FIRST/PLANCK

Operations Interface Requirements Document

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European Space Agency

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ESOC

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CONTENTS

1. INTRODUCTION

1.1 Purpose and Scope

The purpose of this document is to identify the requirements on the FIRST/PLANCK spacecraft and their payloads, necessary for the conduct of all mission operations. In addition, this document defines all requirements related to the major deliverable items needed at the Mission Operations Centre (MOC) for the preparation and execution of the mission operations.

The document will be approved by ESOC and ESTEC Project Office. The document will be controlled by the ESTEC Project Office.

1.2 Structure of the Document

The requirements of section 2 define the functions related to spacecraft and instrument operability and autonomy. Section 3 provides requirements for the definition and function of TM and TC packets. Section 4 provides the detailed requirements concerning contents and deliveries of spacecraft operational information in terms of data and documentation.

This document, in particular its section 3, is derived from the ECSS Packet Utilisation Standard [AD-1]. It should be noted that essential complements to this document will be the Space to Ground Interface Control Document [AD-2] and the FIRST/PLANCK Packet Structure Interface Control Document (PSICD,AD - 5) which will contain all details of the structure and functionality of the TM and TC frames and packets.

Most of the requirements are, in general applicable to both the spacecraft and the payloads, and are marked as **P** for applicability to the payload instrument. Requirements on services offered by the S/C. which are not mandatory for the instruments, but are available if they wish to use them are marked as **PO**. All other requirements are not applicable to the payload instruments.

1.3 Applicable Documents

AD - 1. Telemetry and Telecommand Packet Utilisation Standard ECSS-E-70/41 Draft 04, April 1999

AD - 2. FIRST/PLANCK Space / Ground Interface Control Document (SGICD)

AD - 3. FIRST/PLANCK Instrument Interface Document (IID-A) Issue TBD

AD - 4. FIRST/PLANCK Spacecraft System Specification, PT-SP-00211, Issue TBD

AD - 5. FIRST/PLANCK Packet Structure Interface Control Document (PSICD) – SCI-PT-IF-07527

AD - 6. ESA Packet Telemetry Standard ESA PSS/04-106 Issue 1 1988

AD - 7. ESA Packet Telecommand Standard ESA PSS-04-107 Issue 2 1992

1.4 Reference Documents

RD-1 Ground Segment and Operations Concept Document – Issue 1

RD-2 Ground Segment Interface Document – Issue 1

1.5 General Operations Concepts

This section presents concepts that are used, further in the document, in the definition of satellite and functional requirements which are considered essential to ensure the operability of the FIRST/PLANCK spacecraft and instruments.

The FIRST/PLANCK spacecraft and instruments operations concept must result in simple and safe flight operation procedures To avoid design deficiencies which may compromise this objective, operational aspects must be taken into account already at the concept design phase of the subsystems and instrument's hardware and software. Operations should not be the means to correct design deficiencies by additional ground segment tasks.

During the routine science mission phase, ground station contact and real time control will take place during a few hours per day. During this time, the health and status of the satellite will be verified, and the telemetry stored from the previous science period (about 24 hours) will be downlinked. In parallel to this, the schedule and command for the next science period will be uplinked, and any resulting corrective actions will be executed or scheduled as appropriate. Effectively this means that the science operations will be done outside of ground control. They will be performed from a schedule, but autonomously. In particular, spacecraft and instrument will need on-board monitoring and autonomous features to recover from non-nominal situations. This in turn puts a special emphasis on the corresponding features for satellite control from the ground. The use of packet telemetry should ease this task, in particular for the generation and sequencing of data in the daily telemetry dump, e.g. satellite status first, followed by the operational events and command verification reports, and then the actual observation telemetry.

The sole basis for flight operations is the spacecraft and instruments users' manual. Their quality is instrumental for efficient and safe operations in both routine and contingency cases. This document is required already for early subsystems and instrument's reviews in order to support the iterative process between the instrument and the Spacecraft system for optimising the operational concept.

The operations of the spacecraft and instrument will also be based upon the same telemetry and telecommand database used in the EGSE. It is important that these common databases are made available to the in-orbit operations implementers in a timely manner.

It will be noted that the majority of the requirements presented in this document address aspects of the S/C (and payload) data handling systems, covering both their on-board interactions, and the ways they communicate with the ground. For this reason it is necessary to clarify the terminology that will be utilised in the rest of the document, and explain the concepts that drive the operational requirements. When the term CDMS is used, this refers specifically to the S/C command and data management system, as opposed to the dedicated instrument data handling systems.

The following section provide an introduction to the mayor on-board operational aspects of the S/C and the functional interface requirements on units interfacing with the CDMS.

1.5.1 Packet Telecommand Delivery

All commands to a unit/payload are issued as telecommand packets. Although all telecommands will be sent via the CDMS , they may originate either from the ground, or from the CDMS itself (as directed by the mission time line, or from an on-board procedure). The packet structure and transfer protocol for telecommand packets will be defined in AD-5

A specific on-board destination (e.g. application, subsystem, instrument) is addressed by means of a unique application-Id within the packet header. A specific instance of a telecommand is uniquely identified by the combination of the application-id and sequence control fields within the packet header. The functional meaning of the telecommand is identified by the type and sub-type fields within the data field header. A specific field in the header (Acknowledgement field) will indicate what type of acknowledgement (if any) is needed for each telecommand.

1.5.2 Telemetry Collection and Storage

Data will essentially be polled from a unit by the CDMS. In the following sections data is considered at the packet level. At this level the data collection can be considered to be delivered asynchronously by the unit/payloads. Normally all data collected will be stored on board in the mass memory, whether or not it is being down-linked, until it is "erased" (or the memory freed for over-writing) by ground command.

Data will be gathered in packets of different types, as follows:

i) House Keeping Data

Housekeeping packets contain all parameters that define the health and safe working status of the unit, allowing monitoring of the correct operation of the unit. Selected housekeeping data may be processed and acted on by the CDMS on-board monitor or other services.

ii) Science Data

Science data packets from the experiment may be delivered regularly or in bursts depending from the agreed mode of operation and the allocated bit rate for that instrument mode. Science packets will not be processed by the CDMS .

iii) Telecommand Report

These packets report the acceptance or rejection status of a telecommand packet and the completion status (success or failure) of the stages of the command execution process.. This report provides the ground with the means to monitor the correct processing of commands and hence to assess the performance of the system and instrument in the periods out-of-coverage. The CDMS may use these reports to check for telecommand verification on-board in the context of schedule control.

iv) Event Report

Event packets will be essential for the operational strategy of the FIRST and PLANCK spacecraft. An event packet contains a progress or anomaly report reflecting the units operational status. The CDMS may monitor, and take predefined action on an event packet.

v) Memory Dump

Such packets will contain requested memory dump data

vi) Context Data (TBC)

Data contained within a single Telemetry packet reflecting the current context of the unit (i.e. information necessary to return the unit to the same operational status following power cycling or other reset). The unit may be requested to send current context information to the CDMS for storage at any time. Only one context packet will be stored for each unit. The context packet can be sent to the unit as part of the power on procedure.

1.5.3 Solid State Mass Memory Resources

The SSMM is a shared on-board resource. It's primary use is for buffering telemetry data prior to downlink when ground visibility permits. In addition the SSMM may be used to store other information, e.g. master-timeline data, on-board procedures. (TBC).

1.5.4 Telemetry Packetisation by the CDMS

Some telemetry signals may be furnished to the CDMS as discrete signals (e.g. bi-level status or analogue channels). In these cases the CDMS will sample this telemetry, and generate appropriate housekeeping packets on behalf of that unit.

1.5.5 On-Board Monitoring and Response to Events

The CDMS will, via predefined tables, be able to monitor parameters from Housekeeping packets: a single parameter contained in a TM packet can be monitored against a limit set or an expected status and the result reported at the transition by an event packet.

Note: this is not in accordance with the PUS, which offers a transition reporting list. The functionality is identical and allows the use of event monitoring to react to an out-of-limits condition.

Event monitoring allows additionally to check for an event packet and if required, react if it is received (depending on the contents). Actions will be limited to the release of a telecommand packet (which could e.g. start a predefined on-board procedure).

1.5.6 On-Board Procedures

A principle mode of operation of the Spacecraft will be by execution of pre-defined on-board control procedures (OBCPs) initiated from the mission timeline. These procedures will be able to send telecommands, test parameters and branch on the result. OBCPs will be written using a Spacecraft Control Language (SCL), which will run in the CDMS.

Example of a simple procedure:-

1. Power on experiment
2. Verify experiment current is in range; if not start shut-down procedure and exit this one.
3. Wait predefined time for experiment to boot .
4. Check defined parameters in experiment house-keeping
5. Send time update to experiment
6. Log successful completion with an event packet

1.5.7 Tasks and Functions

From the point of view of control the software running in on-board processors can be considered to be of two types: that which is permanently resident and which provides the essential functionality of the system, and that which can be considered as an application program (or Task), which can be started, stopped, suspended and resumed.

Tasks are thus software applications which can be controlled using the task service that perform one or more pre-determined activities, most likely those which cannot be easily coded in the simple SCL used for OBCPs (e.g. a Task could perform complex mathematical calculations on telemetry parameters for autonomous power management and monitoring purposes).

A function can be addressed as a “black box”: it may, or may not be implemented in software , however it is permanently available (barring substantial software maintenance activity) and is not loadable, and controllable in the same way as a task. A function (e.g. thermal control), can be started or stopped and/or it can receive instructions and execute them (e.g. take an image with these parameter settings).

1.5.8 Synchronisation with Spacecraft Time

All units on-board the satellite will operate using a single Spacecraft furnished time reference, which will be used to time-stamp all TM packets. The experiment units will be furnished with this time during power-on. The CDMS will then perform time updates at agreed intervals or as commanded. The frequency of time updates will be established based upon combined instrument timing requirements. It shall be possible to synchronise instruments individually without disturbing the operations of other instruments or subsystems.

2. SATELLITE OPERATIONS AND FUNCTIONAL REQUIREMENTS

2.1 Spacecraft Control

2.1.1 General

CTRL-1. During all mission phases (including LEOP and transfer to L2) there shall be no requirement for the MOC to send telecommands in nominal or contingency cases with a response time of less than 3 (TBC) minutes. **P**

Note: *the requirement applies to all phases of the mission, during S/C visibility, and covers the possibility that either downlink and/or uplink capability are not immediately available. As a consequence, any control action requiring fast response times shall be handled on-board, without ground intervention. This can be implemented by a watch-dog function from the CDMS (see On-Board Monitoring -Service 12)*

CTRL-2. Situations in which the MOC is expected to react within a short time (< 30 minutes) shall be well identified and agreed by ESA. **P**

CTRL-3. Situations in which the MOC is required to react within a short time (< 30 minutes) shall be unambiguously recognisable in the telemetry available to the MOC, without the need for complex processing (such as historical data processing). **P**

CTRL-4. HK Telemetry shall be continuously generated and recorded in all modes of operations, including Survival Mode. However, when a Subsystem or Instrument - which nominally generates or relays HK Telemetry - is in a specific non-nominal mode (as : processor halted / reset) , this requirement does not apply to the concerned Subsystem or instrument. **P**

CTRL-5. The S/C and on-board users shall always be able to receive, process and distribute all the uplinked command packets at the maximum uplink rate, regardless of packet sizes.. **P**

Note: *This requirement (and the next) may imply the implementation of a priority scheme and buffering for incoming commands, which may arrive simultaneously with commands issued by on-board sources.*

The maximum command data rate to the instruments will be defined in AD - 3

CTRL-6. No slowing down of the commanding rate shall be imposed by on-board limitations in hardware or software for handling the incoming telecommands by any subsystem or instrument. **P**

Note: *details of the command distribution protocol will be defined in AD - 3*

2.1.2 Telecommands

TC-1. Execution of hazardous functions shall be implemented by means of two independent telecommands.

Note: *hazardous functions are those which when executed at the incorrect time could cause mission degradation or damage to equipment, facilities or* *personnel. It is the Project's intention to request the PIs to ensure that the instrument design excludes any hazardous function.*

TC-2. Execution of vital functions (agreed by ESA) shall be implemented by a nominal and a redundant telecommand. **P**

Note: *vital functions are those which if not executed could cause mission degradation. The CDMS will deliver main and redundant (physically separated) lines to the spacecraft units for each required function, including telemetry and telecommand. Details of the electrical interfaces redundancy concept will be defined in AD - 4*

TC-3. Redundant telecommands shall be differently routed from the related nominal telecommand. **P**

TC-4. A telecommand packet shall contain one and only one telecommand function. **P**

Note: *a telecommand function is an operationally self-contained control action. A telecommand function may comprise or invoke one or more low-level control actions.*

TC-5. It shall be possible to command the spacecraft or any subsystem or instrument into each of their pre-defined operation modes by means of a single telecommand **PO**

Note: *This could be achieved by initiating a high level On-Board Control Procedure via telecommand (see description 1.5.6 On-Board Procedures)*

TC-6. It shall be possible to command all on-board devices individually from the ground. **P**

Note: *a device is every individual on-board equipment/unit whose status can be actively modified/controlled.*

TC-7. A telecommand that does not conform to the packet telecommand standard and/or is not recognised as a valid telecommand shall be rejected at the earliest possible stage in the on-board acceptance and execution process. **P**

TC-8. The on-board reception, processing and execution of telecommands shall not affect any other independent on-board process. **P**

Note*: it is possible that, in contingency actions, execution of a telecommand could affect other on board processes. These cases will have to be clearly identified and documented.*

TC-9. Changes to on-board data or software parameters shall be implemented via a dedicated telecommand and not via a multi-purpose software load telecommand. **P**

TC-10. Readouts of loaded on-board data or software parameters shall be requested via a dedicated telecommand and not via a multi-purpose software dump telecommand. **P**

TC-11. The telecommand history (including content) of on-board issued commands shall be kept on-board for interrogation (and/or deletion) by ground.

The telemetry packet structure/service for this data is TBD.

2.1.3 Telemetry

TM-1. The MOC shall be provided throughout the mission with the data, in raw form, required for the execution and analysis of all nominal operations and foreseen contingency operations for the spacecraft subsystems and instruments. **P**

Note*: this top-level requirement covers the availability of all the data from any unit/payload, required for the conduct of operations, in the telemetry streams that is accessible at and processed by the MOC . This to avoid that essential telemetry might be downlinked in the science packets only, (which is not processed in the MOC).*

TM-2. The availability of telemetry information shall be compatible with the required response times which have been identified for any control loops implemented on ground. **P**

TM-3. Telemetry data shall be provided to the ground such that complete and unambiguous assessment of the spacecraft and payload status and performance is possible without the need for reference to the telecommand history to interpret the data. **P**

Note: *performance of instruments is related to the engineering data only and doesn't refer to the quality of scientific data production.*

TM-4. Telemetry shall be provided to allow complete and unambiguous verification of acceptance and execution of all telecommands sent from any source (sent from ground for immediate, delayed or time-tagged execution, and sent from on-board applications). **P**

Note*: the level of verification will be specified by the command Acknowledgement field*

TM-5. Telemetry shall always be provided to unambiguously identify the conditions required for execution of all possible configuration dependent telecommands. **P**

Note: *a configuration dependent telecommand is a telecommand which shall only be executed if a particular subsystem or instrument condition is satisfied.*

TM-6. Status information in telemetry shall always be provided from direct measurements from operating units rather than from secondary effects. This is in particular essential for the status of all on-board relays. **P**

Note*: the requirement is mandatory for all parameters that are essential for the monitoring of vital functions. Deviation from this requirement (like for the measurement of the detector biases in the cryostat) will have to be agreed by ESA.*

TM-7. All mission critical action shall be observable by at least two independently obtained measurements, collected on-board via independent routes.

Note: *a mission critical action at the wrong time or in the wrong configuration could cause the loss of the spacecraft, or the degradation of the mission.*

TM-8. All inputs to on-board autonomous processes, in particular On-Board Control **P**

Procedures, shall be accessible to the ground via telemetry.

***Note:** the inputs actually used by the process as it proceeds will be echoed to allow the ground to check the correctness of the action taken*

TM-9. Information to indicate all actions of operational significance taken by on-board software shall be available in telemetry. **P**

***Note**: these are typically actions related to hardware and software mode and configurations changes*

TM-10. Software status telemetry shall include all commandable parameters such as monitoring and control thresholds, software tables, flags, global variables used by On-Board Control Procedures, etc. **P**

TM-11. The values of telemetry parameters shall be self-contained. **P**

***Note:** This means that only actual values or actual status shall be downlinked, and not changes (or delta values) since the last readout.*

TM-12. The value of a telemetry parameter shall be transmitted in contiguous bits within one packet. **P**

TM-13. It shall be possible to store all telemetry generated on-board in the SSMM, including that currently defined for immediate transmission to ground, until deleted by ground.

TM-14. Event packets (also from the monitoring service) and telecommand acceptance reports shall be stored regardless of the status of the SSMM.

This is to ensure that a minimum reporting capability is available in the absence of the SSMM so that the spacecraft performance during non-coverage periods can be assessed.

TM-15. Any packet carrying engineering measurement and performance information for a unit shall also contain the information necessary to determine the validity of the data, e.g. the unit status. **P**

TM-16. If it is necessary to define synthetic parameters (i.e. parameters which are calculated using other parameters), all the contributing parameters should appear in the same packet. **P**

This is to avoid problems which occur due to the absence of contributing packets, or due to inconsistencies caused by time differences between the contributing packets.

TM-17. All packets shall include the time field in the data field header **P**

TM-18. All event packets shall include a counter (in the data field) which permits the unambiguous identification of the type (severity) of events lost when event packets are found to be missing (from the packet source sequence count). **P**

2.1.4 Timing

TIM-1. All timing information used for on-board functions like time-tagging of telecommands and running of application software and for telemetry time- **P**

stamping shall be synchronised with a single on-board Master Clock.

***Note:** details of the timing synchronisation protocol and accuracy will be defined in AD - 3 and AD - 4*

TIM-2. Timing information provided in telemetry shall allow the correlation of on-board time with TAI with an accuracy defined in AD3 and AD - 4 **P**

TIM-3. It shall be possible to establish by analysis the original on-board sampling time of any spacecraft status telemetry parameter appearing in the telemetry source packets. **P**

TIM-4. After switch on or reset, any unit shall flag in each packet with the time field that the time has not yet been synchronised **P**

2.2 Spacecraft Autonomy

This section contains the requirements related to ground control and monitoring of all on-board autonomous functions.

2.2.1 General

AUT-1. During all active mission phases the spacecraft shall be able to operate without ground contact for a period of 48 hours without interrupting mission product generation. Beyond the 48 hours the spacecraft shall be able to survive in a safe mode for 7 days without the need for ground intervention.

***Note:** the requirement is applicable to the S/C, and allows the dimensioning of the on-board time tag commanding capability. After the last time tagged command is executed, and in absence of direct ground commands, the S/C CDMS (e.g. using a set of pre-defined OBCPs) shall ensure that the spacecraft and instruments are in a safe configuration.*

AUT-2. On-board intelligent units including instruments shall be able to enter their Safe Mode on receipt of a single TC-packet. **P**

AUT-3.

- The spacecraft shall be able to detect failures which are hazardous for the spacecraft or its instruments; if such a condition is detected the spacecraft shall autonomously configure the affected on-board subsystems and instruments into safe modes of operation.
- For the following cases listed below (currently TBD) the S/C shall be capable of recovering from the failure and continue normal operations:

The Spacecraft Prime shall identify these cases and provide an appropriate S/C design, operations and verification concept in Phase B.

AUT-4. The Survival Mode shall initiate any payload re-configuration activities necessary to put the payload in a safe and recoverable mode.

The "Survival Mode" is here assumed to be the mode to which the system falls back when all autonomous recovery actions have been exhausted, whereby a minimal functionality is retained to control the system within the set of constraints necessary for the survival of the S/C and instruments until the ground can intervene.

AUT-5.	When in Survival Mode the spacecraft shall start generating a minimum set of telemetry packets which allow unambiguous and rapid identification of the Survival Mode. The reason for the triggering of the Survival Mode and the history of the defined events occurred before and after the detection of the failure condition shall also be accessible in telemetry either directly or stored in memory areas that can be later dumped and reset by the ground.	
AUT-6.	Essential on-board autonomous functions, including fault management, shall be available in Survival Mode.	
AUT-7.	It shall be possible to enable / disable autonomous entry, and to force manual entry into Survival Mode by telecommand. Autonomous entry shall be enabled by default.	
AUT-8.	No nominal operation shall require inhibition of the Survival Mode nor a forced entry into Survival Mode.	
AUT-9.	The management of anomalies within a subsystem or instrument shall be handled in a hierarchical manner such that resolution is sought on the lowest level possible.	**P**
AUT-10.	All intelligent subsystems and instruments shall perform regular self-checks. ***Note:*** *intelligent units are those able to generate TM packets, and to process TC packets.*	**P**
AUT-11.	Anomalies and actions taken to recover from them shall be reported in event packets.	**P**
AUT-12.	It shall be possible to reconstruct from telemetry the conditions leading to the generation of an event.	**P**
AUT-13.	*D*eleted	**PO**
AUT-14.	Deleted: see EVRP-5	**P**
AUT-15.	The on-board system shall capture sufficient information to enable the ground to analyse failures. *Normally the SSMM wil satisfy this requirement. In the case of failures resulting in the loss of the SSMM* it will be necessary to store telemetry by another means for ground interrogation.	**P**
AUT-16.	It shall be possible for the ground to enable / disable each individual fault management function.	**P**
AUT-17.	*deleted*	**P**
AUT-18.	*deleted*	**P**
AUT-19.	All parameters used for autonomous fault management (e.g. thresholds for limit checks or thresholds and biases for attitude control), including fault management, orbit and attitude control, etc., shall be updateable by telecommand and available in telemetry.	**P**
AUT-20.	The on-board fault management shall avoid continuous toggling of the configuration of a unit between the prime and the redundant element.	**P**
AUT-21.	Deleted	**P**

AUT-22. The spacecraft shall have the knowledge of the actual health status of all the hardware units required for any automatic transitions. This information shall be maintained on-board, updateable by telecommand and available in telemetry. **P**

AUT-23. An on-board safety logic shall be available to prevent inadvertent commanding of forbidden mode transitions. The table of allowed transitions shall be updateable by telecommand and available on request in telemetry. **P**

2.2.2 Attitude and Orbit Control

This section contains the specific requirements related to the operability of the AOCS functions.

AOC-1. *deleted – see AUT-21*

AOC-2. *deleted –see AUT-22*

AOC-3. It shall be possible for the ground to command, via dedicated telecommands, every individual AOCS actuator.

AOC-4. *deleted – see AUT-18*

AOC-5. Sufficient sensor information shall be available on request in telemetry in each of the AOCS modes to allow the ground to determine the spacecraft attitude.

AOC-6. Sufficient information from all actuators and units involved in reaction control shall be available in telemetry to allow the ground to verify the correct attitude and orbit control.

AOC-7. *deleted – see TM-14*

AOC-8. A counter for the accumulated commanded “thruster-on” time shall be available in telemetry for each thruster independently.

AOC-9. *deleted*

AOC-10. *deleted*

AOC-11. *deleted*

AOC-12. *deleted – see AOC-3*

AOC-13. *deleted*

AOC-14. *deleted*

AOC-15. *deleted*

AOC-16. The on-board attitude and constraint tables shall not require an update from ground more frequently than once every 48 hour in all critical phases of the mission.

2.2.3 Payload

In principle no specific requirements on the operability of autonomous payload functions exists, except for those which apply in general to autonomy and fault management of all spacecraft functions which are identified in the sections above. This section is a placeholder in case some specific requirements are identified at a later stage.

2.2.4 In-Flight Testing

INFT-1.	It shall be possible to activate any provided diagnostic mode of a unit without entering safe or survival mode of the spacecraft.	**PO**
INFT-2.	No fault management function shall trigger on test data generated by a unit operating in test mode.	**P**
INFT-3.	Entering a test mode shall not require (or imply) disabling of fault management functions.	**P**

2.2.5 On-board Control Procedures

On-board control procedures are flight control procedures executing in the on-board system. They are associated with an intelligent user. It is expected that typically the CDMS and possibly the ACC will be users for spacecraft OBCPs, however the instruments may choose to implement private versions of the service for their own purposes.

OBCP-1. An OBCP shall be controllable (*e.g. loaded, started, stopped…)* from any command source. **PO**

OBCP-2. An OBPC shall be able to access telemetry , issue telecommands and issue event packets. **PO**

OBCP-3. An OBPC shall be able to execute simple mathematical expressions (e.g. +, -, *, /), simple logical functions (e.g. *if then else; select; repeat; for; while; do; on case etc., and Wait (for a specified time or events)* **PO**

OBCP-4. It shall be possible to have several OBPCs loaded and some or all concurrently executing, without interference. **PO**

This may imply the imposition of simple methods to exclude e.g. calls to a procedure which is already executing. The maximum number of concurrently loaded procedures will be determined based on the mission scenario and the OBCP use profile to be agreed with ESA.

OBCP-5. It shall be possible to load and remove OBCPs without interference with to other OBCPs. **PO**

This includes interference in terms of restrictions on OBCPs to be loaded in the future as a result of e.g. fragmentation of memory assigned to OBCPs.

OBCP-6. The development environment for OBCP s shall provide : **PO**

- a simple language to express the procedure
- tools for testing and debugging procedures
- the procedure as it is to be loaded to the on-board system in a form compatible with the MOC control system.

It is intended that OBCPs shall be developed by operations engineers, and that therefore the tools provided shall be designed to be used by non-software experts.

OBCP-7. The procedure development environment shall be delivered to ESA for installation at the MOC. **PO**

The system could be delivered as software compatible with the MOC environment or as a stand-alone system which is compliant with MOC external interfaces.

3. PACKET FUNCTIONAL REQUIREMENTS

The following table defines the Packet Utilisation Standard services that are applicable to FIRST/Planck. Unless marked “not supported” they are mandatory for the spacecraft and their applicability to the instruments is as defined in the table. The FIRST/PLANCK Packet Structure Interface Control Document (AD - 5) defines the capability sets which are associated with the packet services and hence the range of functionality required. In the case where any subset of a service is mandatory, then the whole service is marked as such. In reality there may only be a small subset which must be supported, with the rest of the subsets being optional. The mandatory subset within the service is referred to as the ‘minimum capability set’. Individual subsets shall be implemented in full, partial subsets will not be supported.

Service Type	Service Name	Applicability for Instruments
1	Telecommand Verification	Mandatory
2	Device Command Distribution Service	
3	Housekeeping and Diagnostic Data Reporting	Mandatory
4	Parameter Statistics Reporting Service	Not supported
5	Event Reporting	Mandatory
6	Memory Management	Mandatory
7	Task Management	Optional[1]
8	Function Management	Optional[1]
9	Time Management Service	Mandatory
10	Not used	
11	On-board Operations Scheduling Service	
12	On-board Monitoring Service	
13	Large Data Transfer Service	Not Supported
14	Packet Transmission Control Service	Mandatory
15	On-board Storage and Retrieval Service	
16	On-board Traffic Management Service	
17	Test	Mandatory
18	OBCP Management	Optional

19	Event/Action Service	
20[2]	Information Distribution CDMS - User	Optional
21	Science Data Transfer	Mandatory
22[2]	Context Saving	Optional

Applicable PUS Services

[1] one of the two is mandatory.

[2] TBC

3.1 General

PACK-0. For both Telecommands and Telemetry packets the Application ID (APID) shall be allocated according to the tables contained in the AD - 5 **P**

PACK-1. Telecommands destined to different spacecraft subsystems and instruments shall be assigned different Application IDs (APIDs). **P**

PACK-2. Telemetry packets originating from a spacecraft subsystems and instruments shall be assigned the same APID as used for the telecommands to that subsystem and instrument wherever possible. **P**

PACK-3. It shall be possible to derive the location of a HK parameter within a telemetry packet from the APID and the Packet Type/Subtype and Structure ID (SID). **P**

PACK-4. All SIDs shall be unique within an APID. **P**

PACK-5. The number of SIDs per APID shall be minimised. **P**

PACK-6. HK Parameter subcommutation within a packet shall not be used. **P**

PACK-7. HK Parameter supercommutation is allowed if the parameter is sampled regularly in time, at an interval which is the same for all occurrences of the packet; consecutive packets guarantee continuous sampling of the parameter; the time offset of the first sample of the parameter within a packet is known. **P**

PACK-8. A telemetry parameter shall always have the same structure and interpretation in all telemetry packets in which it appears. **P**

PACK-9. Telemetry parameters shall be sampled at a frequency ensuring that no information of operational significance, for all nominal and contingency operations, is lost. **P**

PACK-10. The sampling time of a telemetry parameters in a packet with respect to the packet time shall be implicitly and uniquely defined by the packet APID and SID. **P**

PACK-11.	The telemetry packet time field shall report the instant in time of initiation of packet data acquisition. Whenever not feasible a deterministic relationship shall exist between the packet data acquisition and the time stamp.	**P**
PACK-12.	All telemetry packets shall have a time field (with the exception of the Time Packet) and the Idle Packet.	**P**
PACK-13.	APIDs shall be assigned by the ESA Project Office, and defined in AD-2.	**P**
PACK-14.	Telecommand packets shall be validated by the destination application process at the moment of acceptance.	**P**
PACK-15.	FIRST Instrument data packets shall be labelled with an Observation Identifier which will permit the relationship of the data to an observation without reference to external information. The format of the Identifier shall be defined in AD - 3 and AD - 5	**P**

3.2 Telecommand Verification (Service 1)

TCV-0.	The level of verification required in telemetry (acceptance, acceptance and execution) shall be controlled by each telecommand packet. ***Note**: the level of verification will be specified by the command Acknowledgement field*	**P**
TCV-1.	A telemetry packet for successful command acceptance shall be generated by the receiving application for every telecommand packet properly received and containing valid data.	**P**
TCV-2.	A telemetry packet for unsuccessful command acceptance shall be generated by the receiving application for every telecommand packet not properly received or containing invalid data. This telemetry packet shall indicate the reason for not acceptance of the related telecommand.	**P**
TCV-3.	A telemetry packet for successful command execution shall be generated by the receiving application for every telecommand packet properly executed if the acknowledgement field is set accordingly. ***Note**: the level of verification will be specified by the command Acknowledgement field*	**P**
TCV-4.	A telemetry packet for unsuccessful command execution shall be generated by the receiving application for every telecommand not properly executed, if the acknowledgement field is set accordingly. This telemetry packet shall indicate the reason for the failed execution of the related telecommand. ***Note**: the level of verification will be specified by the command*	**P**
TCV-5.	It shall be possible for the ground to suspend transmission to ground of telecommand verification packets.	**P**
TCV-6.	Telecommand verification packets shall indicate the source of the telecommand (i.e. ground, Mission Time line, On-Board Control Procedure). ***Note**: The telecommand source will be defined in the Packet Sequence Control fields, part of the telecommand Source Sequence Counter in the Packet Header, according to AD - 5.*	**P**

TCV-7. A telecommand verification packet shall be generated at reception of the telecommand. **P**

Note: *The delay in issuing a telecommand* ***execution*** *packet should be dependent only on the command, not its contents, so that the verification time-out can be configured correctly on the ground..*

TCV-8. *deleted – see EVRP-8*

TCV-9. Direct confirmation of the effects of all executed telecommands should be provided in the housekeeping telemetry. **P**

3.3 Device Commanding (Service 2)

Note: device commands are available to S/C subsystems only.

DVC-1. Device Telecommands shall be provided to satisfy the general requirement to be able to command individually and directly any on-board device.

Note: *A Device telecommand is a telecommand which is routed with minimum use of SW and executed directly by on-board hardware.*

DVC-2. Where more than one device telecommand is required to execute a specific function it shall be possible, but not mandatory, to pack all required device telecommands into a single telecommand packet. After unpacking the commands shall be sent for execution in the same order as contained in the packet.

DVC-3. It shall be possible to issue pulse device commands directly from the telecommand decoder if needed.

Note: *The purpose of the commands is to present to the user a pulse of fixed duration on a dedicated line. The command must perform a unique and dedicated action within the unit.*

DVC-4. Device telecommands shall include pulse commands (for example ON/OFF) and Register Load commands.

3.4 Spacecraft Status Reporting

3.4.1 Periodic Reporting (Service 3)

PERP-1. An appropriate reserved downlink bandwidth shall be provided for the subset of telemetry housekeeping data which is essential and sufficient to characterise the current status of the spacecraft (and its payloads) and indicate whether there is an anomalous condition that requires ground intervention. **P**

Note: *This will require the definition of a downlink priority scheme.*

PERP-2. *deleted* **P**

PERP-3. It shall be possible for the ground and/or an On-Board Control Procedure to request the generation of a specified housekeeping telemetry packet, with a desired frequency within the constraints of the on-board design. **PO**

PERP-4. To allow the definition of special diagnostic telemetry packets which support **PO**

over-sampling of selected parameters for troubleshooting purposes, the on-board system shall ensure that a minimum sampling interval consistent with the measurement of transient phenomenon (e.g. a pyro firing current) will be possible for all housekeeping parameters.

It is accepted that the use of diagnostic packets will constrain the telemetry available from other sources.

PERP-5. It shall be possible to replace or clear existing, and define new diagnostic telemetry packet structures via a dedicated telecommand. **PO**

***Note**: Modifications are limited to pre-defined parameters only.*

PERP-6. A pre-defined set of housekeeping report telemetry packets with a default generation frequency structured according to the different sources shall be available on-board. **P**

***Note**: Spare SIDs shall be available for the definition of new housekeeping telemetry packets.*

PERP-7. It shall be possible to enable/disable generation of a specified housekeeping (or diagnostic) telemetry packet via a dedicated telecommand. **P**

PERP-8. It shall be possible to request, via a dedicated telecommand, the generation of a telemetry report containing the definition of any specified housekeeping or diagnostic packet. **P**

***Note**: The use of a generic memory dump command is in this case acceptable if location and description of the information is fixed.*

3.4.2 Statistics Reporting (Service 4)

No requirement has been identified for such service. This section is a placeholder in case some specific requirements are identified at a later stage.

3.4.3 Event Reporting (Service 5)

EVRP-1. Event based reporting shall be supported by means of dedicated event telemetry packets .Three types of event reporting packet are identified: **P**

1. Normal events/progress reports/warnings
2. Exceptions requiring on-board action

Errors/anomalies requiring on-ground action

The details for the allocation can be found in AD - 5

EVRP-2. All on-board events of operational significance shall be reported in a complete and unambiguous manner using event report packets. **P**

***Note:** Events of operational significance cover, amongst other:*

- *reporting of failures and/or anomalies detected onboard;*
- *reporting of autonomous onboard actions;*
- *reporting of normal progress of operations/activities, e.g. detection of events which are not anomalous (such as payload events),*

- *reaching of predefined steps in an operation etc.*

EVRP-3. Anomaly reports shall contain a unique identification of the anomaly, its time of occurrence and a record of the data relevant to the anomaly detection function. **P**

EVRP-4. Input data to the anomaly detection function shall be recorded on-board such that they can be reported by the anomaly report packet for an appropriate interval of time centred around the time of occurrence of the anomaly. **PO**

This requirement will in general be satisfied by nominal recording of data on the SSMM – only in the case of SSMM outage are special arrangements required.

EVRP-5. The design of the reporting mechanism shall be such to avoid excessive use of the downlink bandwidth (and of the on-board storage capacity). This means that related events shall be reported as far as possible together; anomaly reports shall be generated only once per anomaly occurrence, even if the detection cycle repeats itself. **P**

e.g. *This implies that only transitions to or from the anomaly state shall be reported and that there shall be a minimum period before the next event packet reporting the same event (e.g. a transition to out-of limits) can be issued (to avoid a continuous stream of transition messages if the anomaly/no anomaly state is toggling – e.g. a parameter value is at the threshold of out-of-limits and crossing in and out).*

EVRP-6. Information to identify the nature (in particular, if action is required) of the report packet shall be contained in the APID and/or packet data field header. **P**

EVRP-7. deleted – see PERP5

EVRP-8. For telecommands initiating a long execution process the start and the end of the process shall be reported in telemetry. In addition, reports of progress either periodically or at pre-determined steps in the execution shall be provided. **PO**

EVRP-9. All event packets of type 2 and 3 of EVRP-1 shall be additionally stored on-board in a so called Critical Events Log which can be accessed regardless of the state of the SSMM.

Note: *the service will be available to all intelligent users, but will be centrally implemented by the S/C CDMS.*

EVRP-10. Dedicated telecommands shall be provided to read and clean the Critical Events Log.

3.5 Memory Management (Service 6)

MM-1. Functionally distinct memory areas shall be assigned to the following categories: **P**

- code;
- fixed data;

- variables and parameters.

MM-2. It shall be possible for the ground to load any changeable memory area. **P**

MM-3. It shall be possible to load with a single telecommand packet a contiguous memory area (e.g. by indicating the start address for loading and the length of the load) **P**

MM-4. Each telecommand packet needed to load any area of memory shall be self-consistent, i.e.: **P**

- the successful load shall not depend on previous packets;
- any single TC packet which is rejected may be uplinked at a later time without forcing re-uplink of other related TC packets already successfully uplinked.

MM-5. As part of the onboard acceptance of a memory load, the destination Application Process shall be able to detect data corruption. **P**

Note: *this verification can be done using checksums*

MM-6. The end-to-end verification of a memory load shall consist of confirming that the data have been correctly loaded into their destination memory **P**

Note: *this verification can be performed on the ground, by dumping the memory and comparing the memory image with the load data.*

MM-7. It shall be possible for the ground to dump any memory area (including non-volatile memories, mass memories). **P**

MM-8. The memory dump request shall specify the name of the memory to be dumped and indicate either a contiguous memory area (e.g. by indicating the start address and the length of the dump). **P**

MM-9. Only a single telecommand packet shall be required for a memory dump request, even if several telemetry source packets are required to convey the dumped data to the ground. **P**

MM-10. It shall be possible for the ground to request a check of a specified area of an onboard memory (over one or a range of addresses defined by start address and length) **P**

MM-11. In response to a request to check memory, the onboard action shall be to perform a checksum over the requested addresses and report the result to the ground. **P**

3.6 On-Board Software Management

OBSM-1. The system and application software of the on-board intelligent users shall reside in non-volatile memories. **P**

OBSM-2. Deleted

OBSM-3. *Deleted.*

OBSM-4. It shall be possible to modify the on-board software, either by modifying the image on non-volatile memory or by patching the image in working memory, while the unit affected is operational.

Note: Certain units may have to be fully operational during SW maintenance activities (e.g. CDMU, ACC, TBC), others can be operated in an Idle / Standby Mode during this phase (typically instruments, TBC)

3.6.1 Task Management (Service 7)

The control of software processes is achieved using this service. Payload control may be managed by using this service or service 8 (Function Management). If the service is used the controls described below can be used.

TSKM-1. It shall be possible to control Tasks , via specific telecommand packets, in the following manner: **PO**

start a Task;
stop a Task;
suspend a Task;
resume a Task;
abort a Task *(not required if covered by "stop a task").*
perform an activity within a task.

TSKM-2. It shall be possible to communicate with an Task (i.e. pass it parameters or modify variables used by the Task) without the need for the ground to first suspend the Task. **PO**

TSKM-3. Any communication between the ground and an Task shall be effected by means of telecommand and telemetry source packets specifically designed for the purpose. **PO**

TSKM-4. It shall be possible for the ground to inspect the loaded data/control parameters utilised by an Task at any time before, during or after the Task has run. **PO**

3.7 Function Management (Service 8)

The function management service supports instructions to functions implemented in hardware or software, where the structure of the command packet is defined by the APID and Function ID

FNM-1. It shall be possible for the ground to exercise control over a function:e.g. **PO**

- To activate a function;
- To deactivate a function.
- To perform an activity of the function .
- To load parameters

FNM-2.	It shall be possible to communicate with a function (i.e. pass it parameters or modify variables) without the need for the ground to first deactivate the function.	**PO**
FNM-3.	Any communication between the ground and a function shall be effected by means of telecommand and telemetry source packets specifically designed for the purpose.	**PO**
4.	It shall be possible for the ground to inspect loaded data/control parameters .	**PO**

3.8 Time Management (Services 9)

OBTM-1.	The CDMS shall produce a time report as defined by AD 6	
OBTM-2.	It shall be possible for the ground to request that the time reference within any on-board application (or on-board intelligent user) be synchronised with the CDMS Master Clock.	**P**
OBTM-3.	It shall be possible for the ground to request generation of time verification report packets, to confirm that the time of any application or user is synchronised with the CDMS Master Clock.	
OBTM-4.	All on-board applications and intelligent users of the CDMS services shall support time synchronisation and verification.	**P**
OBTM-5.	Telemetry produced and stamped with a time known to be out of synchronisation shall be explicitly identified as such.	**P**

3.9 On-Board Mission Time line (Service 11)

The On-Board Mission Timeline (MTL) is the facility which allows the control and execution of commands which have been loaded in advance from the ground.

Normally almost all commanding activities will be executed via the MTL, independent of whether the spacecraft is in visibility of the ground or not. Typically the telecommands loaded on the MTL will be starting execution of OBCPs, activating functions or passing parameters to a task.

Note: *Although the MTL services are available to all payload instruments, the requirements are only applicable to the spacecraft CDMS.*

MTL-1.	It shall be possible to load any telecommand (including those which operate on the *MTL* itself) into storage on-board for execution at a time specified at the time of uplink within the telecommand packet.
MTL-2.	The MTL shall be implemented *in the spacecraft CDMS* as a single, centralised spacecraft function.
MTL-2.1	The MTL shall be active by default whenever the CDMS is active
MTL-3.	The MTL shall be capable of storing any and all the telecommands needed for the execution of all routine operations.
MTL-4.	*deleted*
MTL-5.	It shall be possible to suspend/resume MTL execution by telecommand.

MTL-6. It shall be possible to prevent execution of a specified subset of telecommands contained in the running MTL without having to stop the entire MTL. The selection shall be made by telecommand APID (TBD) or by using a filter class defined at the time of the uplink.

MTL-7. It shall be possible to insert and append commands to the MTL, without the necessity of first stopping it.

MTL-8. It shall be possible to delete commands from the MTL, without the necessity of first stopping it. The delete options shall include:

- all commands (i.e. to reset the MTL contents);
- commands from a specified time onwards;
- commands between specified times;
- individual commands.

These options shall be possible for either "all Application Process IDs" or "specified Application Process IDs only" or "specified filter class (Sub-schedule) only".

MTL-9. It shall be possible to time-shift (advance or retard) commands which have already been loaded in the Onboard Schedule. The maximum time shift allowed is +/- 5 min (TBC). The options for time-shifting shall include:

- commands from a specified time onwards;
- commands between specified times;
- individual commands

These options shall be possible for either "all Application Process IDs" or "specified Application Process IDs" or "specified filter class (Sub-schedule) only".

Note: *this function is required to support re-planning of operations and to avoid having to delete and re-load the affected commands.*

MTL-10. It shall be possible to request a report of the contents of the MTL, with the option of a full report or a summary only (limited to TC header and no data field).The options for MTL report shall include:

- all commands;
- commands between specified times;
- individual commands.

These options shall be possible for either "all Application Process IDs" or "specified Application Process IDs only" or "specified filter class (Sub-schedule) only".

MTL-11. *deleted*

MTL-12. The granularity of the MTL is 1 sec (TBC).

MTL-13. Commands loaded into the MTL with the same execution time shall be executed in the same order they were uplinked to the spacecraft.

3.10 On-Board Monitoring (Service 12)

***Note**: Although the On-Board Monitoring services are available to all payload instruments, the requirements are only applicable to the spacecraft CDMS.*

OBMF-1. An On-Board Monitoring Function (OBMF) shall be provided, capable of monitoring any housekeeping parameter and any non-science telemetry packet generated by the subsystems and/or the payload.

OBMF-2. The OBMF shall be implemented in the spacecraft CDMS as a single, centralised spacecraft function.

***Note:** the* OBMF *is implemented as a set of CDMS Tasks.*

OBMF-2.1 The OBMF shall be active by default whenever the CDMS is active

OBMF-3. It shall be possible to add parameters to the monitoring list by specifying, for each parameter to be monitored:

- the parameter to be monitored by means of a mnemonic which uniquely identifies it independently of the routing used to acquire it e.g. via indexed addressing of its location in a data pool;
- for each parameter which is conditionally valid, an associated validity parameter;
- an upper and lower limit (or a value for status parameters) or the maximum allowed delta limit
- a Boolean parameter which determines whether the check is applied;
- the sampling interval for the onboard monitoring (i.e. the monitoring interval);
- a repetition filter, specifying the number of times that a parameter shall be registered as failing a check before being reported as such;
- the minimum period between consecutive recurrences before triggering the same event.
- the event identifier of the event generated by the monitoring

OBMF-4. It shall be possible to modify any sub-set of the monitoring information for a parameter (i.e. without having to first delete the parameter and then add it again to the monitoring list).

OBMF-5. It shall be possible to clear (i.e. to reset) the monitoring list.

OBMF-6. It shall be possible to delete any sub-set of parameters from the monitoring list.

OBMF-7. Telemetry event report packets shall be generated whenever a monitored parameter has been detected out-of-limits for the above specified monitoring times.

OBMF-8. The telemetry event report packet shall contain the parameter value and the value of the limit being crossed

OBMF-9. It shall be possible to request a report of the contents of the monitoring list, giving the list of monitored parameters together with their associated validity parameters, check definitions and check selection parameters.

OBMF-10. Moved to CPM-5

3.11 Packet Transmission Control (Service 14)

PTXC-1. It shall be possible to enable and disable the transmission to the ground and/or to another on-board user of selected telemetry source packets. The selection shall be at the level of Application Process ID and shall include the following possibilities: **P**

- all packets;
- specified type(s)/sub-type(s);
- specified housekeeping packets;
- specified diagnostic packets;
- specified report packets.

Note*: such commands will be classified as hazardous.*

PTXC-2. On request each Application Process shall provide status information indicating those packets whose transmission is currently enabled and (where appropriate) the generation frequency.. **P**

3.12 On-Board Storage and Retrieval (Service 15)

Note*: Although the On-Board Storage and Retrieval services are available to all payload instruments, the requirements are only applicable to the spacecraft CDMS.*

OBSR-1. An on-board telemetry storage capability shall be implemented in the CDMS as a single, centralised spacecraft function.

OBSR-2. It shall be possible record on the on-board storage all telemetry packets that are generated on-board , independent of the status of the transmission to ground.

OBSR-2.1 Storage shall be organised in virtual stores called Packet Stores. The selection of which Application ID and which packet type shall be stored in which Packet Store shall be maintainable by means of dedicated telecommands. Any number of different APIDs can be assigned to a specific Packet Store. A specific telemetry packet (identified by APID and packet type) shall only be assigned to a single Packet Store.

OBSR-3. Telemetry shall be stored cyclically (may depend on data type), and configurable to overwrite old data or to stop recording once the store is full.

OBSR-4. The onboard storage capability shall be sufficient to store all packets generated onboard for a duration at least equal to 48 hours plus a TBD margin.

OBSR-5. It shall be possible for the ground to retrieve selected telemetry packets (by Packet Store, Application ID, packet time/Source Sequence Count) from the on-board storage.

Note*: the most obvious use of this functionality will be to dump, at the start of the visibility period, all the event and TC verification packets (and selected housekeeping packets, TBD) with a shorter delay than all other packets.*

OBSR-6. Housekeeping information shall be provided on the state of the onboard storage and retrieval function.

OBSR-7. Information on the used and available space on the onboard storage shall be included in the housekeeping telemetry. In particular, the following information shall be provided:

- a count of the number of packets stored;
- the size in words of the occupied storage;
- the above information shall be available for all subsets of telemetry which can be dumped independently.

OBSR-8. It shall be possible for the ground to enable and disable the storage function for selected packets (all packets, by Packet Store, Application ID, packet type …).

OBSR-9. It shall be possible for the ground (and only the ground) to clear the contents of the onboard storage selectively e.g. by Packet Store, Application ID, packet type, packet time range/Source Sequence Count range.

OBSR-10. The storage of packets shall not be interrupted if the ground requests a retrieval from, or reset of, the onboard storage.

3.13 On-Board Traffic Management (Service 16)

OTFM-1. Deleted.

OTFM-2. Deleted

OTFM-3. The onboard packet distribution system shall generate a report whenever a problem arises with the onboard traffic (e.g. a bottleneck in the distribution of telecommand packets or of telemetry source packets on the packet bus).

OTFM-4. Adequate control capabilities shall be provided to permit the ground to resolve all pre-identified onboard problems relating to onboard traffic.

OTFM-5. Packet bus management and resource parameters, such as average and peak bus loading, numbers of packet retransmissions etc., shall be available to the ground in the housekeeping telemetry.

OTFM-6. Concerning the routing of telecommand and telemetry packets on-board, it shall be possible for the ground to access the routing information (Packet Routing Table, PRT) and to modify it via dedicated telemetry and telecommand packets. No software patching/dumping shall be necessary to modify the baseline packet routing information stored on-board.

OTFM-7. It shall be possible to enable/disable the routing of telecommand packets from a particular source to the destination by means of a dedicated telecommand.

Note: A possible use of this command would be to disable commands from the MTL whilst an instrument or subsystem was being recovered by commanding from the ground.

3.14 In-Flight Testing (Service 17)

FTS-1. An "are you alive" function shall be provided for testing the end-to-end connection between ground and the CDMS and/or any other on-board intelligent user. **P**

***Note**: such function will be implemented as an 'I am alive' function, which is called in response to an 'are you alive' request.*

FTS-2. The connection test between CDMS and on-board intelligent users shall be performed by CDMS. **P**

FTS-3. It shall be possible by the ground to request the initiation of this connection test between CDMS and the on-board intelligent user **P**

3.15 OBCP Management (Service18)

OBCP's will be run by the S/C CDMS system and may be also be run by the instrument processors. .

CPM-1. It shall be possible to control OBCPs , via specific telecommand packets, in the following manner: **PO**

Load an OBCP
start an OBCP;
stop an OBCP;
suspend an OBCP;
resume an OBCP;

CPM-2. It shall be possible to communicate with an OBCP (i.e. pass it parameters or modify variables used by the OBCP) without the need for the ground to first suspend, the OBCP. **PO**

CPM-3. It shall be possible for the ground to inspect the loaded data/control parameters utilised by an OBCP at any time before, during or after the OBCP run. **PO**

CPM-4. It shall be possible for the ground to request a list of all OBCPs stored on-board. **PO**

CPM-5. The CDMS shall provide a mechanism to manage multiple triggering of OBCP s e.g. from the OBMF and MTL.

Note: e.g. to prevent parallel running of the same OBCP and handle a queuing mechanism.

3.16 Event/action service (Service 19)

As an extension to the on-board capability for detecting events and reporting them asynchronously to the ground it is foreseen to be able to define an action that is executed autonomously on-board whenever a given event is detected.

EVNT-1 The CDMS shall be able to respond to an event packet which requires on-board action by issuing a telecommand packet.

Note: this could e.g. initiate an OBCP, a function etc.

EVNT-2 The action shall be conditioned by the event as defined by the source APID and the Event Report Identifier

EVNT-3 The CDMS shall maintain an action list.

It shall be possible to:

- Add events to the action list
- Delete events from the action list
- Enable or disable the action associated with an event
- Clear the action list

EVNT-4 It shall be possible to request a report of the current action list

3.17 Information Distribution CDMS - User (Service 20)

INFO-1.	The CDMS software shall be able to exchange with every on-board intelligent user a set of information packets defined as dedicated subtypes of this service (covering, e.g. attitude data).	**PO**
INFO-2.	The information distribution shall be controlled by CDMS only.	**PO**
INFO-3.	The information to be distributed shall be obtained either from internal CDMS data or from TM produced by other on-board users (e.g. via Service 5 or Service 3 TM packets received by the CDMS).	**PO**
INFO-4.	It shall be possible to enable/disable the information distribution of specific subtypes to/from specific users by means of a dedicated telecommand.	**PO**

3.18 Science Data Transfer (Service 21)

SCI-1.	It shall be possible to enable/disable science data generation from any user by APID of the science telemetry packet.	**P**

3.19 Context Saving (Service 22)

CONT-1.	The CDMS software shall provide to every on-board intelligent user a Context Saving service, i.e. the capability to store and retrieve software parameters on request by the user.	**PO**
CONT-2.	It shall be possible for the ground to inspect at any time during the mission the contents of the Context Saving memory areas.	**PO**

4. OPERATIONS DATA

This section defines the requirements on delivery schedule and content of the Spacecraft Users Manual, the Spacecraft Database and the Flight Dynamics Database and the delivery of the On-board software to ESA.

4.1 Satellite Users Manual

4.1.1 Introduction

The Users Manual is the prime source of information used by ESA for establishment of the ground facilities needed to support the mission, and needed to correctly and reliably perform all mission operations. In this respect, the document must provide a clear, concise and comprehensive definition of all design, interface and, most importantly, all operational characteristics associated with control of the spacecraft in flight.

The document shall consist of five parts :

- Mission definition
- System definition
- Subsystem definition
- Instrument definition (to be provided by PIs)
- A set of Annexes

> In simple terms the Users Manual must address the following aspects of the spacecraft and its design :
>
> - What it is
> - What it has to do
> - How it works
> - How to operate it
> - What to do if it doesn't go according to plan

4.1.2 Content Requirements

FUMC-1 The Satellite Users Manual (SUM) shall provide all technical information necessary to permit ESA to

- Prepare and validate the ground segment
- Operate and control the spacecraft in nominal and contingency cases.

FUMC-2 The contents of the SUM shall be internally consistent.

FUMC-3 The content of the SUM shall be consistent with the Satellite Database and indicate to which version it relates.

FUMC-4 The content of the SUM shall be consistent with the Flight Dynamics Database and indicate to which version it relates.

FUMC-5 The content of the SUM shall be consistent with all major releases of the on-board software and indicate to which versions (for each subsystem/instrument) it relates.

FUMC-6 The content of the SUM shall comply with the requirements of Annex 1.

FUMC-7 The procedures presented in the SUM shall be validated at S/C system and subsystem level testing.

FUMC-8 The SUM shall be used by the contractor as a reference document during the AIV programme.

4.1.3 Delivery Requirements

FUMD-1 Issue 0 of the SUM is required at the end of Phase B, in time for Industry preparation of system and subsystem test procedures. This issue shall contain draft design information and skeleton procedures.

FUMD-2 Issue 1 of the SUM is required at L-36 months. This issue shall contain a preliminary Mission Description, System and subsystem Sections and preliminary design information.

FUMD-3 Issue 2 is required at L-24 months. This issue shall contain all the design information, draft nominal operating procedures (no contingency analysis or procedures are expected at this stage).

FUMD-4 Issue 3 is required at L-15 months. This issue shall contain all nominal and contingency procedures. The annexes shall be supplied in draft form.

FUMD-5 Issue 4 is required at L-9 months. This is the final version of the Users Manual; all sections and annexes shall reflect the latest state of knowledge of the Flight spacecraft, such that only minor updating is needed subsequently.

FUMD-6 The Users Manual shall be placed under configuration control at Issue 2 above. Subsequent to Issue 4, any updates to the Users Manual shall be issued as page changes as and when they arise.

FUMD-7 The User Manual shall be delivered in hard copy and in an agreed electronic format

FUMD-8 It shall be possible to view the User Manual through a Hypertext medium.

4.2 Satellite Database

4.2.1 Content Requirements

SDBC-1 The satellite prime contractor and instrument developers shall deliver a Satellite Database (SDB) containing a complete definition of all telemetry and telecommand data, command sequences, software parameters and commands for the satellite subsystems and instruments. The latter shall be provided by the PIs.

SDBC-2 The SDB shall be a single common database used for satellite system engineering, AIV and operations purposes.

SDBC-3 The SDB shall contain information relevant to both ground check out and in orbit operations, clearly identified.

SDBC-4 The content of the SDB shall comply with requirements of Annex 2 covering both the physical and the operational characteristics of the data.

SDBC-5 The contents of the SDB shall be internally consistent

SDBC-6 The contents of the SDB shall be consistent with the FDDB

SDBC-7 The contents of the SDB shall be consistent with all on-board software (subsystems and instruments)

SDBC-8 All updates to the SDB shall be automatically recorded in a Configuration Control Record down to field level.

SDBC-9 The SDB shall include definitions to write and read parameter values to and from on-board RAM.

SDBC-10 The SDB shall be validated by the Prime Contractor at both system and subsystem level.

SDBC-11 The SDB shall not contain irrelevant data.

SDBC-12 The SDB shall not contain duplications.

4.2.2 Delivery Requirements

SDBD-1 At least four deliveries plus an update of the SDB are required as follows :

- Version 0 of the SDB to be compatible with instruments AVM delivery (currently March '2003)
- Version 1 - Required by L-36 months
- Version 2 - Required at L-24 months.
- Version 3 - Required one month before SVT 1. This version shall be complete and contain all flight values.
- Version 4 - Required one month before SVT 2.
- Pre-Launch Update - Required at L-1 month. This version shall contain the final updates to the flight values.

SDBD-2 Each delivery of the SDB shall be accompanied by a Configuration Control File showing changes down to field level.

SDBD-3 Each delivery of the SDB shall include satellite version information:

- identification of the spacecraft build standard (EQM or PFM)
- full definition of the satellite build for all subsystems and instruments
- all characteristics of main, redundant and spare units, where different.

SDBD-4 Each delivery of the SDB shall contain on-board software version information (for all on-board processors) including

- the version of the AOCS on-board software to which it relates
- the version of the Star Tracker on-board software to which it relates
- the version of the CDMS on-board software to which it relates
- the versions of the instrument on-board software to which it relates

SDBD-5 The SDB shall be delivered in a set of ORACLE data files (TBC)

SDBD-6 It shall be possible to deliver/transfer the SDB by digital means to an agreed standard file format.

4.3 Flight Dynamics Database

4.3.1 Content Requirements

FDDC-1 The satellite prime contractor shall deliver a Flight Dynamics Database (FDDB) containing all information needed to establish the ground Flight Dynamics System

FDDC-2 The FDDB shall contain information relevant to both ground check out and in orbit operations, clearly identified.

FDDC-3 The content of the FDDB shall comply with requirements of Annex 3 covering both the physical and the operational characteristics of the data.

FDDC-4 The contents of the FDDB shall be internally consistent

FDDC-5 The contents of the FDDB shall be consistent with the SDB

FDDC-6 The contents of the FDDB shall be consistent with all related on-board software including AOCS, Star Tracker and CDMS.

FDDC-7 All updates to the FDDB shall be automatically recorded in a Configuration Control Record down to field level.

4.3.2 Delivery Requirements

FDDD-1 At least three deliveries plus an update of the FDDB are required as follows :

- Version 1 - Required at end of phase B
- Version 2 - Required at L-24 months.
- Version 3 - Required one month before SVT 1. This version shall be complete and contain all flight values.
- Version 4 - Required one month before SVT 2.
- Pre-Launch Update - Required at L-1 month. This version shall contain the final updates to the flight values.

FDDD-2 Each delivery of the FDDB shall be accompanied by a Configuration Control File showing changes down to field level.

FDDD-3 Each delivery of the FDDB shall include satellite version information

- identification of the spacecraft build standard (EQM or PFM)
- full definition of the satellite build for all AOCS and RCS units
- all characteristics of main, redundant and spare units, where different.

FDDD-4 Each delivery of the FDDB shall contain database and on-board software version information including

- the version of the SDB to which it relates
- the version of the AOCS on-board software to which it relates
- the version of the Star Tracker on-board software to which it relates
- the version of the CDMS on-board software to which it relates

FDDD-5 The FDDB shall be delivered in a set of ORACLE data files (TBC).

FDDD-6 It shall be possible to deliver/transfer the FDDB by digital means to an agreed file format.

4.4 On-Board Software

4.4.1 Content Requirements

OBSC-1 The satellite prime contractor shall deliver all on-board software (except instrument on-board software, which is PI provided) including

- AOCS software
- CDMS software
- Star Tracker software

OBSC-2 The satellite prime contractor shall deliver the on-board software in the following form:

- Complete Source Code
- Target Processor Executable Image
- Link Cross-reference listings (with reference to target environment memory maps)

4.4.2 Delivery Requirements

OBSD-1 The On-board software shall be delivered in machine readable form in accordance with an ICD agreed with ESA

OBSD-2 All releases of the on-board software shall be delivered as they become available

OBSD-3 All releases of the on-board software shall be accompanied by configuration control information including

- Version Number
  - Release date
  - Changes record
  - All SPRs closed by the new release

ANNEX A1 : SPACECRAFT USERS MANUAL CONTENTS

This annex is derived directly from the example of the XMM mission, and therefore the detailed contents still need some adaptation work to the FIRST/Planck characteristics, which will be done in the future issues of the document. For the moment the annex should be used to indicate the type of information required in each of the relevant deliverable products.

A1 Users Manual Content

A.1.0 The Users Manual shall consist of five sections in several volumes as follows :

- Introduction and Mission Definition
- System Definition
- Subsystem Definitions
- *Instrument Definitions (to be provided by PIs to ESA)*
- A set of Annexes providing all necessary supporting data

A.1.1 The Introduction and Mission Definition section shall include the following information, using the given paragraph numbering scheme :

i) Configuration Control for the whole Users Manual
ii) Table of Contents
iii) Glossary of Terms
iv) List of Abbreviations
1.0 Mission Definition
1.1 The mission description
1.2 The mission requirements and constraints
1.3 The mission phases and their purpose
1.4 The mission control concept

A.1.2 The System Definition section shall include the following information, using the given paragraph numbering scheme :

2.0 System Definition

2.1 The system level description of the spacecraft, showing the definition of the subsystems, the distribution of functions and the interfaces between them

2.2 The high-level instrument description including the objectives and descriptions of the instruments, descriptions of the interfaces to the spacecraft and telemetry downlink rate for each instrument

2.3 The system level configurations in the different mission phases (launch, separation, solar panel deployment etc), definition of the reference systems, the functional block diagram and configuration drawings of the spacecraft, instruments and equipment layouts

2.4 The system budgets including

- mass
- mass properties
- unit power consumption for all operational modes
- power available in different mission phases
- thermal budget
- RF link budget
- telemetry budget
- telecommand budget
- data budget
- memory budget
- timing budget (including ground part)
- propellant budget,
- pointing budget (including error apportionment)
- alignment budget
- reliability budget

A.1.3 The System Definition section shall further include the following for all spacecraft systems using the given paragraph numbering scheme:

3.0 System Level Operations

3.1 The baseline LEOP event Time line covering each operational action in the sequence of operations from spacecraft separation until achievement of the final configuration needed to commence mission operations

3.2 The baseline event Time line for all activities in the spacecraft verification and calibration phase including the activities involving the instruments

3.3 The baseline event Time line for daily activities including pre-pass preparations, spacecraft checks at signal acquisition, star tracker operations, nominal science operations, eclipse operations, manoeuvre preparations and executions, orbit manoeuvres, subsystem configurations and end of pass activities.

Note : All timelines shall include identification of the constraints associated with the sequence of activities, the rationale behind establishment of the chosen sequence, absolute timing, relative timing and all logical interrelationships between operations in the sequence.

3.4 The definition of system level autonomy provisions and fault management features

3.5 The definition of potential mission or system level failures at each milestone in the timelines for each mission phase and the necessary recovery actions (including time criticality in relation to each of the timelines/activity sequences given)

3.6 Summary of all nominal and back-up system level modes, including purpose, subsystem status in the mode, operational constraints and when used.

3.7 Summary of all nominal and back-up instrument operational modes, including purpose, when used, operational constraints, resources required and downlink data available.

A1.4. The Subsystem Definition section shall include the following for all spacecraft subsystems using the given paragraph numbering scheme:

4.0 Subsystem Definition

Note : Each subsystem shall be handled as follows (where X is the subsystem number) :

4.X Subsystem X

4.X.1 Subsystem Description, including functional objectives, design description and operating principles

4.X.2 Subsystem Configuration, including hierarchical configuration, physical configuration

4.X.3 Subsystem Functions including functional configuration, functional description, functional block diagram, a switching diagram showing the location of the telemetry outputs and telecommand inputs and logic and circuit diagrams;.

4.X.4 Subsystem Performance including all performance data

4.X.5 Subsystem Operations Modes including

4.X.5.1 A summary of all nominal and back-up modes, their purpose, conditions when they are used and a mode transition diagram.

4.X.5.2 For each mode a detailed description including :

- the pre-requisites needed
- the resources needed
- the operational constraints
- mode transition operations
- unit status in each mode
- subsystem monitoring in the mode

4.X.6 Subsystem Interfaces including

4.X.6.1 External interfaces, including power, data, control, mechanical, thermal, optical

4.X.6.2 Internal interfaces (between units making up the subsystem) including power, data, control, mechanical and thermal

4.X.7 Subsystem Failures including

4.X.7.1 Subsystem fault management and redundancy provisions

4.X.7.2 Subsystem failures, how they are identified and the necessary recovery actions (including time criticality in each mode)

4.X.8 Subsystem On-board Software including

4.X.8.1 Functional description including software task definitions, purpose, actions performed, inputs and outputs for each task, task control and scheduling information, synchronisation and datation information and software flow diagrams.

4.X.8.2 Subsystem on-board software physical description including ROM/RAM descriptions and memory area definitions

4.X.8.3 Subsystem on-board software operations including task monitoring, task control and error handling

4.X.9 Subsystem Operations Procedures (nominal and contingency) including

- purpose
- constraints on use
- time criticality
- system level pre-requisites
- subsystem level pre-requisites
- telemetry parameters to be monitored
- special processing needed to interpret the telemetry
- values expected (raw and engineering)
- commands to be executed
- command parameters needed
- definition of calculations needed to prepare command parameters
- timing between steps in the procedures
- reference to recovery action at each step

4.X.10 Summary of Subsystem Telemetry and Telecommand Data including

4.X.10.1 Summary of Telecommand Packets including

- Master Function Number, packet type and subtype, and purpose
- Summary contents

4.X.10.2 Summary of Telecommand Parameters including

- List of telecommand parameter reference numbers
- The parameter names
- The associated parameter identification number
- The list of telecommand packets in which each parameters may be uplinked

4.X.10.3 Summary of Telemetry Packets including

- Packet Number, type and subtype and purpose
- Generation situations and rate,
- Summary contents

4.X.10.4 Summary of Telemetry Parameters including

- List of telemetry parameter reference numbers
- The parameter names
- The associated parameter identification number
- The list of telemetry packets in which each telemetry parameter may be downlinked
- The telecommand master function directly influencing each parameter

4.X.10.5 Summary of Software Parameters including

- List of software parameter reference numbers
- The parameter names
- The associated parameter identification number
- The associated software parameter mnemonic (where applicable)
- The list of telecommand packets in which each software parameter may be uplinked
- The list of telemetry packets in which each software parameter may be downlinked

4.X.11 Subsystem Budgets including

- power
- data
- mass
- error and alignment
- timing

A1.5 ***The Instrument Definition section (to be delivered by the PIs to ESA)*** *shall include the following for all instruments using the given paragraph numbering scheme:*

5.0 Instrument Definition

Note : Each instrument shall be handled as follows (where X is the instrument number):

5.X Instrument X

5.X.1 Instrument Description, including functional objectives, design description and operating principles

5.X.2 Instrument Configuration, including hierarchical configuration, physical configuration

5.X.3 Instrument Functions including functional configuration, functional description, functional block diagram, a switching diagram showing the location of the telemetry outputs and telecommand inputs and logic and circuit diagrams;

5.X.4 Instrument Performance including all performance data

5.X.5 Instrument Operations Modes including

5.X.5.1 A summary of all nominal and back-up modes, their purpose, conditions when they are used and a mode transition diagram.

5.X.5.2 For each mode a detailed description including :

- *the pre-requisites needed*
- *the resources needed*
- *the operational constraints*
- *mode transition operations*
- *unit status in each mode*
- *instrument monitoring in the mode*

5.X.6 Instrument Interfaces including

5.X.6.1 External interfaces, including power, data, control, mechanical, thermal, optical

5.X.6.2 Internal interfaces (between units making up the instrument) including power, data, control, mechanical and thermal

5.X.7 Instrument Failures including

5.X.7.1 Instrument fault management and redundancy provisions

5.X.7.2 Instrument failures, how they are identified and the necessary recovery actions (including time criticality in each mode)

5.X.8 Instrument On-board Software including

5.X.8.1 Functional description including software task definitions, purpose, actions performed, inputs and outputs for each task, task control and scheduling information, synchronisation and datation information and software flow diagrams.

5.X.8.2 Instrument on-board software physical description including ROM/RAM descriptions and memory area definitions

5.X.8.3 Instrument on-board software operations including task monitoring, task control and error handling

5.X.9 Instrument Operations Procedures (nominal and contingency) including

- *purpose*
- *constraints on use*
- *time criticality*
- *system level pre-requisites*
- *instrument level pre-requisites*
- *telemetry parameters to be monitored*
- *special processing needed to interpret the telemetry*
- *values expected (raw and engineering)*
- *commands to be executed*
- *command parameters needed*
- *definition of calculations needed to prepare command parameters*
- *timing between steps in the procedures*
- *reference to recovery action at each step*

5.X.10 Summary of Instrument Telemetry and Telecommand Data including

5.X.10.1 Summary of Telecommand Packets including

- *Master Function Number, packet type and subtype, and purpose*
- *Summary contents*

5.X.10.2 Summary of Telecommand Parameters including

- *List of telecommand parameter reference numbers*
- *The parameter names*
- *The associated parameter identification number*
- *The list of telecommand packets in which each parameters may be uplinked*

5.X.10.3 Summary of Telemetry Packets including

- *Packet Number, type and subtype and purpose*
- *Generation situations and rate,*
- *Summary contents*

5.X.10.4 Summary of Telemetry Parameters including

- *List of telemetry parameter reference numbers*
- *The parameter names*
- *The associated parameter identification number*

- *The list of telemetry packets in which each telemetry parameter may be downlinked*
- *The telecommand master function directly influencing each parameter*

5.X.10.5 Summary of Software Parameters including

- *List of software parameter reference numbers*
- *The parameter names*
- *The associated parameter identification number*
- *The associated software parameter mnemonic (where applicable)*
- *The list of telecommand packets in which each software parameter may be uplinked*
- *The list of telemetry packets in which each software parameter may be downlinked*

5.X.11 Instrument Budgets including

- *power*
- *data*
- *mass*
- *error and alignment*
- *timing*

5.X.12 Instrument Science Data Definition including

- *The sensor output data available, when generated, content and rate for each operational mode*
- *The processing performed on the sensor data, algorithms used, filtering and selection/rejection criteria*
- *The processing required on the ground*

A1.6 The Users Manual shall consist of the following set of Annexes containing supporting operational data :

Appendix 1 Spacecraft Build Standard

- Provide a table defining the build standard of the Flight Model Spacecraft.
- Provide a table defining the software configuration for each subsystem and instrument

Appendix 2 Unit and Subsystem Mass Properties

- Provide mass properties on unit and subsystem level.

Appendix 3 Power Subsystem Data

- Provide tables of solar array output power generation dependant on temperature.
- Provide tables of battery characteristics charge and discharge characteristics dependant on temperature.

Appendix 4 Unit Power Consumptions

- Provide tables of power consumption for all spacecraft units in all their identified modes of operations.

Appendix 5 Thermal Predictions

- Provide tables and graphs showing the expected thermal behaviour of the spacecraft for normal and for worst case conditions (cold and hot cases)
- Provide the results of the ground thermal tests.

Appendix 6 RF Data

- Provide polar diagrams of the antenna pattern for each on-board antenna (including holes)
- Provide full transponder characteristics (nominal frequencies and temperature dependencies)
- Provide RF link budgets for all operational modes and mission phases.
- Provide location of each antenna in spacecraft body axes.

Appendix 7 Ranging Calibration Data

- Provide the results of the ranging calibration tests, including performance characteristics, system delay measurements and stability.

Appendix 8 System Level Failure and Contingency Analysis

- Provide a system level Failure Modes, Effects and Criticality Analysis (FMECA) In relation to the mission timelines, identify all the failures that can occur, how they can be identified and what recovery action is proposed
- Provide a Fault Tree Analysis (FTA) identifying all potential system level failures
- Provide the list of all single point failures

Appendix 9 Subsystem On-Board Software

- Provide a breakdown of each subsystem memory showing RAM and ROM address areas, areas allocated for program code, buffer space and working parameters (e.g. content of protected memory)
- Provide a word by word listing of program code
- Provide a word by word listing of all software data areas (referencing the software parameter reference number, and mnemonics)
- Provide on-board Software Development Environment description (SDE) and SDE Users Manual
- Provide on-board Software Validation Facility (SVF) description and SVF Users Manual

Appendix 10 Spacecraft Configuration Drawings

- Provide drawings of spacecraft configurations on system, subsystem and unit level.

ANNEX A2: SPACECRAFT DATABASE CONTENTS

A2.1. Spacecraft Database

A2.1.1. The Spacecraft Database shall consist of the following files

- Configuration Control File describing the SDB version and the changes made since the last release
- Spacecraft Configuration File containing spacecraft version information
- Telecommand Packet File describing all telecommand packets and their functions
- Telecommand Parameter File describing all uplinkable parameters
- Telemetry Packet File describing all telemetry packets
- Telemetry Parameter File describing all downlinkable telemetry parameters
- Software Parameter File describing all parameters resident in on-board memory (applicable to telecommand or telemetry packets or both)
- Parameter Calibration File describing parameter engineering conversions
- Parameter Alias File describing parameter interpretation conversions
- Telecommand Sequence File describing all check-out telecommand sequences and parameters

A2.2. Configuration Control File

The Configuration Control File shall contain the following information :

A2.2.1. SDB Version Number

A2.2.2. Date of SDB release to ESA

A2.2.3. Version Number of every File making up the SDB

A2.2.4. Configuration Change Tables for all Files making up the SDB, identifying

- the files updated
- the records updated within the file, referenced by e.g. parameter reference, telecommand number, calibration curve number etc., as appropriate
- the fields updated within the records (for all files)
- the old and the new values

- the date the field was changed
- the initials of the person who made the change

A2.3. Spacecraft Configuration File

The Spacecraft Configuration File shall contain the following information

A2.3.1. Spacecraft Configuration Tables identifying the spacecraft configuration to which the SDB applies, including :

- Spacecraft Model (EQM, PFM)
- Spacecraft build standard identifying the main and redundant units within the subsystems and instruments.

A2.3.2. The Spacecraft On-Board Software Configuration Table indicating the version numbers of all subsystem and instrument on-board software to which the SDB applies.

A2.4. Telecommand Packet File

A2.4.1. The Telecommand Packet File shall provide a complete list and definition of all distinct telecommand packets. These telecommand packets may either be sent from the ground to the spacecraft subsystems and instruments or can be generated by on-board applications. For each packet, the information in the following requirements shall be provided

A2.4.2. Master Function Number being the functional identification number allocated uniquely to the particular function associated with a particular definition of any telecommand packet.

A2.4.3. Application Identifier for the application to which the telecommand packet is to be routed

A2.4.4. Telecommand Destination being the subsystem and the unit upon which the telecommand acts.

A2.4.5. Telecommand Packet Name (Short Description)

A2.4.6. Telecommand Functional Description (Long Description)

A2.4.7. Command category indicating whether the telecommand function is

- hazardous

- vital
- normal

A2.4.8. Telecommand Packet Type and Sub-Type

A2.4.9. For CPDU Telecommand Packets (not having Type and Sub-type information) provide the CPDU Output Line and Pulse Duration.

A2.4.10. For Telecommand Packet Type TC (4,X), provide the Task Identifier (TID) and the Function Identifier (FID)

A2.4.11. Give a complete definition of the structure of the packet including

- The list of all Telecommand Parameters (by Parameter Reference Number) within the packet
- The list of all Software Parameters (by Software Parameter Reference Number) within the packet
- The byte number and start bit of the first bit of every Telecommand Parameter and every Software Parameter in the packet.
- The location of any fixed bits within the packet not represented by Telecommand or Software Parameters
- the value for these fixed bits, in decimal

Note : The following bit-numbering convention shall apply:

  - the most significant bit (MSB) of any command word is the bit sent first in time;
  - the MSB shall be called bit 0 and the LSB shall be called bit n-1 for an n-bit command field.

A2.4.12. For each Telecommand Parameter in the list, provide the following parameter value information:

- Flag indicating that the parameter must either have a fixed value or may be variable
- Allowable range that the parameter may take in this telecommand packet
- Default value/status
- Illegal values for the parameter in this packet

A2.4.13. Operational Constraints for each Telecommand Packet, namely the conditions under which the packet is allowed to be uplinked (in the form of an algorithm utilising telemetry parameters having defined values)

A2.4.14. For each Telecommand Parameter in the list, provide the following end-effect verification information :

- The Telemetry Parameter (by Parameter Reference Number) providing end effect verification
- The value the Telemetry Parameter will take after execution of the Telecommand Packet

A2.4.15. Verification Timing Information for each Telecommand Packet, including

- the elapsed time between receipt of the last bit of the telecommand packet and the release of the TC Acceptance Telemetry Packet.
- the elapsed time between the release of the TC Acceptance Packet and the release of the TC Execution Telemetry Packet
- the elapsed time between the release of the TC Execution Telemetry Packet and the moment the end-effect Telemetry Parameter acquires the defined value.

A2.4.16. For each Telecommand Packet, provide information on related Telecommand Packets including :

- Telecommand Packet which must precede this one (if any)
- Telecommand Packet which must follow this one (if any)
- Telecommand Packet having the same effect (alternative) (if any)
- Telecommand Packet having the same effect (redundant) (if any)
- Telecommand Packet having the reverse effect (complementary) (if any)

A2.4.17. All supplementary information required by the ground to construct the packet.

A2.5. Telecommand Parameter File

A2.5.1. The Telecommand Parameter File shall provide a complete list and definition of all telecommand parameters which are to be transported within the defined telecommand packets to the spacecraft subsystems and instruments.

A2.5.2. The Telecommand Parameter File shall contain ALL parameters that can ever be included in telecommand packets, including parameters resident in on-board software. For each parameter, the information in the following requirements shall be provided.

A2.5.3. Telecommand Parameter Reference Number (PREF) being the ground identification number for the telecommand parameter.

A2.5.4. Telecommand Parameter Identification Number (PID) being the on-board identification number for the telecommand parameter (for example as represented in the on-board software listings).

Note : The relationship between the PREF and the PID is explained in Annex 4.

A2.5.5. Telecommand Parameter Type Code (PTC) and Telecommand Parameter Format Code (PFC) defining the field size and format of the telecommand parameter.

A2.5.6. The Memory Identifier and Absolute Address of the first bit of this parameter in memory (for parameters which are to be written into RAM).

A2.5.7. Telecommand Parameter Units being the engineering units in which the value of the parameter is expressed (where applicable).

A2.5.8. Flag indicating whether the telecommand parameter must always be fixed (for example for mathematical constants) or whether the parameter may take a variable value.

A2.5.9. Telecommand Parameter Default Value (for fixed or variable parameters) (if applicable) (in engineering units).

A2.5.10. Telecommand Parameter Range being the maximum and minimum allowable values for the telecommand parameter (in engineering units).

A2.5.11. Parameter Calibration Data Reference Number being the reference to an entry in the Calibration Data File containing the applicable calibration data.

A2.5.12. Parameter Alias Reference Number being the reference to an entry in the Alias Data File containing numerical or text string interpretational data.

A2.5.13. A complete list of Telecommand Packets in which this Telecommand Parameter may be uplinked (identified by Master Function Number).

A2.6. Telemetry Packet File

A2.6.1. The Telemetry Packet File shall provide a complete list and definition of all telemetry packets which can be generated by the spacecraft subsystems and instruments. For each packet, the information in the following requirements shall be provided.

A2.6.2. Telemetry Packet Number (TPN) being the ground identification number allocated to the different telemetry packet definitions.

A2.6.3. Application Identifier for the application responsible for generation of the telemetry packet.

A2.6.4. Telemetry Packet Source being the spacecraft subsystem unit or instrument unit whose data is contained in the telemetry packet.

A2.6.5. Telemetry Packet Name (Short Description)

A2.6.6. Telemetry Packet Functional Description (Long Description)

A2.6.7. Telemetry Packet Type and Sub-Type

A2.6.8. Telemetry Packet Structure Identifier (SID) (where applicable) defining different structures of the same generic telemetry packet type and subtype.

A2.6.9. A complete definition of the structure of the packet including

- The List of Telemetry Parameters (by Parameter Reference Number) downlinked in this telemetry packet
- The List of Software Parameters (by Software Parameter Reference Number) downlinked in this telemetry packet
- The time offset of the on-board sampling of the (first occurrence of) the Telemetry Parameter from the time-tag in the Telemetry Packet Header for each Telemetry Parameter and for each Software Parameter
- The location and interpretation of any fixed bits within the packet not represented by Telemetry Parameters
- The value for these fixed bits, in decimal
- Note : The following bit-numbering convention shall apply:
    - the most significant bit (MSB) of any command word is the bit sent first in time;
    - the MSB shall be called bit 0 and the LSB shall be called bit n-1 for an n-bit parameter field.

A2.6.10. Packet Generation interval (for Periodic packets)

A2.6.11. Operational conditions when generation of this telemetry packet is possible including

- Mission Phase

- Spacecraft Mode
- Subsystem or Instrument Mode

A2.6.12. Operational conditions causing the generation of this telemetry packet (for non-periodic packet types TM (4,x)) including

- Event causing the generation
- Exception causing generation
- Major Anomaly causing generation

A2.6.13. The list of Telecommand Packet Master Functions which when executed, cause generation of this telemetry packet

A2.6.14. The elapsed time between receipt of the Telecommand Packet and generation of the related Telemetry Packet

A2.6.15. Other Telemetry Packets (by Number) which are not available when this telemetry packet is generated (if any).

A2.6.16. Other Telemetry Packets (by Number) which when generated, preclude generation of this telemetry packet.

A2.6.17. All supplementary information required by the ground to construct the packet.

A2.7. Telemetry Parameter File

A2.7.1. The Telemetry Parameter File shall provide a complete list and definition of all telemetry parameters which are to be transported within the defined telemetry packets.

A2.7.2. The Telemetry Parameter File shall contain ALL parameters that can ever be included in telemetry packets, including parameters resident in on-board software. For each parameter, the information in the following requirements shall be provided.

A2.7.3. Telemetry Parameter Reference Number (PREF) being the ground identification number for the telemetry parameter.

A2.7.4. Telemetry Parameter Identification Number (PID) being the on-board identification number for the telemetry parameter (for example as represented in the on-board software listings).

Note : The relationship between the PREF and the PID is explained in Annex 4.

A2.7.5. The RTU Address and any other hardware channel identifier pertaining to the telemetry parameter (if applicable).

A2.7.6. Telemetry Parameter Type Code (PTC) and Telemetry Parameter Format Code (PFC) defining the field size and format of the telemetry parameter.

A2.7.7. Telemetry Parameter Units being the engineering units in which the value of the parameter is expressed (where applicable).

A2.7.8. Flag indicating whether the telemetry parameter must always be fixed (for example for mathematical constants) or whether the parameter may take a variable value.

A2.7.9. Telemetry Parameter Default Value (for fixed or variable parameters) (if applicable)(in engineering units).

A2.7.10. Telemetry Parameter Range being the maximum and minimum allowable values for the telemetry parameter (in engineering units).

A2.7.11. Parameter Calibration Data Reference being the reference to an entry in the Parameter Calibration Data File containing calibration data.

A2.7.12. If more than one Calibration Data Set is required to cover different but exclusive operational modes, then up to 4 different Parameter Calibration Data References may be given, along with

- The Mode Definition (in terms of an algorithm defined using telemetry parameters as inputs)
- The value resulting from the algorithm for each of the Parameter Calibration References

A2.7.13. Parameter Alias Reference Number being the reference to an entry in the Parameter Alias File containing numerical or text string interpretation data.

A2.7.14. If more than one Alias Definition Table is required to cover different but exclusive operational modes, then up to 4 different Parameter Alias Reference Numbers may be given, along with

- The Mode Definition (in terms of an algorithm defined using telemetry parameters)
- The value resulting from the algorithm for each of the Parameter Alias Reference Numbers

A2.7.15. Telemetry Parameter Validity information including

- The operational mode (spacecraft, subsystem or instrument) in which this parameter may be valid
- The Validity Parameter which must be used to determine the validity of this parameter
- The value that the Validity Parameter must have if the parameter is to be considered as valid

A2.7.16. Telemetry Monitoring information including

- Flag indicating that when valid, the parameter will either have a fixed value or may be variable
- Flag indicating if the parameter is directly influenced by a telecommand

A2.7.17. Associated Telecommand identifying the Telecommand Master Function Number which directly influences the telemetry parameter.

A2.7.18. Fixed Check information including

- Fixed Check Selector defining the mode (mission or spacecraft or subsystem or instrument) in which each of the identified Fixed Checks is to be used

Note : Fixed Check applicable to check out shall be identified using the Fixed check selector

- The value of the different Fixed Checks (in engineering values) for the parameter

Note : Only one Fixed Check may be valid at any time

A2.7.19. Limit Set information including

- Limit Set Selector defining the mode (mission or spacecraft or subsystem or instrument) in which each of the identified Limit Sets is to be used

Note : Limit Sets applicable to check out shall be identified using the selector

- Upper and Lower Warning Limit Sets (in engineering values) for the parameter
- Upper and Lower Alarm Limit Sets (in engineering units) for the parameter

Note : Only one Warning and Alarm Limit Set may be valid at any time

A2.7.20. Illegal values for the parameter (if any) (in engineering units)

A2.7.21. For each Telemetry Parameter, provide information on related Telemetry Parameters including :

- Telemetry Parameter providing exactly the same information (alternative) (if any)

- Telemetry Parameter providing exactly the same information (redundant) (if any)

A2.7.22. A complete list of Telemetry Packets in which this Telemetry Parameter may be found (identified by Telemetry Packet Number).

A2.8. Software Parameter File

A2.8.1. The Software Parameter File shall provide a complete list and definition of ALL fixed and variable parameters resident in on-board memory which can be transported within telecommand or telemetry packets at any time in the mission. For each parameter, the information in the following requirements shall be provided.

A2.8.2. Software Parameter Reference Number (PREF) being the ground identification number for the software parameter.

A2.8.3. Software Parameter Identification Number (PID) being the on-board identification number for the software parameter (for example as represented on-board).

Note : The relationship between the PREF and the PID is explained in Annex 4.

A2.8.4. Software Parameter Mnemonic (if applicable) (MNEM) being the mnemonic used to identify the software parameter in software specifications (only).

Note : The Mnemonic shall NOT be used as an identification

- in test or operations procedures or
- in ground systems for check out or flight operations

A2.8.5. The Memory Identifier and Absolute Address of the first bit of this parameter in memory (for parameters which are read from ROM or RAM).

A2.8.6. Software Parameter Type Code (PTC) and Software Parameter Format Code (PFC) defining the field size and format of the software parameter.

A2.8.7. Software Parameter Units being the engineering units in which the value of the parameter is expressed (where applicable).

A2.8.8. Flag indicating whether the telecommand parameter must always be fixed (for example for mathematical constants) or whether the parameter may be take a variable value.

A2.8.9. Software Parameter Default Value (for fixed or variable parameters) (if applicable)(in engineering units) (applicable to both uplink and downlink).

A2.8.10. Software Parameter Range being the maximum and minimum allowable values for the software parameter (in engineering units)(applicable to both uplink and downlink).

A2.8.11. Parameter Calibration Data Reference being the reference to an entry in the Parameter Calibration Data File containing calibration data (applicable to both uplink and downlink).

A2.8.12. If more than one Calibration Data Set is required to cover different but exclusive operational modes, then up to 4 different Parameter Calibration Data References may be given, along with

- The Mode Definition (in terms of an algorithm defined using software parameters as inputs)
- The value resulting from the algorithm for each of the Parameter Calibration References

A2.8.13. Parameter Alias Reference Number being the reference to an entry in the Parameter Alias File containing numerical or text string interpretation data (applicable to both uplink and downlink).

A2.8.14. If more than one Alias Definition Table is required to cover different but exclusive operational modes, then up to 4 different Parameter Alias Reference Numbers may be given, along with

- The Mode Definition (in terms of an algorithm defined using telemetry parameters)
- The value resulting from the algorithm for each of the Parameter Alias Reference Numbers

A2.8.15. Software Parameter Validity information including

- The operational mode (spacecraft, subsystem or instrument) in which this parameter may be valid (applicable to both uplink and downlink)
- The Validity Parameter which must be used to determine the validity of this parameter (if applicable)
- The value that the Validity Parameter must have if the parameter is to be considered as valid

A2.8.16. Software Monitoring information including

- Flag indicating that when valid, the parameter will either always have a fixed value or may be variable (applicable to both uplink and downlink)

- Flag indicating if the parameter is directly influenced by a telecommand (other than a telecommand containing the software parameter value itself).

A2.8.17. Associated Telecommand identifying the Telecommand Master Function Number which directly influences the software parameter (if applicable).

A2.8.18. Fixed Check information including (if applicable)

- Fixed Check Selector defining the mode (mission or spacecraft or subsystem or instrument) in which each of the identified Fixed Checks is to be used

Note : Fixed Check applicable to check out shall be identified using the Fixed check selector

- The value of the different Fixed Checks (in engineering values) for the parameter

Note : Only one Fixed Check may be valid at any time

A2.8.19. Limit Set information including (if applicable)

- Limit Set Selector defining the mode (mission or spacecraft or subsystem or instrument) in which each of the identified Limit Sets is to be used

Note : Limit Sets applicable to check out shall be identified using the selector

- Upper and Lower Warning Limit Sets (in engineering values) for the parameter
- Upper and Lower Alarm Limit Sets (in engineering units) for the parameter

Note : Only one Warning and Alarm Limit Set may be valid at any time

A2.8.20. Illegal values for the parameter (if any) (in engineering units) (applicable to both uplink and downlink).

A2.8.21. For each Software Parameter, provide information on related Telemetry Parameters including:

- Telemetry Parameter providing exactly the same information (alternative) (if any)
- Telemetry Parameter providing exactly the same information (redundant) (if any)

A2.8.22. A complete list of Telemetry Packets in which this Software Parameter may be found (identified by Telemetry Packet Number).

A2.8.23. For each Software Parameter, provide information on related Software Parameters and related Telecommands including :

- Software Parameter (by Software Parameter Reference Number) performing exactly the same function (alternative) (if any)

- Telecommand (by Master Function Number) performing exactly the same function (alternative) (if any)

A2.8.24. A complete list of Telecommand Packets in which this Software Parameter may be uplinked (identified by Master Function Number).

A2.9. Parameter Calibration File

A2.9.1. The Parameter Calibration File shall provide a complete list and definition of the calibration curves for all telecommand, telemetry and software parameters defined in the SDB

A2.9.2. The Parameter Calibration File shall contain information related to ALL parameters that can ever be included in telemetry packets, including parameters resident in on-board software. For each parameter, the information in the following requirements shall be provided.

A2.9.3. Parameter Calibration Reference Number

A2.9.4. Calibration Data Definition either being in the form of a series of points (maximum 32) describing a polynomial or being in the form of mathematical definition of the polynomial

A2.9.5. Each point in the Calibration Data Definition shall be given as a couplet of raw value and the corresponding value in engineering units.

A2.9.6. Two points shall be given corresponding to the upper and lower extreme values of the raw range (e.g. for an 8-bit wide parameter, points corresponding to the raw values 0 and 255 shall be given).

Note : This applies both to the points definition and to the polynomial definition

A2.9.7. All other points shall be selected such that parameters can be satisfactorily calibrated by linear interpolation between the points.

A2.10.Parameter Alias File

A2.10.1. The Parameter Alias File shall provide a complete list and definition of all parameter aliases for all telecommand, telemetry and software parameters in the SDB.

A2.10.2. The Parameter Alias File shall contain information related to ALL parameters that can ever be included in telemetry or telecommand packets, including parameters resident in on-board software. For each parameter, the information in the following requirements shall be provided.

A2.10.3. Parameter Alias Reference Number

A2.10.4. Alias Definition Table being in the form of a series of interpreted values corresponding to every possible raw value the parameter may take in ascending order.

A2.10.5. The interpreted values may take any one of the following forms :

- logical (0 or 1)
- binary strings
- decimal numbers
- character strings (ON or OFF)

A2.10.6. Any raw values not used or not meaningful shall be identified as such in the Alias Definition Table.

A2.10.7. Any raw values which are illegal shall be identified as such in the Alias Definition Table.

A2.10.8. The number of entries in the Alias Definition Table shall not exceed 256.

A2.10.9. The number of characters in any character string shall not exceed 12.

A2.11.Telecommand Sequence File

A2.11.1. The Telecommand Sequence File shall provide a complete list and definition of all telecommands sequences and associated parameter values as used in check-out.

A2.11.2. The format and content is to be agreed with ESA.

ANNEX A3: FLIGHT DYNAMICS DATABASE CONTENTS

A3.1. Flight Dynamics Database

A3.1.1. The Flight Dynamics Database (FDDB) shall consist of the following files

- Configuration Control File describing the FDDB version and the changes made since the last release
- Spacecraft Configuration File containing spacecraft version information
- Physical Properties File
- Attitude Sensor Alignment Data File
- Attitude Sensor Calibration Data File
- Attitude Sensor Performance Data File
- Actuator Alignment Data File
- Actuator Calibration Data File
- Actuator Performance Data File
- Image decompression algorithms (for NAVCAM, OSIRIS)

A3.2. Configuration Control File

A3.2.1. The Configuration Control File shall contain the following information :

A3.2.2. FDDB Version Number

A3.2.3. Date of FDDB release to ESA

A3.2.4. SDB Version Number to which this version of the FDDB relates

A3.2.5. Version Number of every File making up the FDDB

A3.2.6. Configuration Change Tables for all Files making up the FDDB, identifying

- the files updated
- the records updated within the file, referenced by e.g. parameter reference, telecommand number, calibration curve number etc., as appropriate

- the fields updated within the records (for all fields)
- the date the field was changed
- the initials of the person who made the change

A3.3. Spacecraft Configuration File

The Spacecraft Configuration File shall contain the following information

A3.3.1. Spacecraft Configuration Tables identifying the spacecraft configuration to which the FDDB applies, including :

- Spacecraft Model (EQM, PFM)
- Spacecraft build standard identifying the main and redundant units within the subsystems and instruments.

A3.3.2. The Spacecraft On-Board Software Configuration Table indicating the version numbers of all relevant subsystem on-board software to which the FDDB applies including

- AOCS
- Star Tracker
- DMS

A3.4. Physical Properties File

A3.4.1. The mass property file shall specify mass properties in the following configurations :

- At launch
- After each orbit manoeuvre until insertion into operational orbit
- At nominal mission end time

A3.4.2. For each of the above configurations the following data should be provided :

- Total dry mass
- Mass of propellant
- Position of the centre of gravity in S/C physical coordinate frame
- Principal moments of inertia (Ixx, Iyy, Izz) and the principal axes of inertia in SC_O_P.

A3.4.3. The following properties shall be provided:

- Cross section area

- Reflectivity coefficients of surfaces used for the estimation of solar torques and forces due to solar radiation pressure.
- Equivalent magnetic dipole
- Transponder delays

A3.5. Attitude Sensor Alignment Data File

A3.5.1. The Attitude Sensor Alignment Data File should provide nominal and actual (measured) alignment data for all AOCS sensors and all P/L optical instruments.

A3.5.2. The data should refer to the S/C functional co-ordinate frame SC_O_f and should be expressed in degrees.

A3.5.3. For each optical unit the following data shall be provided :

- The unit identifier
- The unit line of sight expressed in terms of two angles together with their uncertainties
- The mounting angle of the field of view, i.e. the rotation angle of the unit transverse axes.

A3.5.4. For each inertial unit (gyro, accelerometer) the following data shall be provided :

- The unit identifier
- The unit input axis expressed in terms of two angles together with their uncertainties.

A3.5.5. Position and orientation of SC_O_f w.r.t. SC_O_P

A3.6. Attitude Sensor Calibration Data File

A3.6.1. The Attitude Sensor Calibration Data File shall provide for each sensor all information needed to convert instrument measurement data into engineering units.

A3.6.2. In cases where there is temperature dependency, separate sets of data covering the expected operational range shall provided.

A3.6.3. For each star tracker unit the following acceptance test data shall recorded :

- The unit identifier

- The focal length
- The conversion factors between CCD co-ordinates and angular offsets
- The conversion factors between magnitude and CCD counts
- The magnitude corrections to be applied as function of the star spectral class

A3.6.4. For each fine sun sensor unit, the following data shall provided :

- The unit identifier
- Coefficients of the transfer function between raw measurements and actual angles

A3.6.5. For each rate sensor unit, the following data shall be provided :

- The unit identifier
- Conversion factor between raw measurement and engineering data
- additional scale factor

A3.7. Attitude Sensor Performance Data File

A3.7.1. The Attitude Sensor Performance Data File shall provide data describing the sensor operating domain for every sensor (field of view, temperature range, STR limiting magnitude, other limitations) and its accuracy.

A3.7.2. For each Star Tracker (STR) unit the following acceptance test data shall be provided :

- The unit identifier
- The dimensions of the field of view
- The star magnitude range
- The operating temperature range
- The bias errors on star positions as function of star magnitude and spectral class
- The Noise Equivalent Angle errors as function of star magnitude and spectral class
- The star magnitude measurement errors as function of star magnitude and spectral class
- The maximum tracking rate
- The dimensions of search/tracking fields of view
- The maximum number of stars simultaneously tracked

A3.7.3. For each Sun Sensor unit the following data shall be provided :

- The unit identifier

- The dimensions of the field of view
- The accuracy of the transfer function
- The accuracy on measured sun position (bias & noise)

A3.7.4. For each rate sensor unit, the following data shall be provided :

- The unit identifier
- The maximum measurable rate
- The temperature operating range
- The drift errors (systematic bias, short and long terms)
- The scale factor errors (linearity, short and long terms)

A3.8. Actuator Alignment Data File

A3.8.1. The Actuator Alignment Data File shall provide nominal and actual (measured) data about the alignments of all AOCS actuators (e.g. reaction wheels, thrusters).

A3.8.2. The data shall refer to the S/C physical co-ordinate frame SC_O_P.

A3.8.3. The data shall be expressed in degrees.

A3.8.4. For each thruster unit the following data shall be provided :

- The unit identifier
- The direction of the thrust expressed in terms of two angles together with their uncertainties

A3.8.5. For each reaction wheel the following data shall be provided :

- The unit identifier
- The input axis expressed in terms of two angles together with their uncertainties

A3.9. Actuator Position Data File

A3.9.1. The Actuator Position Data File shall provide nominal and actual (measured position) data for all AOCS thrusters.

A3.9.2. For each thruster the following data shall be provided :

- The unit identifier
- The position of the thruster (centre of force) with respect to the S/C physical co-ordinate frame SC_O_P.

A3.10.Actuator Performance and Calibration Data File

A3.10.1. The Actuator Calibration Data File shall provide for each actuator measurements collected during on-ground calibration/acceptance tests.

A3.10.2. For each thruster operated in steady state the following performance data, measured during acceptance tests, shall be provided:

- The unit identifier
- The coefficients of the transfer function for the propellant flow rate as function of the pressure and commanded opening time
- The coefficients of the transfer function for the thrust force as function of pressure and temperature

A3.10.3. For each thruster the following calibration data shall be provided :

- The unit identifier
- The accuracy of the transfer function providing the thrust force as defined in A3.10.2
- The thrust level noise in steady state
- The thrust direction noise in steady state
- The minimum and maximum duration of an actuation

A3.10.4. For each reaction wheel the following performance data shall be provided:

- The unit identifier
- The accuracy of the transfer function providing the actual reaction torque as function of the torque demand
- The maximum torque demand
- The maximum angular momentum
- The maximum wheel speed

A3.10.5. For each reaction wheel the following calibration data, measured during acceptance tests, shall be provided :

- The unit identifier
- The coefficients of the transfer function giving the actual reaction torque as function of the demanded torque

- The wheel moment of inertia
- Stiction and friction torques as function of wheel speed
- The conversion factor between wheel speed and tacho measurement

A3.11.Spacecraft Antenna Performance and Ranging Data File

A3.11.1. The Spacecraft antenna performance Data File shall provide data about the directions of the antennas and their performance.

A3.11.2. For each antenna the following data shall be provided :

- The unit identifier
- The antenna direction expressed in the S/C mechanical axes
- The antenna coverage patterns for both TM and TC expressed in terms of directions within which link margins over a range of values for the geocentric distance are met.

A3.11.3. For each Transponder the following information shall be provided :

- the transponder delay as a function of temperature and signal level

A3.12.Spacecraft Model Data File

A3.12.1. The geometric model data file shall contain all data needed for the ground to predict the external forces and torques (due to solar radiation pressure, infra-red emission, magnetic moment) acting on the S/C as function of attitude and position on the orbit.

A3.12.2. The following data shall be provided :

- location, size and shape of elementary surfaces
- reflectivity coefficients of those elements

A3.12.3. Magnetic model data : dipole equivalent model

A3.13.Pointing Constraints Data File

A3.13.1. The Pointing Constraints Data File shall provide constraint data at system and unit level.

A3.13.2. Spacecraft constraints applicable to solar panels deployed.

A3.13.3. Spacecraft constraints applicable to articulated antennas

A3.13.4. Star tracker constraints

A3.13.5. Radiator constraints: time limits depending on attitude w.r.t. sun and earth and distances.

ANNEX A4: TC AND PARAMETER IDENTIFICATION CONVENTIONS

A4.1. General Conventions

A4.1.1. The following conventions shall be imposed across the board from system level down to unit level for the whole of the FIRST/PLANCK Project.

A4.1.2. A single alphabetic character shall be used as the subsystem or instrument identifier.

A4.1.3. The allocation of subsystem identifiers shall be as follows :

- A for the Attitude and Orbit Control Subsystem (AOCS)
- D for the On-Board Data Management Subsystem (DMS)
- P for the Power Subsystem (PS)
- T for the Thermal Control Subsystem (TCS)
- R for the Radio Frequency Subsystem (RF)

A4.1.4. In view of the potentially large number of Software Parameters, the following further allocation of subsystem identifiers shall be used :

- B for the AOCS Software Parameters
- C for the DMS Software Parameters
- S for the Star Tracker Software Parameters

A4.1.5. The allocation of instrument identifiers shall be as follows :

- To be provided later

A4.1.6. Allocations other than the above shall be agreed with ESA

A4.1.7. The characters O, Q and I shall not be used.

A4.2. Telecommand Packet Identification Conventions

A4.2.1. All Telecommand Packets shall be identified by the Telecommand Master Function Number (MF).

A4.2.2. Every instance of a Telecommand Packet having a distinct purpose (function) shall be assigned a unique Master Function Number.

A4.2.3. A Master Function Number shall be a four digit number in the range 0000 to 9999, preceded by the relevant subsystem code letter.

A4.2.4. All Telecommand Packets shall be identified in Test and Operations Procedures by the letters TC followed by the Master Function Number (e.g. TC A212).

A4.2.5. Command Mnemonics shall not be used to identify Telecommand Packets.

A4.3. Telemetry Packet Identification Conventions

A4.3.1. All Telemetry Packets having a distinct structure (and hence containing a distinct set of telemetry or software parameters) shall be assigned a Telemetry Packet Number (TPN).

A4.3.2. A Telemetry Packet Number shall be a five digit number in the range 00000 to 99999.

A4.3.3. All Telemetry Packets shall be identified by the letters PKT followed by the Telemetry Packet Number (e.g. PKT 212).

A4.3.4. Mnemonics shall not be used to identify Telemetry Packets.

A4.4. Parameter Identification Conventions

A4.4.1. All telecommand, telemetry and software parameters in the on-board system shall be assigned a Parameter Identification (PID)

A4.4.2. The Parameter Identification (PID) shall be used by the on-board subsystems and instruments in the construction of telemetry packets or in the processing of telecommands

A4.4.3. The Parameter Identification (PID) shall be a number in the range 0 to 65535

A4.4.4. All telecommand, telemetry and software parameters in the on-board system shall be assigned a unique Parameter Reference Number (PREF) for the purposes of identification in the ground systems.

A4.4.5. The PREF shall be employed exclusively in all ground system and flight operations activities namely

- within systems for unit, subsystem and system check-out
- within systems for flight operations
- within documentation for ground testing and flight operations

A4.4.6. There shall be a one to one relationship between the PID and the PREF.

A4.4.7. The Parameter Reference Number (PREF) shall be a four digit number, preceded by the relevant subsystem code letter .

A4.4.8. All telecommand, telemetry and software parameters in the ground systems shall be identified in Test and Operations Procedures by the letters PARA followed by the Subsystem Identifier followed by the Parameter Reference Number (e.g. PARA A1024).

A4.4.9. Mnemonics shall not be used to identify telecommand or telemetry parameters.

A4.4.10. Mnemonics may be used to identify software parameters (for example in code) but shall nonetheless be only referenced according to the assigned PREF in ALL test and flight operations activities.

ANNEX A5 : LIST OF ACRONYMS

AIV	Assembly, Integration and Verification (on-ground)
AP	Application Process
APID	Application ID
ACN	Attitude Control and Navigation
AOCS	Attitude and Orbit Control System
AUT	Autonomy
CPDU	Central Processing Data Unit
CTR	Control
DMS	Data Management Subsystem
DVC	Device Commanding
EQM	Engineering Qualification Model (of spacecraft)
ESA	European Space Agency
ESOC	European Space Operations Centre
EVRP	Event Reporting
FD	Flight Dynamics
FDDB	Flight Dynamics Data Base
FDDC	Flight Dynamics Database Content
FDDD	Flight Dynamics Database Delivery
FID	Function Identifier
FMECA	Failure Mode Effects Criticality Analysis
FTA	Fault Tree Analysis
FTS	In-flight Testing
ICD	Interface Control Document
ID	Identification
IF	Interface

INFT	In-flight Testing
LEOP	Launch and Early Orbit Phase
LSB	Least Significant Bit
MM	Memory Management
MNEM	Mnemonic
MSB	Most Significant Bit
OBCP	On-Board Control Procedure
CDMS	On-Board Data Handling
OBMF	On-Board Monitoring Function
MTL	On-Board Mission Timeline
OBSM	On-Board Software Management
OBSR	On-Board Storage and Retrieval
OBTM	On-Board Time Management
PACK	Packet (Telecommand or Telemetry)
PERP	Periodic Reporting
PFC	Parameter Format Code
PFM	Proto-Flight Model (of spacecraft)
PI	Principal Investigator
PID	Parameter Identification Number
PREF	Parameter Reference Number
PRT	Packet Routing Table
PTC	Parameter Type Code
PTXC	Packet Transmission Control
RAM	Random Access Memory
RCS	Reaction Control System
RD	Reference Document
RF	Radio Frequency
ROM	Read Only Memory
RTU	Remote Terminal Unit

S/C	Spacecraft
SDB	Spacecraft Data Base
SDBC	Spacecraft Data Base Content
SDBD	Spacecraft Data Base Delivery
SDE	Software Development Environment
SID	Structure ID
STR	Star Tracker
STRP	Statistic Reporting
SUM	Satellite Users Manual
SVF	Software Validation Facility
TAI	Temps Atomique International
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand
TCV	Telecommand Verification
TIM	Timing
TM	Telemetry
TPN	Telemetry Packet Number
UTC	Universal Time Co-ordinated