LYRA
Instrument Manager
Description

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This document is a DRAFT version and object to change.
It shall serve as a discussion basis.

Content

1 Acronyms

ADPMS	Advanced Data and Power Management System
CS	Checksum
CSL	Centre Spatial de Liège, Belgium
FIFO	First In First Out memory
FOV	Field-of-view
HK	Housekeeping
H/W	Hardware
IIU	Instrument Interface Unit
I/F	Interface
LED	Light Emitting Diode
LDM	LYRA Data Manager
LIM	LYRA Instrument Manager
LOB	LYRA Optical Box, called LYRA (only) when no ambiguity
LOS	Line of Sight
LYRA	The Lyman-alpha Radiometer onboard PROBA
MCPM	Mass memory Compression and Packetization Module
MSB	Most Significant Bit
MUX	Multiplexer
PMOD	Physikalisch-Meteorologisches Observatorium Davos
PROBA	PRoject for On-Board Autonomy
QE	Quantum Efficiency
ROB	Royal Observatory of Belgium
S/C	SpaceCraft
SNR	Signal to Noise Ratio
S/W	Software
SWAP	Sun Watcher using APS detectors and image Processing
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand
TM	Telemetry
UTC	Coordinated Universal Time
UV	Ultraviolet
VFC	Voltage to Frequency Converter
VIS	Visible

2 Reference Documents

[RD-1]LYRA Data Manager (LDM)
Marie Dominique, Silvio Koller, J-F. Hochedez
V2R9, 2004/10/05

3 Applicable Documents

[AD-1]Electrical Interface Control Document (EICD)
2004/09/21
S. Koller (PMOD)
[AD-2]LYRA Data Manager (LYRA-LDM-SPEC-V2R6-20040406-MD.doc)
Marie Dominique, Silvio Koller, J-F. Hochedez
V2R6, 2004/04/08
[AD-3]LYRA_Operational_ICD.doc
Laurence Wauters
[AD-4]Telemetry Packet (blue book), CCSDS [CCSDS 102.5-B-5], November 2000;
[AD-5] SWAP/LYRA IIU Specification (SP-CSL-SWP-04017)
J.-M. Gillis
Issue 01 Rev 00, 2004/03/08

Warning:

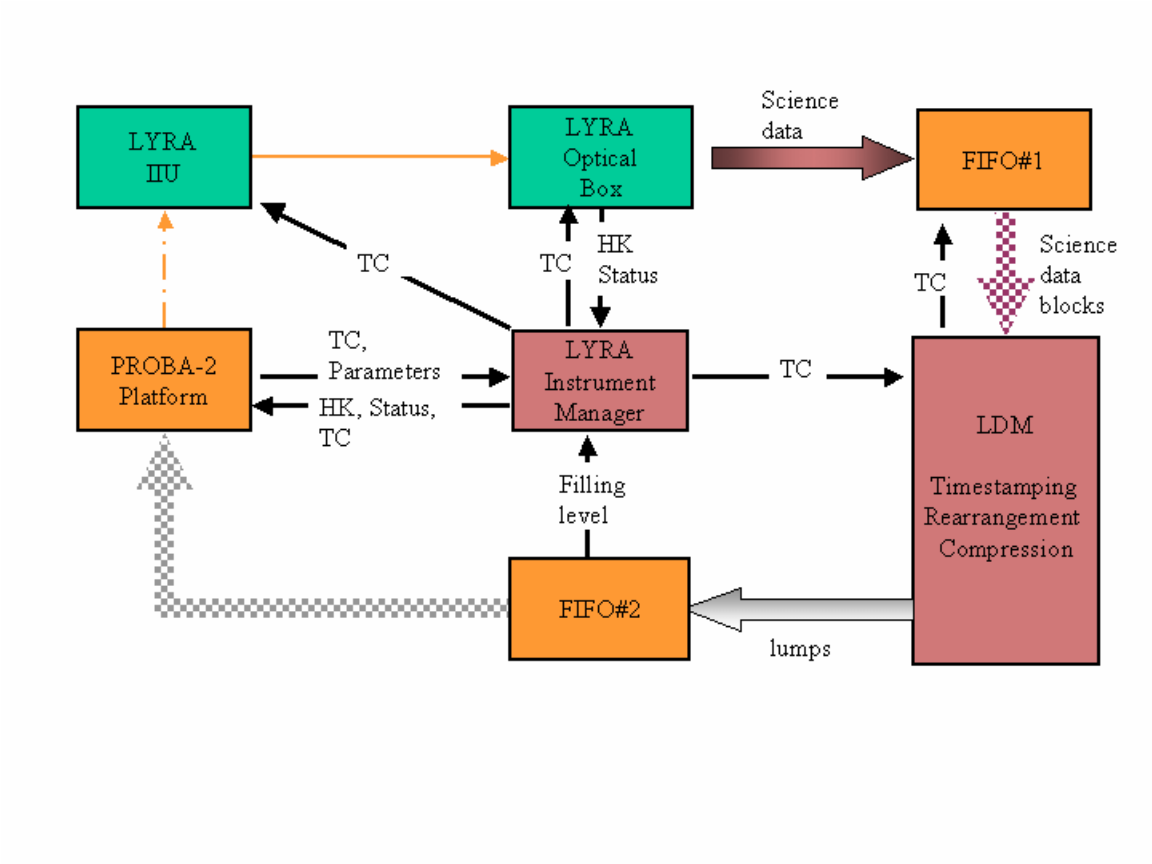
In this document, we will assume:
1. a PROBA-2 orbit with several eclipses and occultations per day.
2. Storage of LYRA data on the ADPMS memory (no LYRA access to the MCPM)

If one of these assumptions is not fulfilled, the present document is not applicable.

4 Introduction

The onboard LYRA software (S/W) running on the main spacecraft computer (ADPMS) is split into two parts:

1. **The *instrument manager*** (LIM) manages the overall LYRA operations. It interacts with the PROBA-2 platform (sending and reading commands, parameters or ancillaries), with the data manager and with the LYRA hardware (through the two RS422 channels and a digital line). The Instrument Manager can perform activities at a maximum rate of 20 Hz[1] (in the sense that it can access the various H/W at a maximum rate of 20 Hz). The timestamping operation, which is faster, is handled by the LDM using a dedicated system, described in the LDM document.
2. **The *data manager*** (LDM) checks the validity of the data, adds a timestamp to them, rearranges and compresses the data before they are packetized and stored in the ADPMS memory. The ADPMS is responsible for their sending to the ground by telemetry.



[1] The 20Hz value isn't a requirement but is information from SBI.

5 Activities of the LIM

The LIM is a process created by the software piloting the spacecraft. It will manage several tasks in parallel:

1. Application of the operating modes and the atomic commands sent from the ground or the spacecraft
2. Transmitting the HK of LYRA to the SC
3. Checking the FIFO dedicated to data lump storage and reacting in case of not enough free memory
4. Reloading the ASIC

All these tasks will be described hereafter.

5.1 Application of the operating modes and the atomic commands

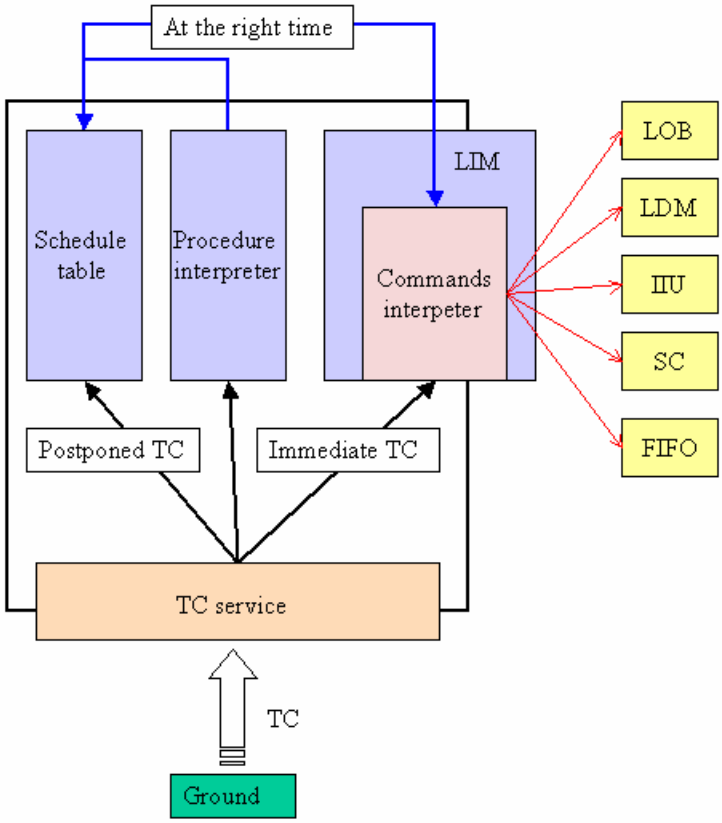
The LIM interacts with the SC, the LOB, the LDM, the IIU and the FIFO dedicated to LYRA data storage. The LIM can send to and receive from them commands or data. All these interactions are summarized in the chapter 7. Most of the time, the succession of the commands sent by the LIM will remain constant during an orbit. That is why some sequences of commands are preprogrammed: the operating modes. These modes are described in chapter 8.

5.1.1 Sending of a TC to the LIM

The chronological list of the procedures and commands to be applied during the next period will be regularly (cfr [AD-3]) uploaded to the satellite[2]. Commands can also originate from the autonomous function of the SC. Before transmission to the LIM, commands are sorted between immediate tasks (atomic commands or modes) and tasks to be postponed. Postponed commands are stored in a schedule table, which will release them at the moment they have to be applied. Immediate commands (e.g. emergency switch to survival mode) are transmitted to the command interpreter of the LIM. Also a distinction is made between routine and non-routine tasks. Routine tasks are implemented as functions and can be triggered by one command. Every non-routine task will be implemented as a procedure. They will be handled by the procedure interpreter, which interacts with the scheduler. For safety reasons, the schedule table can be changed[3] or cleaned by a command from the ground.

[2] A re-send procedure will be implemented in case a command is lost during the uplink to the spacecraft.

[3] Ground commands (TC) will be accepted that add, delete or replace scheduled tasks.



The LIM provides the capability to perform task activities with a granularity of 20 Hz (see remark above). The flight software shall maintain spacecraft time in UTC for observation scheduling and acquisitions handling. The schedule table shall manage:

- tasks with an absolute timing
- tasks with a relative timing

Note: Some operating modes imply high power consumption (e.g. UV calibration mode). The same argument is also valid from a SWAP point of view. Therefore it will be necessary to coordinate such SWAP and LYRA activities in such a way that they are desynchronized. This coordination shall be handled by ground scheduling and operators.

5.1.2 Application of the TC

Every command received will be checked for consistency prior to execution. This includes parameter checks. Valid parameters of atomic command and of operating modes are respectively described in the tables in chapter 7 and in the modes description 8.
It will also be checked if the received command is available within the current configuration. This implies:

- to check if the application of previous command is finished before to send a new one. This also applies for modes. The only mode that shall be immediately triggered without any other consideration is the survival mode.
- to check if the logical succession of commands is respected (for example, before to open a door, it has to be powered). The commands which have to be executed prior or after the each possible command are described in the tables of chapter7.
- to check if the required mode is available from the current one (allowed transitions are described in the chapter 8).

Valid commands sent (or dispatched) by the LIM as well as invalid commands (those whose parameters are wrong or those which are not available from the current operating mode) sent to the LIM will be timestamped and logged as events[4]. Of course, invalid commands sent to the LIM will not be acted on while valid commands will be interpreted and executed (when dedicated to the LIM itself) or dispatched by the LIM to the appropriate module (LOB, LDM, SC, IIU, FIFO).

After having dispatched a command, the LIM will wait a few milliseconds before checking whether the command has been applied or not. If not, the command will be resent, sometimes with the application of a small safety procedure (see the "commands to the LOB"). If this second attempt fails, the command will also be considered as invalid and, thus, neglected and logged as an event.
The checking method depends on the element to which the command was dedicated:

Commands to the LOB

Commands sent to the LOB consist of a 48-bit word. Once the LOB receives the first bit of the TC, an internal timer starts. If the entire TC is not received within 2ms[5], the command is neglected. Thus after each TC sending, the LIM shall wait 10 ms (this is a parameter that shall be adaptable) and then check the status to ensure that the command is applied (when there is a status bit associated to the command result). This status will then be transmitted to the spacecraft for further transmission to the ground with its own ancillary data (data bank). If the status is not the one corresponding to the command, a small safety procedure will be applied in which the command will be resent to the LOB. As said before, if this second attempt fails, this will be logged in the events file.

Notes:

1. To avoid repeating tests in excess, a status table will indicate which status leads to the application of the safety procedure when it is wrong. This table can be modified by ground commands.
2. Safety procedure is described in annexe.

[4] The chapter 6 is dedicated to the events.

[5] 2 ms is the delay after which the LOB neglects the command.

Commands to the IIU

The power to the IIU and focal plane shall be controlled by on-board software via a digital line, separately for each instrument (see [AD-5]). Thus after having sent a command to the IIU, the LIM shall check the application of the command by reading information in this digital line after TBD sec (adaptable parameter).

Commands related to PROBA-2, to LYRA memory in the ADPMS and to data manager

No particular checking.

5.2 Management of the LYRA housekeeping

Once every 10 seconds, the LIM reads the HK of LYRA on the RS422#2[6] and forwards them to the SC (data bank). The analysis of the HK will be handled by the event detection service. It consists in comparing them to predefined limit values which can be changed by TC from the ground. It should be possible to enable or disable the analysis of the HK. A list of first estimations of the validity intervals as well as the appropriate reaction can be found on the next page.
Note that, as it was the case with the status, it is possible to avoid to check one of the HK. The unchecked HK are listed in HK table which can be modified by commands from the ground.

The frequency of the HK reports to the ground shall be defined by the ground segment (most of the time, 10 will be sufficient). Note that, in case of day maneuver, the maximum report cadence of the pointing parameters will be required (every second).

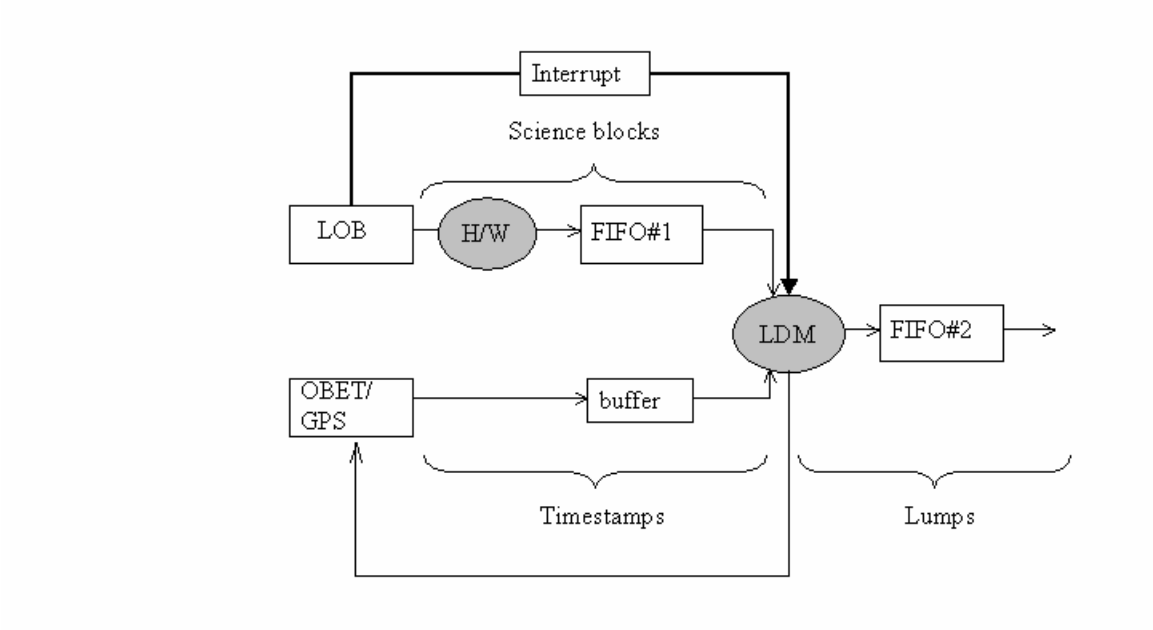
Remark : The VFC dedicated to HK must regularly be calibrated by the application of a known voltage as input. As it is the case for the other VFC (see chapter 8.3), three voltages are provided to calibrate the VFC. Each of them will be successively selected every 4 minutes (this value should be adaptable), once all the HK have been read when cycling.

[6] When cycling on HK, to read all HK values will need around 4 minutes.

SN	Description	Type	min val	max val	Vin min	Vin max	Low. TH	Up. TH	Reaction
HK1	Temp Filter Detector 1	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	40C	
HK2	Temp Diode Detector 1	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	40C	
HK3	Temp Filter Detector 2	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	40C	
HK4	Temp Diode Detector 2	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	40C	
HK5	Temp Filter Detector 3	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	40C	
HK6	Temp Diode Detector 3	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	40C	
HK7	Reserve								
HK8	Voltage + 9.5V	Op Out	9V	10V	6.62V	7.35V	8V	11V	Switch off all except prox. Logic if out of TH's
HK9	Voltage - 9.5V	Op Out	-10V	-9V	6.00V	6.66V	-11V	-8V	Switch off all except prox. Logic if out of TH's
HK10	Voltage + 5V	Op Out	4.75V	5.25V	4.59V	5.08V	4V	6V	Switch off if out of TH's
HK11	Temp VFC Print	Ref43	-25C	+60C	0.414V	0.756V	-20C	60C	Switch off if > UTH
HK12	Temp Power Print	Ref43	-25C	+60C	0.414V	0.756V	-20C	60C	Switch off if > UTH
HK13	Current + 28V	Hall Sens	0A	0.5A	2.5V	2.9V	0A	0.5A	
HK14	Current + 9.5V	Hall Sens	0A	0.5A	2.5V	2.9V	0A	0.3A	
HK15	Current - 9.5V	Hall Sens	0A	0.5A	2.5V	2.9V	0A	0.3A	
HK16	Current + 5V	Hall Sens	0A	0.5A	2.5V	2.9V	0A	0.4A	
HK17	Temp Heatsink	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	50C	Switch off if > UTH
HK18	Temp Cover Plate	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	50C	Switch off if > UTH
HK19	Temp Digital Print	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	60C	Switch off if > UTH
HK20	Temp Instrument Print	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	60C	Switch off if > UTH
HK21	Temp Reference Foot	YSI 44031	-25C	+60C	0.11V	2.8V	-20C	50C	Switch off if > UTH

5.3 Checking the filling of the FIFO dedicated to packet storage

Scientific data will be treated by the data manager to form data lumps. All these lumps are then stored in a FIFO (FIFO#2) before transformation into telemetry packets and sending to the ground.



Once per orbit, simultaneously to the reset of the counter used to timestamp the data (i.e. at the entrance in acquisition mode X2), the LIM shall check the memory occupation of the FIFO#2 (with a security margin). Knowing this and the time remaining until the next contact with the ground, it will be able to deduce the maximum acquisition cadence allowed to avoid an overflow of this FIFO. If the scheduled cadence is higher than this maximum possible cadence, the LIM shall autonomously adapt (decrease) the cadence.

In parallel, the event detection service will insure that none FIFO is 99 % (adaptable value) full. When this happens, an event is logged and LYRA is placed in night mode.

5.4 LOB safety: ASIC Reload

An independent signal for the LYRA optical box shall be implemented on the ADPMS side:

1. The ASIC of the LYRA optical box shall be reloaded every orbit (during orbit night-time). This action shall prevent that a SEU causes more than one orbit data loss. To initiate this reload the LIM shall send a pulse through a dedicated line.

2. If a latch-up is detected by the LOB, the LOB-internal power switch turns the ASIC off. Thus, no data are sent from the LOB and the FIFO#1 is still empty. If after 11 (adaptable value) readings of this FIFO no data have been registered and if the lumps have not been closed by the LIM (acquisition shouldn't have stopped), the LDM will conclude that a latch up occurred and an event will be logged, followed by a closing of the current lumps by the LDM and the turn on procedure of the ASIC.

6 Events file

The events file is managed by the SC. It contains a log of all the unusual events. For each event, the SC shall store the type of event, its name, its timestamp and, if necessary, some associated values. Sometimes the detection of an event will give rise to the application of a function. For example, if the spacecraft begins a manoeuvre, the pointing parameters shall be reported more often (every second) in the ancillaries. On the contrary, when the end of the manoeuvre is detected, the reporting cadence shall decrease (every 10 sec).
The table below represents these four fields and gives a list of all the possible event natures. The events file will be sent to the ground together with the ancillaries of the SC.

Events			
Event type	Name	Timestamp	Values
Commands sent by LIM	Command name		Command parameters + scheduling method[7]
Invalid commands sent to LIM	Command name		Invalid parameter or incompatibility with the state of LYRA
Wrong status (of LOB or IIU)	Status Name		
Invalid commands sent to LOB	Command name		Command parameters
Invalid commands sent to IIU	Command name		Command parameters
Temporal warnings	X1, X2, X3, Y1 or Y2		
Beginning of manoeuvre			Pointing parameters
End of manoeuvre			Pointing parameters
HK anomalies	Deficient HK		HK value
Latch up detection			
ASIC reload			
LDM parameters change			New LDM parameters New S/W version
Modification of a mode in the LIM	Mode name		New S/W version
FIFO overflow warning	FIFO implied		

[7] i.e. pre-defined block, or self-schedule due to event detection

Event management	
Event	Function to apply
Commands sent by LIM	
Invalid commands sent to LIM	
Wrong status	
Invalid commands sent to LOB	
Invalid commands sent to IIU	
Temporal warnings	Application of the corresponding operating mode
Beginning of manoeuvre	Report of the pointing parameters every sec.
End of manoeuvre	Report of the pointing parameters every 10 sec.
HK anomalies	Reaction depending of the HK (see HK management)
Latch up detection	Turn on procedure of the ASIC + close the lumps
ASIC reload	
LDM parameters change	Closing of the current lumps Update the version number
LIM mode modification	Update the version number
FIFO overflow warning	Triggering of the night mode

Notes:

1. Different warnings will be emitted by the SC:
   - Beginning and end of a manoeuvre
   - Temporal warnings at
     - X1, X2, X3 sec from sunrise (before or after depending on the sign of Xi)
     - Y1, Y2 sec from sunset (before or after depending on the sign of Yi)

   corresponding to the beginning or the end of an operating mode.
   All these warnings will be used later, when analyzing data received on the ground.
2. The LDM manages all the scientific data of LYRA in order to create data lumps, which can be sent to the ground by telemetry. Interactions between LIM and LDM can be summarized as follows. When the LIM commands the LOB to stop the acquisitions, it should also command the LDM to close the three current lumps (cfr. Chapter 7). Closing of the lumps shall also happen once an orbit (temporal warning X2), when the integration time is changed, when the LDM

parameters are changed and in case of latch up. However, this does not imply intervention from the LIM.
Note that, if the LIM can run independently from the LDM, all the data acquired will be lost if the LDM is not running.

7 Atomic LYRA services and data exchange

The "Atomic LYRA services" are commands that perform elementary functions. The parameters of the atomic services are either Instrument Manager processing variables, or constants uploaded from the ground.

All commands provided by the electronics shall be available to the LIM.

Most of the time, commands are coming from the ground, but the spacecraft could also require them. The LIM dispatches the commands to the element concerned (either the LDM, the SC, the LOB or FIFO). It is also possible that the command, sent by the ground or the spacecraft, is dedicated to the LIM itself. In this case, the LIM will simply apply it instead of dispatching it. In addition, some commands from the ground concerning LYRA are dedicated to the SC and do not transit by the LIM.
Beside from commands, data are also exchanged between the LIM and other elements. A summary of commands and data transmitted can be found in the table below (execution time and current-voltage columns to be reviewed).

Note: Multiplexers appearing in the commands to the LOB are used for two applications. The first is the selection of the recorded housekeeping input. The second is the selection of the unit used to perform acquisitions. As it is possible to use two units simultaneously (see "back up mode" below), two groups of multiplexers are provided, each of them consisting of four multiplexers (one per channel) connected to four VFC's. A TC defines which input will be selected for all the multiplexers in the same group [AD-1].

COMMANDS SENT BY THE LIM TO OTHER COMPONENTS

Command	Executio Time	Current-Voltage	Parameters	Remarks
LOB				
VFC **X** Power ON or OFF	10 ms		X = 1, 2 or 3; ON or OFF	TO DO : close the lumps if the nominal VFC is powered OFF ON not available in night and survival mode
HK group Power ON or OFF	10 ms		ON or OFF	ON not available in survival mode
Head **X** Power ON or OFF	10 ms		X = 1, 2 or 3; ON or OFF	ON not available in night and survival mode
Cover **X** Power ON or OFF	10 ms		X = 1, 2 or 3; ON or OFF	ON not available in night and survival mode
Cover **X** lock or unlock	10 ms		X = 1, 2 or 3; lock or unlock	not available in survival mode; cover must be powered
Cover **X** open or closed	10 ms		X = 1, 2 or 3; open or closed	not available in survival mode, open not available in night mode; cover must be
VIS LED's Switch ON or OFF	10 ms		ON or OFF	ON not available in night and survival mode
UV LED's of unit X Switch ON or OFF	10 ms	<1A ; 5V	X = 1, 2 or 3; ON or OFF	ON not available in night and survival mode
heater X on unit head Y Switch ON or OFF	10 ms		X = AB or CD, Y = 1, 2 or 3; ON or OFF	ON not available in survival mode
Select integration time **X**,	10 ms		X = 10ms, 20ms, 50ms, 100ms, 200ms, 500ms, 1s, 2s, 5s or 10s	TO DO: interrupt emission to record a timestamp not available in night and survival mode
Select input **X** of multiplexer group **Y**	10 ms		X = 1, 2, 3, 6, 7 or 8; Y = 1 or 2	not available in night and survival mode
Select HK address	10 ms		X C [1,8] , Y C [1,3]	not available in survival mode
Activate HK continuous loop	10 ms			not available in survival mode 4 min to read all the HK's
IIU				
LYRA Switch ON or OFF	10 ms	<1A ; 5V		TO DO when OFF : to close the lumps in the LDM
UV LED's ON/OFF procedure				

SC				
Request the time remaining before the next contact with the ground				
FIFO				
Get FIFO#2 occupation level				
LDM				
Conclude/seal the three current lumps				compression if needed, addition of the lump header

COMMANDS REQUESTED FROM THE GROUND TO COMPONENTS

Command	Execution Time	Current-voltage	Parameters	Remarks
LIM				
RS422				
Get the unread HK word(s) thru the RS422				
Check IIU LYRA switch ON				
ASIC reload				if in night mode
Transmit HK or status to the SC data bank for downlink				
Add a new mode				update LIM version number
Delete a mode				not if this mode is running, update LIM version number
Replace a mode				not if this mode is running; update LIM version number
Check FIFO#2 filling and give max acq. Cadence				TO DO : update the acquisition cadence

SC				
Change frequency of reports of data X in the data bank				data X can be an HK, a status, a pointing parameter, …
Update LIM-LDM version number				
Change HK limit values			HK concerned	
Disable - enable HK analysis				not disable within the TBD s after the detection of an error
Modify HK table				
Modify status table				
Load new version of the LDM code				TO DO : update the version number
Change LDM parameters			compression en-/disable, rearrangement en-/disable, keep one science block out of X,	TO DO : close current lumps; update LDM version number
Reset FIFO#2				
Change the values of temporal warnings			X1, X2, X3, Y1 or Y2	TO DO : to update the schedule table
Add in schedule table				
Delete in schedule table				
Replace in schedule table				

COMMANDS SENT BY THE LDM TO OTHER COMPONENTS

Command	Execution Time	Current-voltage	Parameters	Remarks
FIFO#1				
Reset FIFO#1				
OBET				
store the timestamp				

DATA SENT BY THE LIM TO OTHER COMPONENTS

Data	Remarks
SC	
HK	
Satus	

DATA SENT TO THE LIM BY OTHER COMPONENTS

Data	Remarks
SC	
Time remaining before the next TM	
LOB	
HK	
Status	

Data	Remarks
FIFO#2	
lumps	

DATA SENT TO THE LDM BY OTHER COMPONENTS

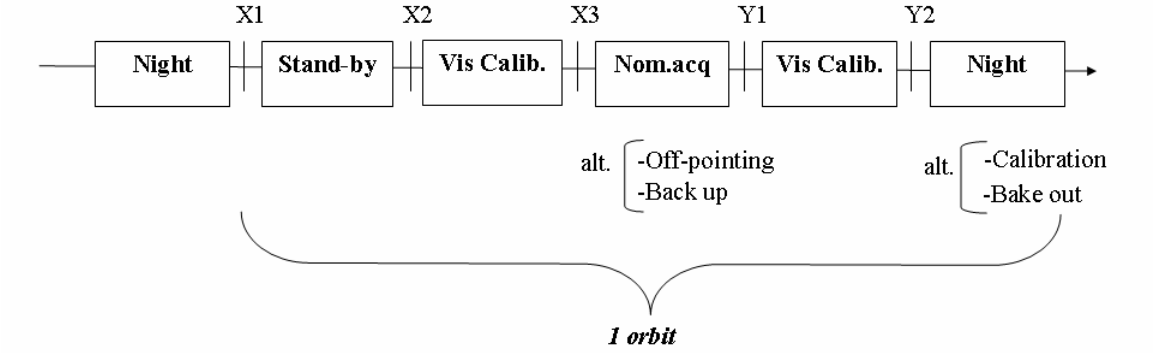
Data	Remarks
LOB	
Science data blocks	
Gate signal	
OBET	
Timestamps	
SC data bank	
SW version number	

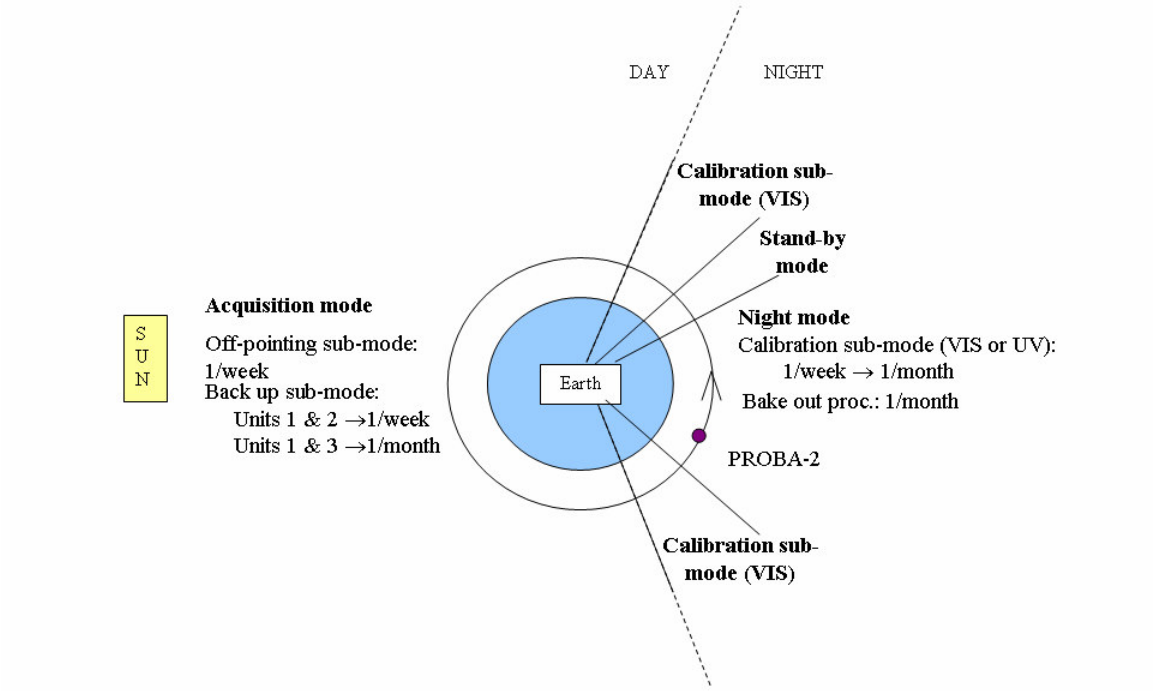
8 LYRA operating modes (scenarios)

Some atomic commands described in the previous chapter are regularly applied in a fixed order. For sake of simplicity, these successions of commands shall be preprogrammed using functions called operating modes. As for atomic commands, mode parameters are either Instrument Manager processing variables or constants uploaded from the ground. Note that, when in orbit, new versions of these modes can be uploaded from the ground. For example, a study of the luminescent clouds at high altitude is foreseen as a test during a few orbits (cfr. chapter 9). If these first acquisitions appear to be successful, this acquisition configuration could be implemented as a new mode (taking into account the compatibility with other experiments onboard).

8.1 Occurrence of the modes during an orbit

The default succession of modes is represented below. Alternative modes or sub-modes are indicated.





8.2 Stand-by mode

The stand-by mode consists not in acquisitions but in switch-on procedures[8] (most of the LOB components are switched off every night) followed by tests to ensure that LYRA is in a thermal/electronic status allowing it to switch quickly to acquisition mode. This mode is nothing else than an intermediate state between night mode or the survival mode and acquisition modes. It includes a check of temperature sensors and a switch on of the VFC1 and detector1, which are required for the next default mode in order to allow them to be stabilized before the beginning of observations. In parallel, the LIM waits for a S/C command (usually corresponding to the timing signal X2).
Thereafter the acquisition mode (which comprise nominal sub-mode, off-pointing sub-mode, the back up sub-mode or the calibration sub-mode) can be triggered upon reception of the S/C command.
At the end of this mode, VFC1 and detector 1 are thus powered.

8.3 Acquisition mode

This mode shall aim at acquiring time series with the four channels of the desired unit(s). Once every 10 sec (baseline but shall be adapted during the mission), during acquisition

[8] At the beginning of the satellite's life (the first time it will enter in stand-by mode), this procedure will be the "first switch on" described in annexes. Thereafter, a simpler switch on procedure will be used. Flowchart diagrams describing procedures can be found in annexes.

periods, the VFC's in function have to be calibrated. To do that a known voltage will be applied as input of the VFC. Three values of voltage are provided: 0V, 2.5V and 5V, each of them being thus triggered every 30 sec (following the VFC calibration cadence), in alternation with the others. Data acquired with one of this three inputs are recognized by their MUX address.
Note that, before to begin acquisitions, the status of the VFC(s) and the detector head(s) specified in parameters must be checked. The status corresponding to the end of stand by mode is VFC1 and detector1 powered. If this doesn't correspond to the required configuration, the missing VFC(s) and detector(s) must be switched on while the redundant ones must be switched off.
Thereafter, the desired doors shall be powered, open, and disconnected, while, the required LED's shall be switched on

Parameters are:

- LOB unit(s) involved (1, 2 or 3),
- Chosen VFC(s) (1 or 2),
- LED status (ON or OFF, UV or VIS, unit 1, 2 or 3),
- Acquisition cadence (possible values: 10ms, 20ms, 50ms, 100ms, 200 ms, 500ms, 1s, 2s, 5s, 10s)
- Beginning and end of acquisition (e.g. X3 and Y1, respectively) or duration (in sec)
- Off pointing scheme/path (to be chosen between pre-defined schemes comprising the pointing with a constant angle) Frequency of the VFC calibration (max 1 voltage every sec)
- Cover status (ON or OFF)

As we can see, the duration of such a sequence is either fixed (number of hours) or bounded by "sunset" warning (default) Y1.
TC can change these parameters
Sometimes, it will be possible to observe the Sun through the Earth atmosphere (after sunrises and before sunsets). These periods shall be dedicated to Earth atmosphere absorption study.
Note: As said before, the acquisition cadence can be autonomously adapted in case the place remaining in the FIFO dedicated to data storage is too low.

8.3.1 Nominal sub-mode

This mode is the most often used. It aims at acquiring sun irradiance time series, which requires that the satellite is pointing at the sun (which has to be at least partly visible). It consists simply in acquiring with one unit at a cadence of 100Hz. The parameters defining this mode are the following :

Default parameters are:

- Unit 1
- VFC 1
- All LEDs OFF
- Acquisition cadence: 100 Hz
- X3 and Y1
- Constantly sun-centered
- 10 sec
- Cover 1 open

8.3.2 Back up (redundancy) sub-mode

This mode shall permit to evaluate the performance of the radiometers (detectors + filters) and their possible degradation (in term of effective area) as a function of time by comparing the results of two units having different utilization rate. To achieve this, samples shall be acquired at 100Hz (maximum) in the 4 channels of two units simultaneously. This shall occur once a week for units 1 & 2 and once a month for units 1& 3 when pointing is sun-centered.

Default parameters are:

- Units 1 and 2
- VFC 1 and 2
- All LEDs OFF
- Acquisition cadence: 100 Hz
- X3 and Y1
- Sun-centered
- 10 sec
- Covers 1 and 2 open

8.3.3 Off pointing sub-mode

This sub-mode shall permit to evaluate the performance of the detectors and their possible degradation (in term of flat-field) as a function of time. It is possible to access information on the spatial map of the detectors by paving the FOV with off-points. During SC manoeuvres, acquisitions should not be interrupted. The identification of data acquired during SC movements and during stabilized periods will be made on the ground when comparing the data with the manoeuvre warnings logged in the events file. Stabilized periods and corresponding acquisitions should last more than TBD sec (in order to have a sufficient amount of data for each stabilized position of the SC).

This sequence should be run early in the instrument life, for consistency check with on-ground calibrations. Baseline is to perform these acquisitions once every three months but this cadence might change during the mission.

Default parameters:

- Unit1
- VFC 1
- All LEDs OFF
- Integration time = 10 ms
- X3 and Y1
- Detector paving
- 10 sec
- Cover 1 open

8.3.4 Calibration sub-mode

This sub-mode shall permit to evaluate the performance of the detectors and their possible degradation (in term of QE) as a function of time. It will consist in acquiring time series at 100 Hz, while the spacecraft is not looking at the Sun (i.e. during eclipses, or door closed). This includes dark records and data taken with the calibration lamps (either the UV or the Visible ones) ON. Such a sub-mode will typically be activated twice an orbit (VIS LED) and once a week to once a month (UV LED). Again, these frequencies must be adaptable during the flight. The duration of this mode will be determined by the parameters. In the default sequence, this mode is bounded by temporal alarms X3 or Y2. During this sub-mode, attention must be paid to the power consumption. Indeed, to switch on all the UV calibration LED at the time when SWAP is compressing data or baking out will probably consume too much power. These activities have thus to be desynchronized.

Default Parameters:

- Unit 1
- VFC 1
- LED type : VIS (but UV are also possible)
- 10ms
- X2 and X3
- Pointing : none
- 10 sec
- All covers closed

8.4 Night mode

A specified time interval after/before entering the night, it shall send a temporal warning (cf. PROBA-2 atomic services: Y2) and a command to the LIM. The LIM shall close the covers and switch off the instrument, placing it in non-operating status, with the minimum power consumption (only heaters and HK VFC shall be ON).

A specified time interval after/before sunrise (X1 or X2 warning) or after the reception of a TC (for example to switch to bake out procedure), LYRA shall enter the stand-by mode, ready to trigger other modes.

The switch off procedure is described in annex 11.
Remark : the stand-by mode should always be triggered from night mode prior to any acquisition mode. If a command is received to trigger an acquisition mode, this would be neglected and an event should be logged

Parameters:

- Beginning of the mode (in seconds)
- End of the mode (in seconds)

Default parameters:

- Y2
- X1

8.5 Bake out procedure

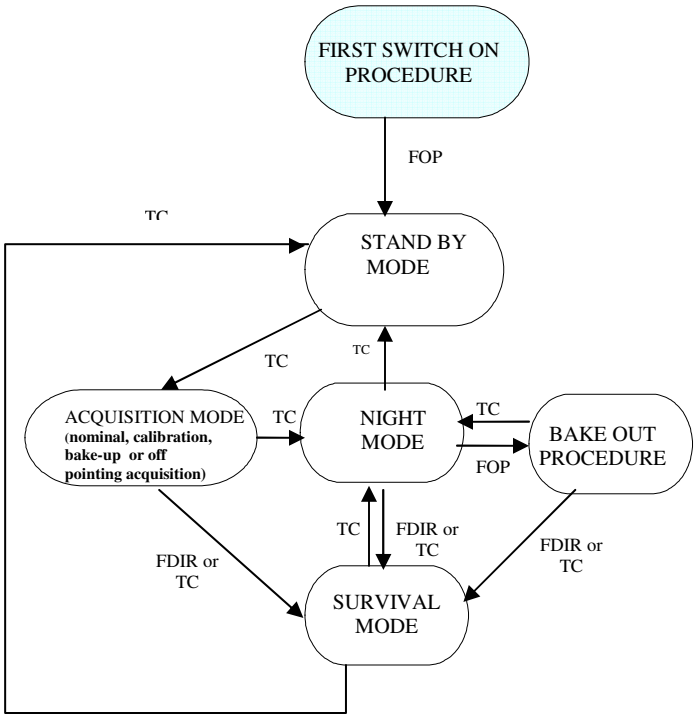
Once per month (depending on the ground request), each detector shall be decontaminated by heating it. In order to do so, a TC will be sent specifying the unit head(s) and the heater(s) involved as well as the duration of the bake-out. Since we cannot be certain of the effectiveness of such a procedure (instruments may be hot enough to avoid contamination), this will be tested in flight. This is also why it will be implemented as a procedure

Parameters:

- Unit (1, 2 or 3)
- Heater (AB or CD)
- Duration (in seconds)

8.6 Survival mode

In case of emergency the survival mode shall be triggered by the spacecraft or the ground. Survival mode implies a complete switch off of LYRA after having closed the doors. This mode requires no parameters. Exit from survival mode can only be ordered by TC and can only be used to trigger stand-by or night mode. If a command triggering an other mode is received, it would be neglected and an event should be logged. Survival mode shall be accessible at any time from any other mode. It is considered prior to any other activity. As the application of any other mode required that the previous mode is finished, this mode should also offer the possibility to escape from an undesired trap configuration.

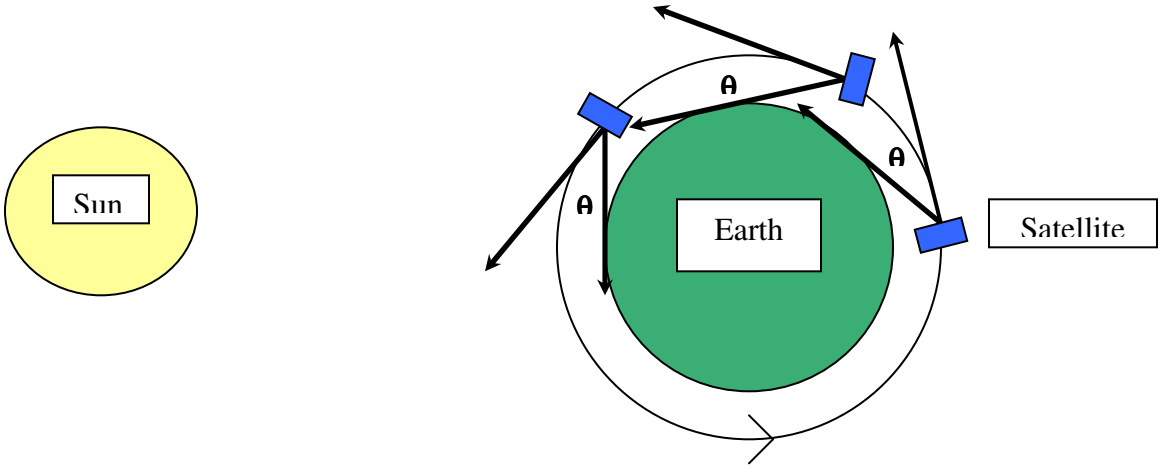

FIRST SWITCH ON PROCEDURE
FOP
TC
STAND BY MODE
TC
TC
ACQUISITION MODE (nominal, calibration, bake-up or off pointing acquisition)
TC
NIGHT MODE
TC
FOP
BAKE OUT PROCEDURE
TC
FDIR or TC
FDIR or TC
FDIR or TC
SURVIVAL MODE

9 Annexes: Aeronomy acquisitions

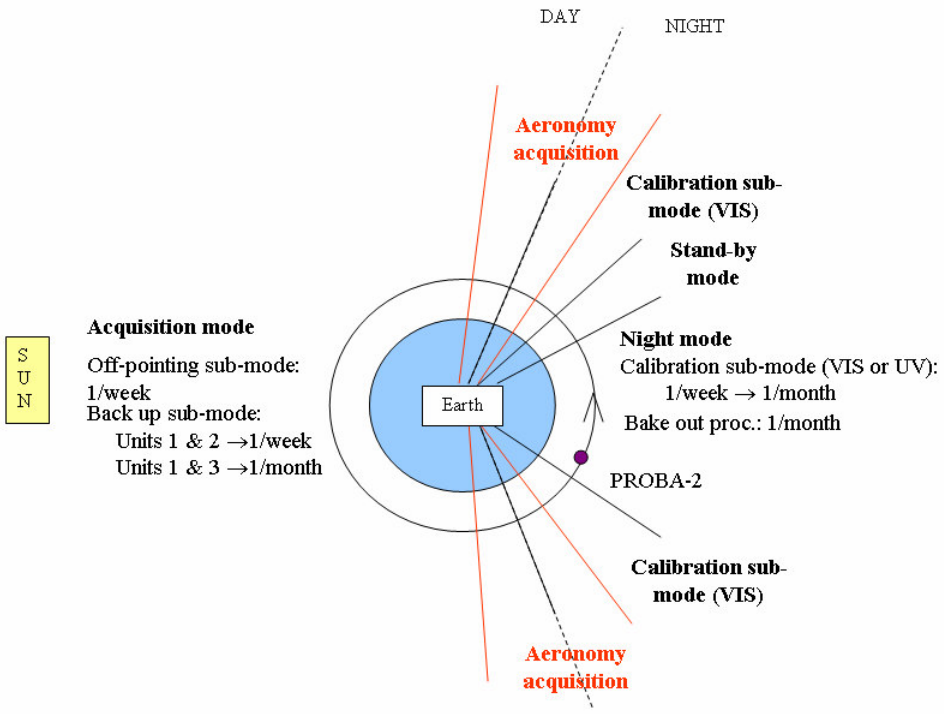
This configuration is dedicated to the Earth atmosphere study and will be triggered during a few orbits, between calibration mode and nominal mode (before sunrise and sunset, see drawing below). It consists in pointing the detector to form an angle θ between the line of sight (LOS) and the displacement direction of the satellite. By default, θ will be put at 0° before sunrise and at 180° before sunset, but it could take any value in the [-180°, 180°] interval.

The goal of such acquisitions is to measure faint luminescence of the Earth atmosphere in UV. In view of the anticipated signal weakness, having the Sun in the FOV must be avoided.

In flight, acquisition tests will be performed to establish the pertinence of such a mode. If it appears to produce interesting data, this should be introduced as a current mode in the



LIM.


DAY
NIGHT
Aeronomy acquisition
Calibration sub-mode (VIS)
Stand-by mode
Night mode
Calibration sub-mode (VIS or UV):
1/week → 1/month
Bake out proc.: 1/month
PROBA-2
Calibration sub-mode (VIS)
Aeronomy acquisition
Earth
S U N
Acquisition mode
Off-pointing sub-mode:
1/week
Back up sub-mode:
Units 1 & 2 →1/week
Units 1 & 3 →1/month

10 Annexes: specifications

10.1 Data format

10.1.1 Science data block from the LOB (see more in LDM description and [AD-1])

The onboard detectors shall acquire at a maximum rate of 100Hz (nominal cadence). Usually, only one unit (default unit is unit 1) shall be operated except during the backup mode periods when two units shall be used. However, eight signals shall always be transmitted from LOB to ADMPS in order to keep the same data pattern as in backup mode. Each science data channel has a maximum resolution of 24 bits per integration cycle. Four Bytes are used to store a counter, a flag, the integration time and the multiplexer addresses. The counter is reset every orbit simultaneously with the recording of the timestamp. Afterwards, timestamps are obtained every 10 sec, when the counter is reset, or when the integration time is modified. A bit/flag identifies the Science blocks associated with a timestamp. A checksum method is implemented which requires one more Byte to store the checksum. Including start and stop bits of the RS422 protocol, the maximum data rate is 29000 bps.

Byte	# of Bytes	Description	Remarks
Byte 28 – 25	4	Header	20 bit Block counter value 1 bit Synch flag 4 bit Integration time setting 3 bit Mux address group 2 3 bit Mux address group 1 1 bit Reserve
Byte 24 – 22	3	Channel 4	Nominal Instrument
Byte 21 – 19	3	Channel 3	Nominal Instrument
Byte 18 – 16	3	Channel 2	Nominal Instrument
Byte 15 – 13	3	Channel 1	Nominal Instrument
Byte 12 – 10	3	Channel 4	Backup Instrument or 0
Byte 9 – 7	3	Channel 3	Backup Instrument or 0
Byte 6 – 4	3	Channel 2	Backup Instrument or 0
Byte 3 – 1	3	Channel 1	Backup Instrument or 0
Byte 0	1	Checksum	

10.1.2 HK and status data

Housekeeping and Status data are directly transmitted to the LIM via the other RS422#2 connection. They will then be stored into the ADMPS data bank before being sent to the ground by telemetry joined to the ancillary of the s/c.
The data set contains either housekeeping or status data. An identification bit (MSB of the first byte) allows distinguishing between housekeeping and status.
A housekeeping / status data set consists of 4 bytes. 5 bits will be taken as HK address identification, 1 bit as HK or Status differentiation and 16 bits for data value.

Byte		Description	Remarks
Byte 3	Bit 7	1 = HK data set 0 = Status data set	
	Bit 6..5	not used, reserve	
	Bit 4..0	HK address identification	Range: 0 – 24
Byte 2	Bit 7..0	HK or status value	HK High byte or SB[15:8]
Byte 1	Bit 7..0	HK or status value	HK Low byte or SB[7:0]
Byte 0	Bit 7..0	Checksum	

Including start and stop bit (no parity) a HK / Status data set consists of 40 bits.

The order of the sampled HK channels can be set by the LIM: either cycling through all channels or setting a fixed channel for observation reasons. HK data will be sent every 10 seconds.

The status information is sent after each execution of a TC

a) Housekeeping channels (cfr. [AD-1])

Short Name	Description	Type
HK1	Temp Filter Detector 1	YSI
HK2	Temp Diode Detector 1	YSI
HK3	Temp Filter Detector 2	YSI
HK4	Temp Diode Detector 2	YSI
HK5	Temp Filter Detector 3	YSI
HK6	Temp Diode Detector 3	YSI
HK7	Reserve	
HK8	Voltage + 9.5V	Op Out
HK9	Voltage - 9.5V	Op Out
HK10	Voltage + 5V	Op Out
HK11	Temp VFC (2.5V Ref)	Ref43
HK12	Temp Power (2.5V Ref)	Ref43
HK13	Current + 28V	Hall Sens
HK14	Current + 9.5V	Hall Sens

HK15	Current - 9.5V	Hall Sens
HK16	Current + 5V	Hall Sens
HK17	Temp Heatsink	YSI
HK18	Temp Cover Plate	YSI
HK19	Temp Digital Print	YSI
HK20	Reserve	
HK21	Temp Reference Foot	YSI

Note : the three inputs left are dedicated to the calibration voltages.

b) Status Information (cfr. [AD-1])

Short Name	Description		
SB0	Power On Detector Head 1	0 = off	1 = on
SB1	Power On Detector Head 2	0 = off	1 = on
SB2	Power On Detector Head 3	0 = off	1 = on
SB3	Reserve		
SB4	Reserve		
SB5	Reserve		
SB6	Checksum Error	0 = no	1 = yes
SB7	Power On VFC Group 1	0 = off	1 = on
SB8	Power On VFC Group 2	0 = off	1 = on
SB9	Power On HK Group	0 = off	1 = on
SB10	Cover 1 Open	0 = not open	1 = open
SB11	Cover 1 Closed	0 = not closed	1 = closed
SB12	Cover 2 Open	0 = not open	1 = open
SB13	Cover 2 Closed	0 = not closed	1 = closed
SB14	Cover 3 Open	0 = not open	1 = open
SB15	Cover 3 Closed	0 = not closed	1 = closed

10.2 Commands to the LOB

Commands dispatched by the LIM are received by LOB via RS422#2. A TC data set consists of 6 bytes data and 1 byte checksum.

Byte		Description	Remarks
Byte 6	Bit 7..0	TC Bit [47:40]	MSByte
Byte 5 .. 2	Bit 7..0	TC Bit [39:8]	
Byte 1	Bit 7..0	TC Bit[7:0]	LSByte
Byte 0	Bit 7..0	Checksum	

Including start and stop bit (no parity) a TC data set consists of 70 bits.

After receiving a TC the LOB verifies the checksum byte. In case of a difference a status bit “checksum error” is set. In this case the instrument manager shall resend the TC.

To minimize failure rate a time window for receiving TC’s will be implemented on LYRA. A TC should be received within 2ms.

A description of the command format can be found in [AD-1].

11 Annexes : switch ON/OFF procedures

In the sequel, the following couple of actions are conventionally represented by **SCW-W**

- Send CW (command word) to LOB
- WAIT x1 (TBD) ms

Read and verify Status bit (TBD) will be called **RVS**.

11.1 First Switch ON procedure

During and immediately after launch, all the LYRA S/W and H/W are off. Once in orbit, LYRA has to wait the end of PROBA-2 and LOB outgasing before switching on. This first switch ON procedure is not really a mode because it will happen only once.

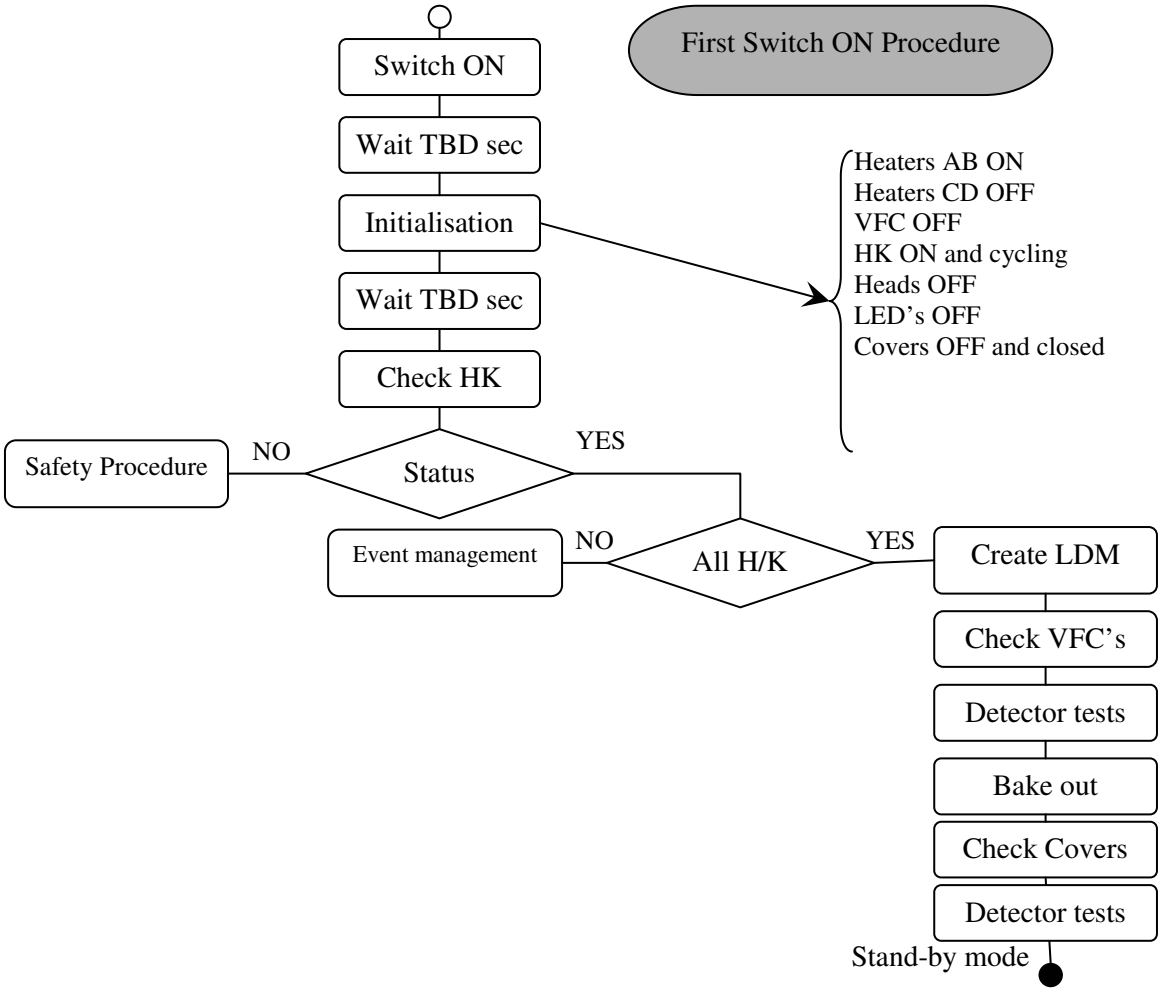
First switch on procedure (indicative/TBC):

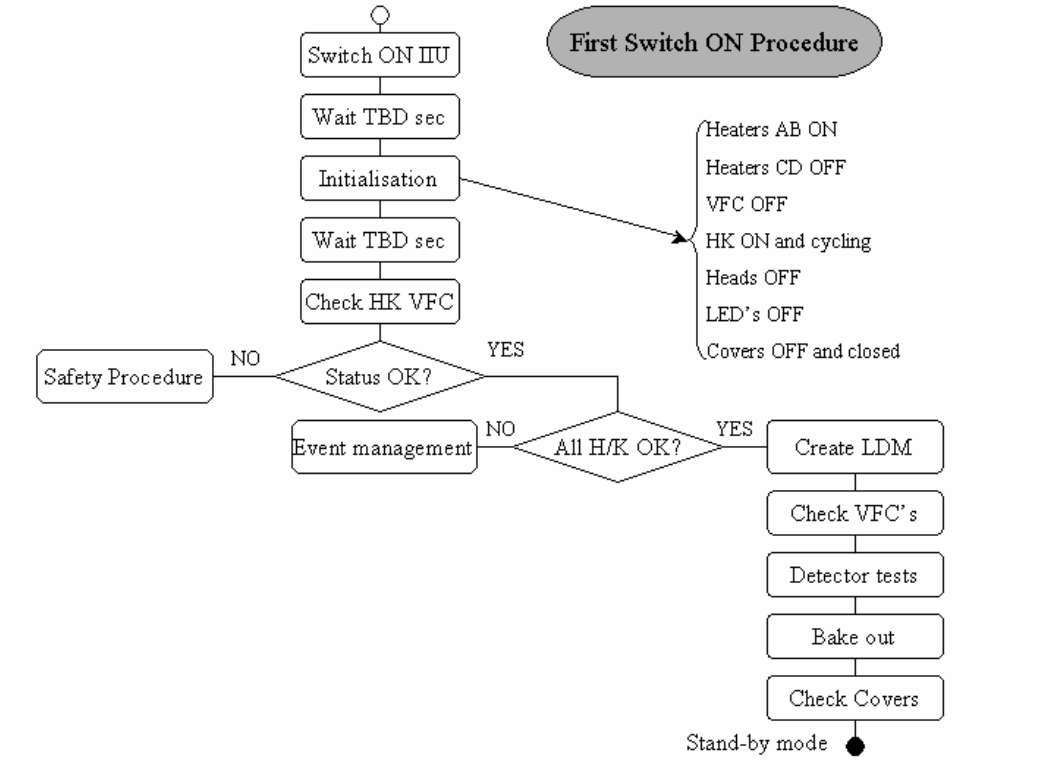
Initialization	Switch ON LOB (Command to IIU) WAIT TBD sec Switch OFF all CD heaters of all 3 unit-heads Switch ON all AB heaters of all 3 unit-heads Power both VFC OFF Power HK ON Select cycling HK Power all 3 Heads OFF Switch OFF all VIS LEDs Switch OFF all UV LEDs Power OFF Cover 1, 2, 3 Close Cover 1, 2, 3 **SCW-W (duration TBD)** **RVS**
Check HK VFC	Select calibration channel **SCW-W (10 sec TBC)** Check channel
HK verification	Read All HK signals (once) and verify their values (4 min duration)
Check VFC 1	Power VFC X1 ON **SCW-W (10 sec TBC)** **RVS** Select calibration channel **SCW-W (10 sec TBC)** Check channel

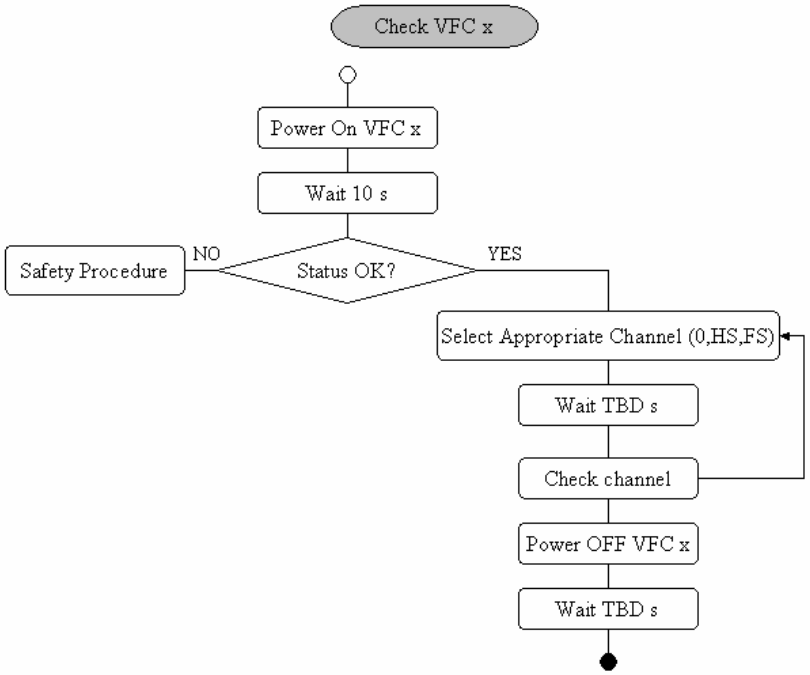
	Power VFC X1 OFF **SCW-W (duration TBD)**
Check VFC 2	Power VFC X2 ON **SCW-W (10 sec TBC)** **RVS** Select calibration channel **SCW-W (10 sec TBC)** Check channel Power VFC X2 OFF **SCW-W (duration TBD)**
Detector tests: covers closed (dark current, calibration with LED's.)	TBD
Bake out procedure	
Check cover 1	Power ON Cover 1 **SCW-W (duration TBD)** **RVS** Unlock Cover 1 **SCW-W (200s TBC)** Open Cover 1 **SCW-W (200s TBC)** **RVS** More to do TBD Close Cover 1 **SCW-W (200s TBC)** **RVS** Power OFF Cover 1 **SCW-W (duration TBD)**
Check cover 2	Power ON Cover 2 **SCW-W (duration TBD)** **RVS** Unlock Cover 2 **SCW-W (200s TBC)** Open Cover 2 **SCW-W (200s TBC)** **RVS** More to do TBD Close Cover 2 **SCW-W (200s TBC)** **RVS** Power OFF Cover 2

	SCW-W (duration TBD)
Check cover 3	Power ON Cover 3 **SCW-W (duration TBD)** **RVS** Unlock Cover 3 **SCW-W (200s TBC)** Open Cover 3 **SCW-W (200s TBC)** **RVS** More to do TBD Close Cover 3 **SCW-W (200s TBC)** **RVS** Power OFF Cover 3 **SCW-W (duration TBD)**
Test of the detectors (doors open)	TBD

Flowcharts


First Switch ON Procedure
Switch ON
Wait TBD sec
Initialisation
Wait TBD sec
Check HK
Heaters AB ON
Heaters CD OFF
VFC OFF
HK ON and cycling
Heads OFF
LED's OFF
Covers OFF and closed
Safety Procedure
NO
Status
YES
Event management
NO
All H/K
YES
Create LDM
Check VFC's
Detector tests
Bake out
Check Covers
Detector tests
Stand-by mode


First Switch ON Procedure
Switch ON IIU
Wait TBD sec
Initialisation
Wait TBD sec
Check HK VFC
Status OK?
NO
Safety Procedure
YES
Event management
NO
All H/K OK?
YES
Create LDM
Check VFC's
Detector tests
Bake out
Check Covers
Stand-by mode
Heaters AB ON
Heaters CD OFF
VFC OFF
HK ON and cycling
Heads OFF
LED's OFF
Covers OFF and closed


Check VFC x
Power On VFC x
Wait 10 s
Status OK?
NO
Safety Procedure
YES
Select Appropriate Channel (0,HS,FS)
Wait TBD s
Check channel
Power OFF VFC x
Wait TBD s