			1	1

Table 15.1-3 Identification matrix for the detectors

Processing type: identifies the operations performed on the data present into the packet. A further description of the processing is given in chapter 15.1.3.

The processing activities are numbered from 0 to 6 according to the description given below.

Processing Group A/B	Spare	Type
1 bit	3 bits	4 bits

Being:

Processing Group A/B defines which of the 2 possible processing groups, which can be performed at the same time, produced this packet:

0: Mode A

1: Mode B

Type:

- 0 uncompressed raw data
- 1 uncompressed time averaged sky and reference samples
- 2 uncompressed time averaged linear combination of sky and reference
- 3 uncompressed time averaged sky - reference differences
- 4 compressed raw data
- 5 compressed time averaged linear combination of sky and reference
- 6 compressed time averaged sky - reference differences
- 7 Not used

Phase Switch: together with the processing type it specifies the order given to the data in the output packet. This information is given by the REBA that builds the TM science packets accordingly.

Phase Switch Status Bits	Processing type		
	0, 1, 4	2, 5	3, 6
00	load, load, load, ...	p1, p2, p1, ... only load samples	p1, p1, p1, ... only load samples
01	load, sky, load, ...	p1, p2, p1, ...	p1, p1, p1, ...
10	sky, load, sky, ...	p1, p2, p1, ...	p1, p1, p1, ...
11	sky, sky, sky, ...	p1, p2, p1, ... only sky samples	p1, p1, p1, ... only sky samples



Where p_1 and p_2 are the computed samples generated using respectively the GMFs 1 and 2.
For the Processing types 3 and 6 that generate only one kind of processed samples the GMF used in its calculation will always be GMF1.

Cyclic packet counter: it contains a number that could be used to reconstruct the sequence of packets related to that data source address.

Processing Status:

Spare	Compression errors	Processing errors
2 bits	1 bit	1 bit

Spare set to 0

Compression errors:

0: Compression successful. Obtained compression factor is greater than 1. Data in this packet are output compressed.

1: Compression failure. Obtained compression factor is less than 1. Data in this packet are output not compressed.

This field is meaningless (set to 0) if the data processing type is not compressed (Science processing type 0, 1, 2 and 3).

Processing errors:

0: Processing successful

1: Circular buffer overflow. This packet is the last one within continuous time ordered data set. Some data for this channel are lost. Next TM packet for this channel will be produced after some time gap and packet counter will be reset.

Uncompressed samples:

This field is the number of uncompressed samples which have been compressed in the packet. This value is needed to check that the decompression is performed successfully. The field is meaningful for uncompressed packets.

N average: contains the number of raw samples averaged to generate a single data unit. Obviously this field applies only if the data are at least time averaged.

GMF 1 and 2: they are the Gain Modulation Factor that are the values (real number) that multiplies the average of reference raw samples to be subtracted from the average of sky raw samples. For packets coming from processing types that use only one GMF it will be placed in the field named "GMF 1"; the "GMF 2" will be meaningless. When no GMF is used in the data contained in the packet both the GMF fields will be meaningless.

Offsets adjust: it is the factor used to optimise the operation of the second quantisation regulating the differenced data around zero.



Second quantisation: it is the factor used to convert the floating point data coming from the sky – load difference (using the r-factor) into integer numbers that can be managed by the data compressor.

15.1.3 PROCESSING DESCRIPTION

Here described is the definition of the LFI science processing types. This definition is based on the actual REBA resources available and it is intended to detail a very general science mode definition given before.

3 extraction points have been considered for data processing pipeline:

- Raw data
- Time averaged (over N samples) data
- Time averaged, differenced data or linear combinations of the data

As each data can be produced compressed or uncompressed, totally there are 7 types (from 0 to 6) of data. They are presented in the Figure 15-1.

Science data can be operated in two independent blocks: primary (A) or primary + secondary (A+B) through a dedicated setting via TC:

Each block (A or B) can be set in one of 6 types. In addition each block (A or B) can be configured to process a number of channels (even all of them).

Note that the number *N Averaged* (number of samples to be averaged in time to obtain the value of one third of a pixel in the sky) can be set different one value per each radiometer. But if a given channel is processed both in A and B blocks at the same time, its number N is the same for both A and B.

Below is reported the detailed list of the 7 possible types of processing allowed for each of the blocks A and B.

Type 0: Raw data without compression

When this configuration is chosen for a processing block the selected channels are downloaded to ground as just packed raw data without any processing inside the REBA. Obviously this configuration is very demanding from the throughput point of view therefore only one channel at a time could be set in this configuration.

LFI reorganises scientific data, extracting from data stream two separate data sets with sky and load values. There are two detectors per radiometer (even detector and odd detector), and so there are four types of output data sets per radiometer: even detector sky (*j det0 sky*), even detector load (*j det0 load*), odd detector sky (*j det1 sky*), and odd detector load (*j det1 load*).



Even detector of the radiometer j after reorganisation has two lists of values:

$$\left\{ \dots, T_{t_i}^{j \det 0 sky}, T_{t_{i+2}}^{j \det 0 sky}, T_{t_{i+4}}^{j \det 0 sky}, T_{t_{i+6}}^{j \det 0 sky}, \dots \right\}, \quad j = 0, \dots, 21$$

$$\left\{ \dots, T_{t_{i+1}}^{j \det 0 load}, T_{t_{i+3}}^{j \det 0 load}, T_{t_{i+5}}^{j \det 0 load}, T_{t_{i+7}}^{j \det 0 load}, \dots \right\}, \quad j = 0, \dots, 21$$

Odd detector of the radiometer j after reorganisation has two lists of values:

$$\left\{ \dots, T_{t_{i+1}}^{j \det 1 sky}, T_{t_{i+3}}^{j \det 1 sky}, T_{t_{i+5}}^{j \det 1 sky}, T_{t_{i+7}}^{j \det 1 sky}, \dots \right\}, \quad j = 0, \dots, 21$$

$$\left\{ \dots, T_{t_i}^{j \det 1 load}, T_{t_{i+2}}^{j \det 1 load}, T_{t_{i+4}}^{j \det 1 load}, T_{t_{i+6}}^{j \det 1 load}, \dots \right\}, \quad j = 0, \dots, 21$$

Data of the processing type 0 (“T” values) are output as unsigned integers of 16 bits. Two data sets per detector (sky and load) are output in the same packet.

In order to simplify the on ground the analysis of these data they are sent as TM(21,2).

Type 1: Time averaged (N samples) data without compression

When this configuration is chosen for a processing block the selected channels are N-averaged according to their own values of N and sent to ground in couples of figures each representing the N-average of Sky and Reference samples.

The resulting TM rate depends on the actual value of N but with nominal N values there is no chance to download all the channels together. Therefore a subset of channels must be selected for this processing block.

Baseline and default values are 126, 88, 52, for the radiometers of frequencies 30, 44, 70, respectively. Valid values for parameters N are in the range 10-65 535.

Even detector sky ($j \det 0 sky$):

$$S_{t_i}^{j \det 0 sky} = T_{t_i}^{j \det 0 sky} + T_{t_{i+2}}^{j \det 0 sky} + \dots + T_{t_{i+2(N-1)}}^{j \det 0 sky} \quad j = 0, \dots, 21$$

Even detector load ($j \det 0 load$):

$$S_{t_i}^{j \det 0 load} = T_{t_{i+1}}^{j \det 0 load} + T_{t_{i+3}}^{j \det 0 load} + \dots + T_{t_{i+2(N-1)+1}}^{j \det 0 load} \quad j = 0, \dots, 21$$

Odd detector sky ($j \det 1 sky$):

$$S_{t_i}^{j \det 1 sky} = T_{t_{i+1}}^{j \det 1 sky} + T_{t_{i+3}}^{j \det 1 sky} + \dots + T_{t_{i+2(N-1)+1}}^{j \det 1 sky} \quad j = 0, \dots, 21$$

Odd detector load ($j \det 1 load$):

$$S_{t_i}^{j \det 1 load} = T_{t_i}^{j \det 1 load} + T_{t_{i+2}}^{j \det 1 load} + \dots + T_{t_{i+2(N-1)}}^{j \det 1 load} \quad j = 0, \dots, 21$$

Data of the processing type 1 (“S” values) are output as unsigned integers of 32 bits, in order to avoid the division by N on board. Two data sets per detector (sky and load) shall be output.



This type of processing is used during the mission to verify the correctness of the uploaded values of r and the second quantisation parameters.

In order to simplify and speed-up on ground the analysis of calibration science data it is useful to send them as TM(21,3).

Type 2: Time averaged (N samples) data linear combinations without compression

a) Averaging of linear combinations of sky and reference load:

Two sky-load linear combinations data are obtained for each detector (even det0 and odd det1) of the same radiometer j independently by:

$$F_{t_i, p_1}^{j \det 0} = \frac{S_{t_i}^{j \det 0 sky} - r_{p_1}^{j \det 0} S_{t_i}^{j \det 0 load}}{N^j}, \quad j = 0, \dots, 21$$

$$F_{t_i, p_1}^{j \det 1} = \frac{S_{t_i}^{j \det 1 sky} - r_{p_1}^{j \det 1} S_{t_i}^{j \det 1 load}}{N^j}, \quad j = 0, \dots, 21$$

$$F_{t_i, p_2}^{j \det 0} = \frac{S_{t_i}^{j \det 0 sky} - r_{p_2}^{j \det 0} S_{t_i}^{j \det 0 load}}{N^j}, \quad j = 0, \dots, 21$$

$$F_{t_i, p_2}^{j \det 1} = \frac{S_{t_i}^{j \det 1 sky} - r_{p_2}^{j \det 1} S_{t_i}^{j \det 1 load}}{N^j}, \quad j = 0, \dots, 21$$

This operation is performed as floating point operation. The results are 32 bit floating point numbers.

Parameters “ r ” are positive floating-point numbers. They are changeable by a TC and can be selected for each of 44 detectors independently and for each linear combination p_1 and p_2 . Default values are $r_1=1$ and $r_2=0.85$.

b) Offset addition:

Constant offset shall be added for each detector:

$$\tilde{F}_{t_i, p_1}^{j \det 0} = F_{t_i, p_1}^{j \det 0} + D^{j \det 0}, \quad j = 0, \dots, 21$$

$$\tilde{F}_{t_i, p_1}^{j \det 1} = F_{t_i, p_1}^{j \det 1} + D^{j \det 1}, \quad j = 0, \dots, 21$$

$$\tilde{F}_{t_i, p_2}^{j \det 0} = F_{t_i, p_2}^{j \det 0} + D^{j \det 0}, \quad j = 0, \dots, 21$$

$$\tilde{F}_{t_i, p_2}^{j \det 1} = F_{t_i, p_2}^{j \det 1} + D^{j \det 1}, \quad j = 0, \dots, 21$$

This operation is performed as floating point operation. The results are 32 bit floating point numbers.



Parameters D are either positive or negative floating-point numbers in the range $0-2^{127}$. They are changeable by a TC and can be selected for each of 44 detectors independently. Default values are 0.

c) Requantisation and truncation:

Multiplication by q factor is performed:

$$Q_{t_i, p_1}^{j \det 0} = [q^{j \det 0} \tilde{F}_{t_i, p_1}^{j \det 0}]; \quad Q_{t_i, p_1}^{j \det 1} = [q^{j \det 1} \tilde{F}_{t_i, p_1}^{j \det 1}], \quad j = 0, \dots, 21$$

$$Q_{t_i, p_2}^{j \det 0} = [q^{j \det 0} \tilde{F}_{t_i, p_2}^{j \det 0}]; \quad Q_{t_i, p_2}^{j \det 1} = [q^{j \det 1} \tilde{F}_{t_i, p_2}^{j \det 1}], \quad j = 0, \dots, 21$$

[] means truncation operation for conversion of floating point values to integer values. Truncation operation is ROUND.

Parameters q, re-quantisation factor, are positive floating point number in the range $0-2^{127}$. They are changeable by a TC and can be selected for each of 44 detectors independently. Default values are 1.

Data (“Q” values) are signed integers of 16 bits.

Since this processing is the uncompressed case of the nominal science processing this can be used for a control of the compression efficiency.

In order to simplify the on ground the analysis of these data they are sent as TM(21,2).

Type 3: Time averaged (N samples) differenced data without compression

When this configuration is chosen for a processing block the selected channels are processed according to the nominal processing scheme that is N-average according to their own values of N but only one difference between Sky and Reference samples including the correction made with the r factor. No compression is foreseen therefore only a subset of channels should be activated in this mode.

The differencing operation is performed as floating point operation and the results are 32 bit floating point numbers.

After the difference the result is converted back into an integer number adding a constant offset and multiplying by a quantisation factor that are also reported into the tertiary header of the data packet.

a) Offset addition:

Constant offset is added for each detector:

$$\tilde{F}_{t_i}^{j \det 0} = F_{t_i}^{j \det 0} + D^{j \det 0}, \quad j = 0, \dots, 21$$



$$\tilde{F}_{t_i}^{j \det 1} = F_{t_i}^{j \det 1} + D^{j \det 1}, \quad j = 0, \dots, 21$$

This operation is performed as floating point operation. The results are 32 bit floating point numbers.

Parameter D is a positive or negative floating-point number. It is changeable by a TC and can be selected for each of 44 detectors independently. Default values are 0.

b) Requantisation and truncation:

Multiplication by q factor is performed:

$$Q_{t_i}^{j \det 0} = \left[q \tilde{F}_{t_i}^{j \det 0} \right]; \quad Q_{t_i}^{j \det 1} = \left[q \tilde{F}_{t_i}^{j \det 1} \right], \quad j = 0, \dots, 21$$

[] means truncation operation for conversion of floating point values to integer values. Truncation operation is ROUND.

Parameter q, re-quantisation factor, is a positive floating point number. It is changeable by a TC and can be selected for each of 44 detectors independently. Default values are 1.

Data of the processing type 2 (“Q” values) are output as signed integers of 16 bits. One data set per detector is output.

In order to simplify the on ground the analysis of these data they are sent as TM(21,2).

Type 4: Raw data with compression

When this processing type is activated for a processing block the raw data coming from the detectors are sent directly to the data compressor without any other operation. Also in this case there is a strong limitation in the number of channels that could be downloaded therefore the number of channels to be activated in this configuration is limited to 1 or 2 maximum.

In order to simplify the on ground the analysis of these data they are sent as TM(21,2).

Type 5: Time averaged (N samples) data linear combinations with compression

This is intended to be the nominal science processing type for the acquired data.

a) Averaging of linear combinations of sky and reference load:

Two sky-load linear combinations data shall be obtained for each detector (even det0 and odd det1) of the same radiometer j independently by:

$$F_{t_i, p_1}^{j \det 0} = \frac{S_{t_i}^{j \det 0 sky} - r_{p_1}^{j \det 0} S_{t_i}^{j \det 0 load}}{N^j}, \quad j = 0, \dots, 21$$



$$F_{t_i, p_1}^{j \det 1} = \frac{S_{t_i}^{j \det 1 sky} - r_{p_1}^{j \det 1} S_{t_i}^{j \det 1 load}}{N^j}, \quad j = 0, \dots, 21$$

$$F_{t_i, p_2}^{j \det 0} = \frac{S_{t_i}^{j \det 0 sky} - r_{p_2}^{j \det 0} S_{t_i}^{j \det 0 load}}{N^j}, \quad j = 0, \dots, 21$$

$$F_{t_i, p_2}^{j \det 1} = \frac{S_{t_i}^{j \det 1 sky} - r_{p_2}^{j \det 1} S_{t_i}^{j \det 1 load}}{N^j}, \quad j = 0, \dots, 21$$

This operation is performed as floating point operation. The results are 32 bit floating point numbers.

Parameters “r” are positive floating-point numbers. They are changeable by a TC and can be selected for each of 44 detectors independently and for each linear combination p1 and p2. Default values are $r_1=1$ and $r_2=0.85$.

b) Offset addition:

Constant offset is added for each detector:

$$\tilde{F}_{t_i, p_1}^{j \det 0} = F_{t_i, p_1}^{j \det 0} + D^{j \det 0}, \quad j = 0, \dots, 21$$

$$\tilde{F}_{t_i, p_1}^{j \det 1} = F_{t_i, p_1}^{j \det 1} + D^{j \det 1}, \quad j = 0, \dots, 21$$

$$\tilde{F}_{t_i, p_2}^{j \det 0} = F_{t_i, p_2}^{j \det 0} + D^{j \det 0}, \quad j = 0, \dots, 21$$

$$\tilde{F}_{t_i, p_2}^{j \det 1} = F_{t_i, p_2}^{j \det 1} + D^{j \det 1}, \quad j = 0, \dots, 21$$

This operation is performed as floating point operation. The results are 32 bit floating point numbers.

Parameters D are either positive or negative floating-point numbers in the range $0 - 2^{127}$. They are changeable by a TC and can be selected for each of 44 detectors independently. Default values are 0.

c) Requantisation and truncation:

Multiplication by q factor is performed:

$$Q_{t_i, p_1}^{j \det 0} = [q^{j \det 0} \tilde{F}_{t_i, p_1}^{j \det 0}], \quad Q_{t_i, p_1}^{j \det 1} = [q^{j \det 1} \tilde{F}_{t_i, p_1}^{j \det 1}], \quad j = 0, \dots, 21$$

$$Q_{t_i, p_2}^{j \det 0} = [q^{j \det 0} \tilde{F}_{t_i, p_2}^{j \det 0}], \quad Q_{t_i, p_2}^{j \det 1} = [q^{j \det 1} \tilde{F}_{t_i, p_2}^{j \det 1}], \quad j = 0, \dots, 21$$



[] means truncation operation for conversion of floating point values to integer values. Truncation operation is ROUND.

Parameter q, re-quantisation factor, is a positive floating point number. It is changeable by a TC and can be selected for each of 44 detectors independently. Default values are 1.

Data of the processing type 2 (“Q” values) are output as signed integers of 16 bits. One data set per detector is output.

In order to simplify the on ground the analysis of these data they are sent as TM(21,2).

d) Compression

Data sets $Q_{t_i, p_1}^{j \det 0}$, $Q_{t_i, p_1}^{j \det 1}$, $Q_{t_i, p_2}^{j \det 0}$, $Q_{t_i, p_2}^{j \det 1}$ are compressed for each detector. Both the data streams coming out of a detector are put in the same packet alternating the samples produced by the two linear combinations of each detector. This is possible because the linear combination produces packets with more or less the same average value and the same statistical properties. In order to distinguish between the two linear combination within an incoming packet all the scientific packets end with a $Q_{t_i, p_2}^{j \det x}$ that is the same as the following always starts with a $Q_{t_i, p_1}^{j \det x}$.

This is the default processing type and the data are downloaded as TM(21,1).

Type 6: Time averaged (N samples) differenced data with compression

In this processing type, that is intended to be a backup of the nominal one, after the N-averaging of Sky and Reference samples, they are subtracted after the introduction of the corrective factor r and requantized according to the algorithm described in the processing type 2. Finally the stream of single-number-per-sample are sent to the data compressor and packed to be downloaded.

In order to simplify the on ground the analysis of these data they are sent as TM(21,2).

Summarising the processing of scientific data is subdivided into two groups each capable of processing all the channels or a subset. The processing within a group is homogeneous but one or more channels can be processed in both groups at the same time. The use of these 7 processing types is restricted only by the availability of CPU time, memory and TM bandwidth.

The two processing groups are managed separately. Therefore when a changing of one or more parameters is required via TC to one of the groups, the processing of this group is stopped, the parameters changed then the processing is restarted. No impact is foreseen on the activities of the other processing group.

The use of the two groups is the following: group A devoted to the acquisition of nominal data therefore containing all the detectors processed according the type 5. Group B contains a single



detector (changing every about 15 minutes across the 44) in order to monitor continuously the behaviour of the instrument for the calibration of r-factors and the 2nd quantisation factor. This is the calibration channel switching.

The following table is an example of a table that could be kept for the control of the configuration of the two processing groups. In this example the first group is processing all the channels in the default type whereas the second group contains just one channel used to monitor the effectiveness of the non-deterministic part of the processing flow.

	Group A	Group B
Processing type	5	1
Channels configuration		
Channel 0	Yes	No
Channel 2	Yes	Yes
Channel 3	Yes	No
...	...	...
...	...	...
Channel 43	Yes	No

Table 15.1-4 Example of the assignment of the processing types

A matrix logically equivalent to this table is loaded on board.

Notice again that also some kind of on board diagnostic can be obtained by means of a proper selection of the processing types as described below.

Diagnostic	Description
1	Check the compression comparing the results of corresponding compressed and uncompressed processing types
2	Stop the phase switching to check the symmetry within the radiometers.

Table 15.1-5 Diagnostic sub-mode implementation

Other diagnostics can be implemented using the flexible programmability of LFI.

A pictorial explanation of the path of science data and its extraction points is reported in the following Figure 15-1.

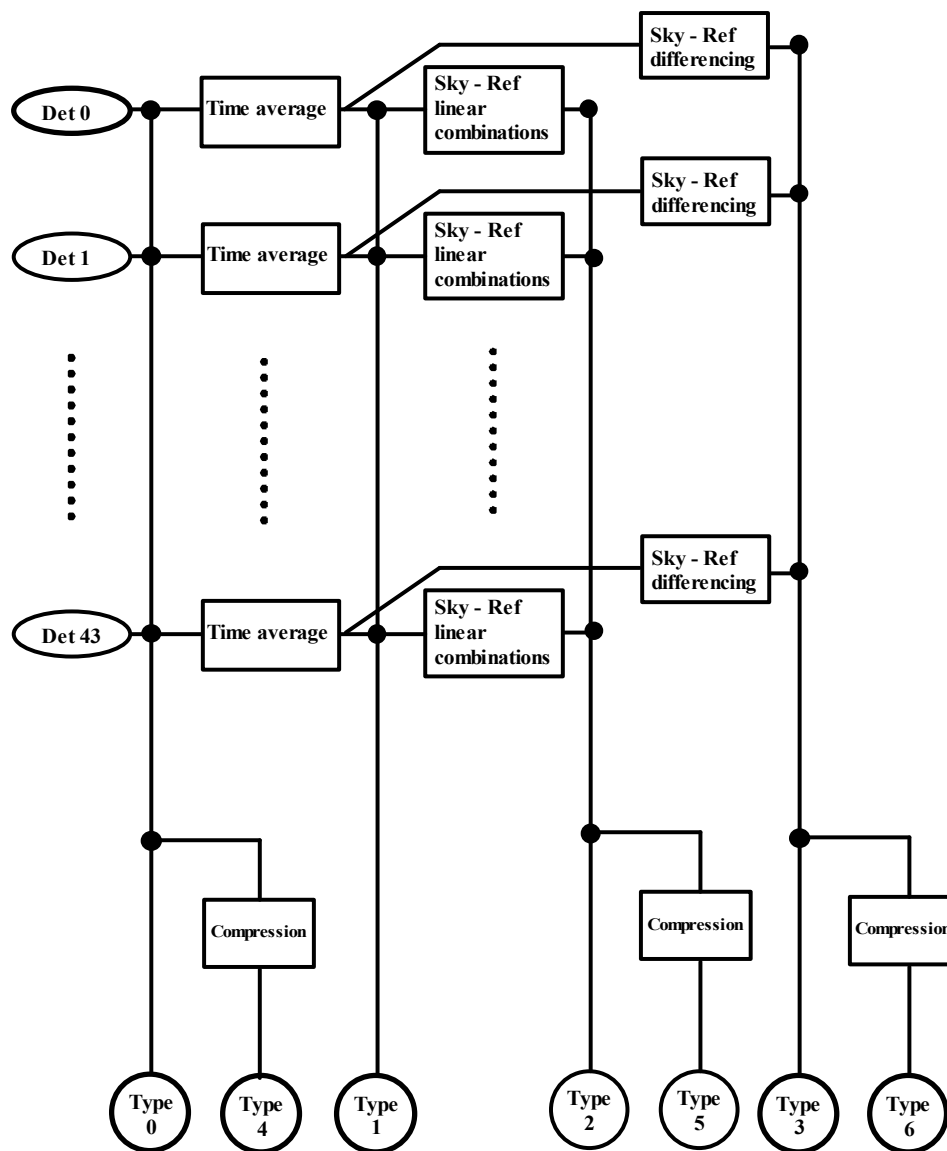


Figure 15-1 Science data flow and Science TM packets

15.2 DATA REPORT

15.2.1 NOMINAL SCIENCE DATA REPORT – TM (21,1)

The general format for the “Source Packet Header” of this packet is the following:

Source Packet Header



PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH
Version	Type	Data Field Header Flag	Application Process ID	Segmentation Flags	Source Sequence Count	
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits
'000'	'0'	'1'	'110 0000 0100' 0x604	'11'		'0011 1111 1001'

The value of the “Source Sequence Count” field is provided by a counter packet by packet.
The “Packet Length” field can be different in case of incomplete packet filling during transitions of the processing inside LFI.

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
'0'	'000'	'0000'	'0001 0101'	'0000 0001'	'0000 0000'	

The “Time” field contains the value of the OBT register sampled at the time of acquisition of the first sample contained into the packet.

Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
SID	2 bytes	(2,16) <12> 12 for compressed data
Tertiary header	24 bytes	See definition in chapter 15.1.2
Science data	980 bytes (max)	

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN16] for definition of LFI specific monitoring and definition parameters as described in [AD6].

Science data are not defined inside *SCOS-2000* because they are not compliant with the MIB *SCOS-2000* table definition. These data are interpreted and analysed by the Level-1.



15.2.2 DIAGNOSTIC SCIENCE REPORT – TM (21,2)

This type of packet will contains data coming from the radiometers of LFI but not necessarily used for the sky map reconstruction. These packets will be instead used for all the diagnostic purposes needed.

The general format for the “Source Packet Header” of this packet is the same of the TM(21,1).

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0001 0101’	‘0000 0010’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled at the time of acquisition of the first sample contained into the packet.

Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
SID	2 bytes	(2,16) <11 or 12> 11 for uncompressed data 12 for compressed data
Tertiary header	24 bytes	See definition in chapter 15.1.2
Science data	980 bytes (max)	

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN17] for definition of LFI specific monitoring and definition parameters as described in [AD6].

Science data are not defined inside *SCOS-2000* because they are not compliant with the MIB *SCOS-2000* table definition. These data are interpreted and analysed by the Level-1.

15.2.3 DIAGNOSTIC SCIENCE REPORT – TM (21,3)

This type of packet contains data coming from the radiometers of LFI but not used for the sky map reconstruction. These packets are instead used for all the diagnostic purposes needed.



The general format for the “Source Packet Header” of this packet is the same of the TM(21,1).

Data Field Header						
Spare	TM Packet PUS version Number	Spare	Packet Type	Packet Subtype	Spare	Time
1 bits	3 bits	4 bits	8 bits	8 bits	8 bits	48 bits
‘0’	‘000’	‘0000’	‘0001 0101’	‘0000 0011’	‘0000 0000’	

The “Time” field contains the value of the OBT register sampled at the time of acquisition of the first sample contained into the packet.

Source Data		
DATA	SIZE	COMMENTS (PTC,PFC) <range>
SID	2 bytes	(2,16) <11> 11 for uncompressed data
Tertiary header	24 bytes	See definition in chapter 15.1.2
Science data	980 bytes (max)	

The packet is terminated by 16 bits CRC field.

See the addenda [AN1] for definition of monitoring parameters and parameters location in the packet as defined in *SCOS-2000 Database Import ICD* [AD6].

See the addenda [AN18] for definition of LFI specific monitoring and definition parameters as described in [AD5].

Science data are not defined inside *SCOS-2000* because they are not compliant with the MIB *SCOS-2000* table definition. These data are interpreted and analysed by the Level-1.