Rosetta - MUPUS

To Planetary Science Archive Interface Control Document

RLGS-SPEC-SONC_DPS-SCIE-9242-CNES

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Distribution List

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Change Log

Date	Sections Changed	Reasons for Change
29/06/2015	First delivery	Issue 1.1 for Cruise and Comet phase
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TBD ITEMS

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1 Introduction

1.1 Purpose and Contents

The purpose of this EAICD (Experimenter to (Science) Archive Interface Control Document) is twofold. First it provides users of the MUPUS instrument with detailed description of the product and a description of how it was generated, including data sources and destinations. Secondly, it is the official interface between the instrument team and the archiving authority.

1.2 Archiving Authorities

The Planetary Data System Standard is used as archiving standard by

- NASA for U.S. planetary missions, implemented by PDS
- ESA for European planetary missions, implemented by the Research and Scientific Support Department (RSSD) of ESA

1.2.1 ESA's Planetary Science Archive (PSA)

ESA implements an online science archive, the PSA,

- to support and ease data ingestion
- to offer additional services to the scientific user community and science operations teams as e.g.
    - search queries that allow searches across instruments, missions and scientific disciplines
    - several data delivery options as

direct download of data products, linked files and data sets

- ftp download of data products, linked files and data sets

The PSA aims for online ingestion of logical archive volumes and will offer the creation of physical archive volumes on request.

1.3 Contents

This document describes the data flow of the MUPUS instrument on ROSETTA/Philae from the spacecraft until the insertion into the PSA for ESA. It includes information on how data were processed, formatted, labeled and uniquely identified. The document discusses general naming schemes for data volumes, data sets, data and label files. Standards used to generate the product are explained. Software that may be used to access the product is explained further on.

The design of the data set structure and the data product is given. Examples of these are given in the appendix.

1.4 Intended Readership

The staff of the archiving authority (Planetary Science Archive, ESA, RSSD, design team) and any potential user of the MUPUS data.

1.5 Applicable Documents

AD1. Planetary Data System Preparation Workbook, February 1, 1995, Version 3.1, JPL, D-7669, Part1

AD2. Planetary Data System Standards Reference, June 1, 1999, Version 3.3, JPL, D-7669, Part 2

AD3. Rosetta Archive Generation, Validation and Transfer Plan, January 10, 2006, Issue 2, Rev. 3, RO-EST-PL-5011

AD4. ROSETTA Archive Conventions RO-EST-TN-3372 Issue 7, Rev. 9, 06 April 2015

AD5. Planetary Data System Standards Reference, Aug. 1, 2003, Version 3.6, JPL, D-7669, Part 2

AD6. Command and Data Management System (CDMS) Subsystem Specification, Issue 3, Rev. 5, 29/08/2001, RO-LCD-SP-3101

AD7. Rosetta Time handling, RO-EST-TN-3165, Issue 1, Rev. 0, February 9, 2004

AD8. MUPUS OnBoard Software – Version 7.0, 7.1, 7.2, 7.3 – RO-LMU-SP-3401-DLR, Rev SVN#2440, February 12, 2010

1.6 Acronyms and Abbreviations

CDMS	Rosetta Lander Command and Data Management System
CG-67	Comet Churyumov-Gerasimenko, the target of the Rosetta mission
CoI	Co-investigator
DDS	Data Dissemination System
EAICD	Experiment Archive Interface Control Document
ESA	European Space Agency
FSS	First Science Sequence (on the comet)
HK	Housekeeping data
LOBT	Lander onboard time send by CDMS
MUPUS	Multi Purpose Sensors for Surface and Subsurface Science
(MUPUS)-ANC	Anchor sensor subsystem of MUPUS, comprises of an accelerometer (ANC-M) and a temperature sensor (ANC-T)
(MUPUS)-DS	MUPUS Depth sensor
(MUPUS)-PEN	Penetrator sensor subsystem of MUPUS (16 RTD's on kapton foil mounted inside a glass fibre tube of 32 cm length)
(MUPUS)-PENEL	Penetrator Electronics
(MUPUS)-TM	Thermal Mapper (infrared sensors) subsystem of MUPUS
OOBT	Orbiter On-Board Time
PC	Payload Checkout
PDS	Planetary Data System
PHILAE	Lander of the Rosetta mission
PI	Principal Investigator
PSA	Planetary Science Archive (of ESA)
RSOC	Rosetta Science Operations Center
RTD	Resistance Thermometer Device
SDL	Separation-Descent-Landing
SONC	(PHILAE) Science Operations and Navigation Center
TBC	To Be Confirmed (later)
TBD	To Be Defined (later)
UTC	Universal Time

1.7 Contact Names and Addresses

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2 Overview of Scientific Objectives, Experiment Design and Data Products

2.1 Scientific Objectives and Experiment Design

The MUPUS package consists of three major sensor heads, the penetrator MUPUS PEN with its subsystems, the radiometer MUPUS TM, and the anchor sensors MUPUS ANC. Their positions on the Lander are coloured red in Figure 1. The MUPUS central electronics (CE) controls the external sensors and exchanges commands and data with the CDMS. The CE comprises of a ComDPU as processing unit and two additional signal conditioning boards (DSB-1 and DSB-2). The CE is integrated into the Common Electronics Box inside the warm compartment of the PHILAE Lander, together with the main electronics of other experiments and Lander subsystems.

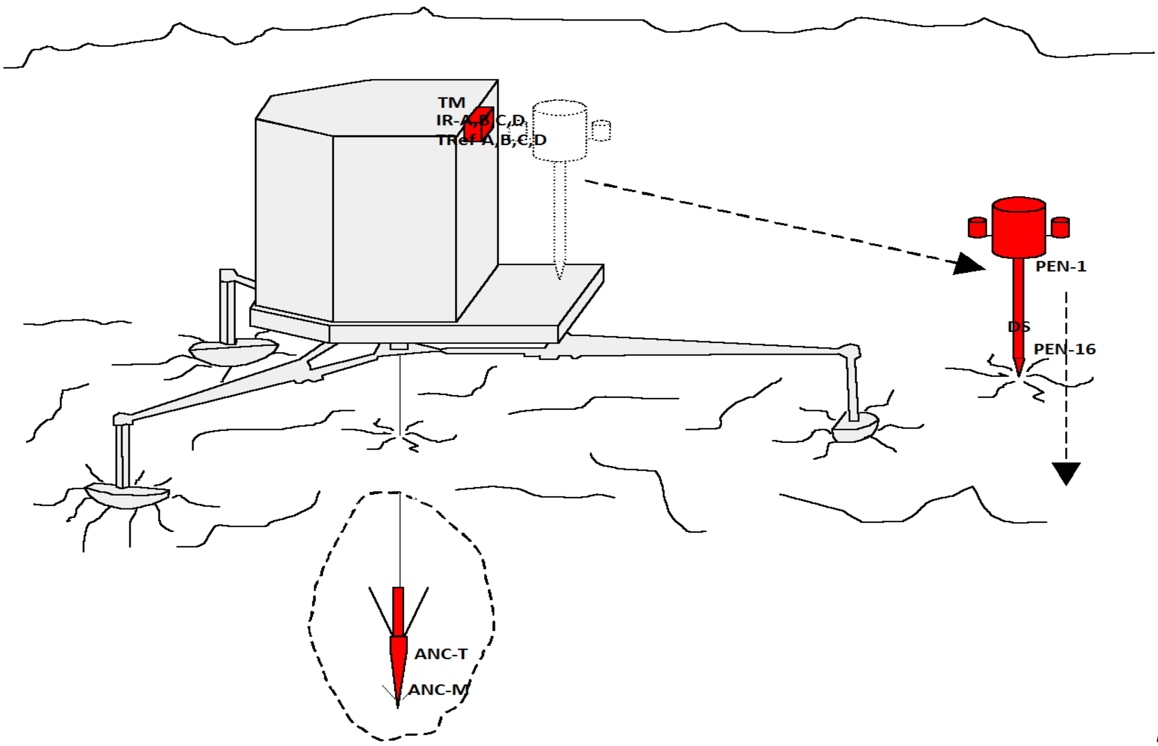

Figure 2-1. MUPUS instrument package configuration overview. The penetrator carrying 16 temperature sensors alog its rod is placed on the surface away from the Lander by a deployment arm (not shown). Both anchors of the Lander harbour a temperature sensor (ANC-T) and an accelerometer (ANC-M). The 4-channel infrared radiometer TM is attached to the V-strut of the Lander on the upper part of the balcony and looks to the ground at an angle of 45° w.r.t. the horizontal plane.

The central part of MUPUS is a thermal probe (PEN) that, after insertion into the regolith of the comet nucleus up to a depth of 32 *cm*, aims to measure both the temperature profile underneath the surface and the thermal diffusivity and conductivity profiles. The thermal diffusivity and conductivity will be derived from the time rates of change of sensor temperatures during active heating cycles. In addition, MUPUS-TM will measure the surface temperature and thermal inertia. The temperatures and the thermal transport parameters will be measured regularly over the life time of the PHILAE Lander. Furthermore, the mechanical strength of the material will be derived from the energy spent per unit distance penetrated during the hammered insertion. Profiles of penetration resistance will also be derived from MUPUS accelerometer (designated as ANC-M) measurements in each of the Lander's two harpoon anchors. The anchors also contain MUPUS temperature sensors (ANC-T).

In doing these measurements, MUPUS can contribute to an assessment of the energy balance of the comet nucleus and the physical properties of its material. Since the thermal conductivity and diffusivity are strong functions of the structure of the porous ice and the degree to which it has been sintered (Seiferlin et al., 1995), MUPUS can constrain the microstructure and the degree to which the comet material has been thermally altered. MUPUS will thus predict at what depth pristine material can be expected. This is important for characterizing the context of the samples extracted by the drill, as well as for our understanding of the thermophysics of cometary activity. The scientific objectives of MUPUS are summarized as follows:

– To understand the physical properties and layering of the near-surface matter as these evolve with time as the comet nucleus spins and approaches the Sun.

– To understand the energy balance at the surface and its variation with time and depth.

– To understand the mass flow at the surface and its evolution with time.

– To provide ground truth for thermal mapping from the Orbiter, and to support other instruments on the Rosetta Lander (e.g. SESAME-CASSE)."

2.2 MUPUS Operations

MUPUS can be operated in a number of different operational modes which are dedicated to specific scientific or test purposes. The MUPUS modes are summarized in Table 1 where the modes generating scientific data (which needs to be archived) are typed in bold. Only one mode can be active at a given time. Each mode can be configured in a variety of ways, either by explicit parameters in the corresponding telecommand or via the general MUPUS configuration. To provide the necessary operational context a dump of the actual configuration (in a dedicated science packet) is made at the beginning of every new operational mode.

Mode	Main Purpose
Power ON	Switch MUPUS devices on and performs warm-up heating, if necessary
Power OFF	Switch MUPUS devices off
MAPPER	Perform TM surface temperature and ANC-T measurements
CMAPPER	Perform TM inflight calibration as dedicated mode
TEM	Perform temperature measurements with all MUPUS sensors (PEN, TM, ANC-T)
THC	Perform thermal properties measurements by actively heating one or more PEN sensors and simultaneous scanning of all MUPUS temperature sensors
LONGTERM	Macromode containing of TEM and THC phases
Default LONGTERM	Default mode after 10 min (CFG) idle time Perform MAPPER and PENEL (if deployed) measurements
Raw ADC	Perform raw (single samples)ADC measurements with configurable channels and timings
Average ADC	Perform averaged ADC measurements with configurable channels and timings
ANCHOR mode	Fast anchor accelerator measurements during touch-down
ARM	PEN deployment
HAMMER	PEN insertion

Table 1. 1MUPUS operational modes

For the scientific operation of the MUPUS experiment (on the comet, starting at SDL), four different scenarios (which generate different types of data) can be distinguished:

- Anchor shot: this special scenario applies only during the touchdown of PHILAE on the cometary surface, or, during the shot of the second harpoon at a later time. During the anchor shot(s) MUPUS will record the ANC-M accelerometers with a sampling frequency of 48 kHz, thus providing the deceleration vs. time while the anchor penetrates the cometary soil.
- Before PEN deployment/insertion: this scenario applies to the first part of MUPUS operation on the comet in the “First Science Sequence” (FSS). Here, the surface brightness temperature in four infrared channels is measured by TM together with both ANC-T temperature sensors located inside the harpoons (“Mapper mode” operation).
- During PEN deployment/insertion only depth sensor (DS) readings are taken between the sequences of hammer 4-strokes (“Hammer mode”).
- After PEN deployment/insertion: in this scenario all MUPUS temperature sensors are operated simultaneously (16 PEN sensors, 2 ANC-T, 4 TM brightness temperatures) thereby providing a time dependent depth profile of the comet’s subsurface temperature. In addition, to the passive measurement of temperature profiles (“TEM mode” operation), active heating of PEN sensors shall also be performed during the long term operation on the comet (starting during the second part of the FSS, “THC mode” operation) to acquire a thermal properties profile.

Mainly for test purposes additional MUPUS modes exist (e.g. “Raw ADC mode”) but data acquired in these modes are not scientifically relevant and shall not be archived in the PSA.

2.3 Data Handling Process

SONC is responsible for the generation of the MUPUS PDS data sets and the delivery to the PSA. The MUPUS team will support this acitivity by delivering calibrated data as ASCII files. The relevant contact information is provided in section 1.7 . The MUPUS PI is responsible for the distribution to the MUPUS team.

The science data packets are retrieved in SFDU format from ESA's Data Distribution System (DDS) and archived at SONC in CDMS packets format, along with the housekeeping telemetry packets that are necessary to monitor the instruments.

The packet-specific fields are stripped out in order to reconstitute the science raw data, which are also time stamped in UTC, and stored in the SONC database. These data are furthermore converted to physical units.

All these data are electronically accessible to the PI's and CoI's (http://soncv2-rosetta.cnes.fr) according to data distribution agreements between these people and enforced by access rights at SONC.

The elaboration of PDS files is handled by SONC with the necessary support from the MUPUS team:

As soon as the Science and HK data are available at SONC (starting with the data from PC4), the PDS files with preliminary calibrated data might be produced from the archived data at SONC.

After this first formatting, these data shall be recalibrated by the MUPUS team as well as qualified according to their quality. SONC will derive the geometry related keyword parameters from the adequate Spice kernel for data sets level 2 and above. SONC will also insert relevant geometry data as time series (Lander orientation as function of time) into the data files.

Then, just after the proprietary period (six month as a minimum), the SONC team will provide the raw and calibrated data to the PSA.

At any rate, the long-term archive is constituted at SONC. SONC is responsible for the gathering of the necessary data from the MUPUS team and the distribution of the PDS-formatted data to the archive team of the RSOC. The PI's are responsible for the organization of data and their scientific correctness.

The SONC controls the archive completeness before handing it over to the archive team of the RSOC, and generates the global indices.

2.4 Overview of Data Products

MUPUS will deliver all data acquired during the SDL and on-comet phases (FSS and long term operations) to the PSA as well as a limited set of cruise phase data.

The MUPUS experiment has implemented completely rewritten flight software (Version 7.0) with associated re-definition of telemetry packets during PC4 in November 2006. Because of a flaw in the MUPUS ComDPU a further revision of the software (version 7.1) was needed to achieve stable MUPUS operations from PC#6 on. Because the data gathered before is of very limited value only data acquired with MUPUS flight software version 7.1 and higher shall be delivered to PSA. In addition, only the subset of cruise data acquired in operational modes relevant also for the on-comet operation (TEM, THC, MAPPER, ANCHOR) shall be provided to the PSA.

Furthermore, starting with PC#6 MUPUS regularly (during each PC) performs an “In-flight calibration procedure” aimed at improving the calibration of the PEN and TM sensors. Therefore, after each execution of the “In-flight calibration procedure” new sets of calibration coefficients are derived by the MUPUS team and the former data shall be re-calibrated.

The data products shall be formatted as comma-separated ASCII files, containing a time stamp for each measurement record followed by columns with the calibrated values (temperatures) for each active sensor. For all measurements involving PEN operations, e.g. during TEM, THC, or LONGTERM modes, additionally one column with the actually used heating power per sensor shall be created to make the interpretation of active thermal properties measurements feasible.

2.4.1 Instrument Calibrations

The calibration procedure of MUPUS is relatively complex and shall be described in the MUPUS User Manual, to be stored within the documents directory of the data set. The calibration constants used for the actual delivery of MUPUS data to the PSA shall be provided by the MUPUS team and archived together with the data set.

2.4.2 In-Flight Data Products

Most In-Flight (science) data will be produced during mission phases “Close Observation Phase” to “Near Perihelion” (depending on Lander survival).

In flight data products cover four data processing levels:

***Raw telemetry* (CODMAC level 1):**

HK and SC MUPUS packets (rolbin files) as received from DDS.

These data will be available at ESOC, SONC, MUPUS and PSA. They will be delivered to PSA during period A (after the proprietary period).

Raw data (CODMAC level 2):
SC raw data (edited data). The data will be available at SONC, MUPUS and PSA. They will be delivered to PSA during period A (after the proprietary period).

Calibrated HK data (CODMAC level 3):

Housekeeping data in scientific units and time tagged. Calibration is carried out by the MUPUS team.

The data will be available at SONC, MUPUS and PSA. They will be delivered to PSA during period A (after the proprietary period).

Calibrated SC data (CODMAC level 3):

Calibrated science data, time-tagged and separated for the MUPUS sensors (according to the four basic MUPUS measurement scenarios described in section 2.1) PEN, TM/ANC-T, ANC-M, and DS. Calibration will be carried out by the MUPUS team.

The data will be available at SONC, MUPUS and PSA). They will be delivered to PSA in period B (when ready).

Reduced (or derived) data (CODMAC level 5):

Derived data will not be provided for archiving by MUPUS.

The in-flight data are produced during following mission phases:

Table 2 MUPUS In-flight data products

MISSION_PHASE_NAME	**Abbreviation**	**Start Date** (dd/mm/yyyy)	**End Date** (dd/mm/yyyy)	**MUPUS data** (1)
Commissioning (part 1)	CVP1	05/03/2004	06/06/2004	**X**
Cruise 1	CR1	07/06/2004	05/09/2004	
Commissioning (part 2)	CVP2	06/09/2004	16/10/2004	**X**
Earth Swing-by 1 (including PC#0)	EAR1	17/10/2004	04/04/2005	**X**
Cruise 2 (including PC#1,2)	CR2	05/04/2005	28/07/2006	**X**
Mars Swing-by (including PC#3,4,5)	MARS	29/07/2006	28/05/2007	**X**
Cruise 3	CR3	29/05/2007	12/09/2007	
Earth Swing-by 2 (including PC#6,7)	EAR2	13/09/2007	27/01/2008	**X**
Cruise 4-1 (including PC#8)	CR4A	28/01/2008	03/08/2008	**X**
Steins Flyby	AST1	04/08/2008	05/10/2008	**X**
Cruise 4-2 (including PC#9)	CR4B	06/10/2008	13/09/2009	**X**
Earth Swing-by 3 (including PC#10)	EAR3	14/09/2009	13/12/2009	**X**
Cruise 5 (including PC#12)	CR5	14/12/2009	16/05/2010	**X**
Lutetia Flyby	AST2	17/05/2010	03/09/2010	
RV Manoeuver 1 (including PC#13)	RMV1	04/09/2010	07/06/2011	**X**
Cruise 6	CR6	08/06/2011	20/01/2014	
Post Hibernation Commissionning	PHC	09/04/2014	24/04/2014	**X**
Pre-delivery calibration Science	PDCS	25/04/2014	11/11/2014	

(1) The last column indicates if MUPUS data are available

After the release of the Lander, we distinguish four phases, characterized by:

- The Start and Stop dates need to be expressed in seconds
- The Lander has its own Auxiliary data

Separation/Descent/Landing	SDL	2014/11/12 08:35:02	2014/11/12 15:34:04	X
Rebounds	RBD	2014/11/12 15:34:05	2014/11/12 17:30:20	X
First Science Sequence	FSS	2014/11/12 17:30:21	2014/11/15 01:00:00	X

2.4.3 Software

The MUPUS team delivers EGSE quick-look software for data extraction, checking and visualization of level 1 data to SONC and PSA. It is archived in the EXTRAS directory of the data sets. The quick-look software can be used to export the raw data as ASCII files which are then used as input for the calibration pipeline (realized as a sequence of IDL routines) at DLR, Berlin. The MUPUS team will also develop scientific analysis software for the interpretation of the measurements in terms of thermal (e.g. thermal inertia, thermal diffusivity, and thermal conductivity) and mechanical properties of the cometary near-surface layers. This software is not intended to be included into the PSA.
Note: as the Level 2 data are archived, the EGSE software usage shouldn't be needed.

2.4.4 Documentation

The documentation directory contains the following documents:

- EAICD (this document, in PDF format)
- MUPUS User Manual (in PDF format)
- MUPUS_CALIBRATION_DESC.TXT
- TIMELINE_ph.TXT, timeline ASCII file for phase ph
- TIMELINE_ph_DESC.TXT, description of the timeline file for phase ph
- TIMELINE_ph_obty.PNG, timeline Image file for phase ph and observation type obty

2.4.5 Derived and other Data Products

MUPUS does not intend to deliver derived data products to the PSA.

2.4.6 Ancillary Data usage

The Lander Auxiliary Data on the comet (Position/Orientation/Illumination at any time + Comet models + Ancillary Data from the instruments) will be available in an ANCDR (Ancillary Data Record) whose definition is in progress, pending the Lander auxiliary data reconstruction.

During the on-comet operation phases, the following parameters are needed for MUPUS data processing:

- Orientation of the Lander / rotation angle, tilt angle, and height
- Localization in Space, esp. Sun-comet separation
- Sun direction and inclination
- Rosetta Lander Timeline

The "Rosetta/Lander Timeline" is a text file describing the working context and scheduling (on-off of each experiment, performed commands etc.). This file will be produced by SONC from CDMS and HK telemetries.

3 Archive Format and Content

3.1 Format and Conventions

Throughout this document, the MUPUS data processing status will be indicated by the CODMAC code levels (Table 3)

Level	Designation	Definition
1	Raw Data	Telemetry data with data embedded.
2	Edited Data	Corrected for telemetry errors and split or decommutated into a data set for a given instrument. Sometimes called Experimental Data Record. Data are also tagged with time and location of acquisition. Corresponds to NASA Level 0 data.
3	Calibrated Data	Edited data that are still in units produced by instrument, but that have been corrected so that values are expressed in or are proportional to some physical unit such as radiance. No re-sampling, so edited data can be reconstructed. Corresponds to NASA Level 1A.
4	Re-Sampled Data	Data that have been re-sampled in the time or space domains in such away that the original edited data cannot be reconstructed. Could be calibrated in addition to being re-sampled. Corresponds to NASA Level 1B
5	Derived Data	Derived results, as maps, reports, graphics, etc. Corresponds to NASA Levels 2 through 5.
6	Ancillary Data	Non-science data needed to generate calibrated or re-sampled data sets. Consists of instrument gains, offsets, pointing information for scan platforms etc.

Table 3 CODMAC Data processing levels

3.1.1 Deliveries and Archive Volume Format

A data set will be delivered for each simple mission phase. Each data set will contain only one level of data processing. The list of simple mission phases is given in §2.4.2.

A data set is be level-stamped as below:

Level 1 when it contains raw telemetry data:

- SC and HK packets as received from DDS and mixed together in binary files (.rolbin).

Level 2 when it contains raw science data:

- SC edited data (uncalibrated) separated by instrument in ASCII files (.TAB).

Level 3 when it contains calibrated data:

- HK calibrated data in ASCII file (.TAB)
- MUPUS calibrated time series (temperature vs. time)

In addition a data set contains:

- Software (in level 1 datasets)

- Calibration files (in level 3 datasets)
- Documents (see § 3.4.3.7)

A new data set release is provided when:

- The calibration information has been refined
- Additional data has been processed
- Data have been processed to a higher CODMAC level.

3.1.2 Data Set ID / Name Formation

The following naming scheme will be used for MUPUS data sets:

DATA_SET_ID=<INSTRUMENT_HOST_ID>-<target ID>-<INSTRUMENT_ID>-<data processing level number>-<mission phase abbreviation>-<version number>

DATA_SET_NAME=<INSTRUMENT_HOST_ID>-<target ID>-<INSTRUMENT_ID>-<data processing level number>-<mission phase abbreviation>-<version number>

See appendix F (16.1.1, 16.1.2) of Archive Plan Issue 2/2 [AD3].

Examples of DATA_SET_ID and DATA_SET_NAME for MUPUS data obtained in-flight during CR4A mission phase :

DATA_SET_NAME = "ROSETTA-LANDER CAL MUPUS 2 CR4A V1.0"

DATA_SET_ID = "RL-CAL-MUPUS-2-CR4A-V1.0"

3.1.3 Data Directory Naming Convention

The DATA directory will be subdivided according to the different sensor heads which are active in the corresponding measurement scenarios. Each measurement mode will have its own directory according to These directories are subdivided into subdirectories HK for housekeeping data and SC for science data, respectively.

Measurement scenario	Active sensor heads	associated modes	Directory name
Anchor shooting	ANC-M	ANCHOR	ANCSHOT
Before PEN deployment	TM, ANC-T	MAPPER	MAP
PEN deployment & insertion		ARM, HAMMER	HAMMER
After PEN deployment	PEN, TM, ANC-T	TEM, THC	PENEL

Table 4 DATA directory's subdirectories

3.1.4 File Naming Convention

A file name has a length of exactly 27+3 characters (27 characters for file identification, 3 characters for file name extension, and a separating dot between them).

The following file naming scheme will be used:

{**exp**}_{**source**}{**datatype**}_{**begin of observation**}.{**ext**}

- **exp** (3 characters) = **MUP** (fixed)
- **source** (3 character) :
  - PEN / MAP /ANC / HAM for SC files
  - XXX when unknown, that is in rolbin files and HK files.

- **datatype** (2 or 3 characters) = XYz
  - X = **S** for Science Data, **H** for Housekeeping Data, **B** for files with both data mixed together
  - Yz = CODMAC level : **1** for raw data, **2** for edited data, **3A** for SONC calibrated data, **3B** for LAB calibrated data
- **begin of observation** (12 characters) = time of test or working session in UTC yymmddhhmmss:
  - yy = year
  - mm = month
  - dd = day
  - hh=hour
  - mm = minute
  - ss = second
- **ext** = extension of file.
  - ROL for Raw Data containing HK and SC data
  - TAB for raw and calibrated SC data (CODMAC levels 2 and 3)
  - TAB for calibrated Data containig HK Data (CODMAC level 3)

Example :

MUP_PEN_S3A_060603123400.TAB
Data included in this file was recorded on 03 Jun 2006 beginning at 12:34:00 (UTC), containing MUPUS PEN coarse calibrated data.

3.2 Standards Used in Data Product Generation

3.2.1 PDS Standards

The archive structure given in this document complies with PDS standard version 3.6.

3.2.2 Time Standards

3.2.2.1 Generalities

This paragraph gives a summary of the different existing formats in the Rosetta Ground segment, from their generation by the instruments to their availability at SONC :

- The Lander CDMS requires the scientific instruments to transmit the data by bursts of 8 or 64 bytes (4 or 32 16-bit words)

- When sufficient data are received, the CDMS builds packets containing 256 bytes of instrument data. The CDMS adds 18 bytes header (unit PID, sequence count, OOBT : Orbiter OBT, data type) and a 2 bytes checksum (DECW) and creates packets with a fixed length of 276 bytes[1]. For

[1] The Lander CDMS header and the headers of the telemetry source packets from the Orbiter instruments are quite similar. There is a difference in the data field header. The byte containing PUS version, checksum flag and

transmission between Lander and Orbiter, a 4 bytes synchro header and a 2 bytes trailing checksum (PECW) are added, increasing the packet size to 282 bytes. The extra bytes are removed by the ESS.

To comply with ESA requirements, the time registered in the CDMS packets is the **OOBT**. It is reconstituted from the LOBT, as shown in Figure 3-1:

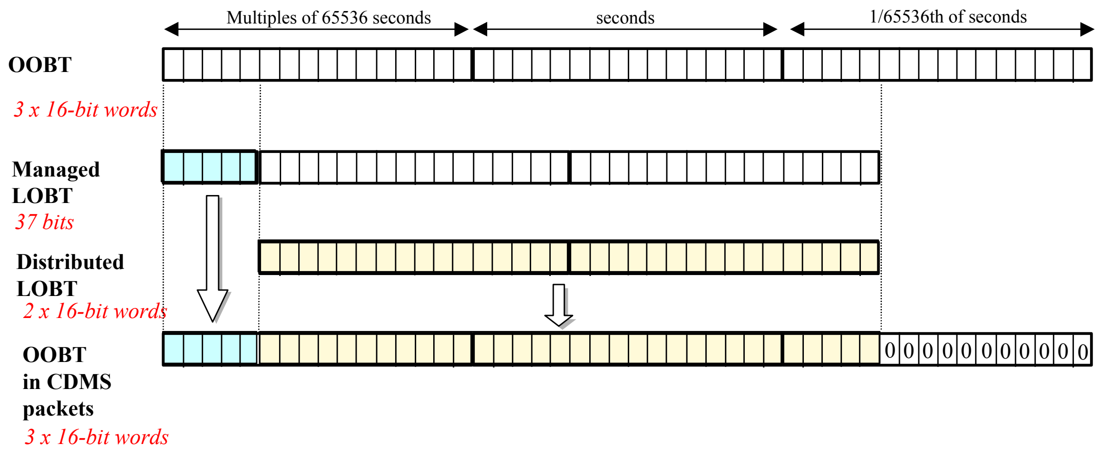

Figure 3-1 Reconstruction of on board time in CDMS packets

- The ESS groups together several packets and passes them to the Orbiter OBDH, which transmits them according to the Space/Ground interface. This part is transparent for the Lander ground segment.

- The data are delivered by the Rosetta Data Distribution System (DDS) to the SONC in SFDU format. A SFDU file is basically a collection of 276-byte packets interspersed with auxiliary information records. An 18 bytes SFDU header is added to the CDMS 276-byte packets. This header contains information added at the ground station (time correlated OBT, ground station id, virtual channel id, service channel, type of data, time quality)

- SONC processes the SFDU files to retrieve the 276-byte packets. This format is available in the SONC database.

The relationship between both time (OOBT and LOBT) formats is given § 2.3.2.6 AD6.

spare fields is set to zero in the CDMS header. Besides the last byte of the OOBT is set to zero in the CDMS header. The CDMS header has an additional word (2 bytes) after the data field header named "FORMAT ID". This word is mainly used for HK data and it contains the HK scanning period and the SID (structure identification).

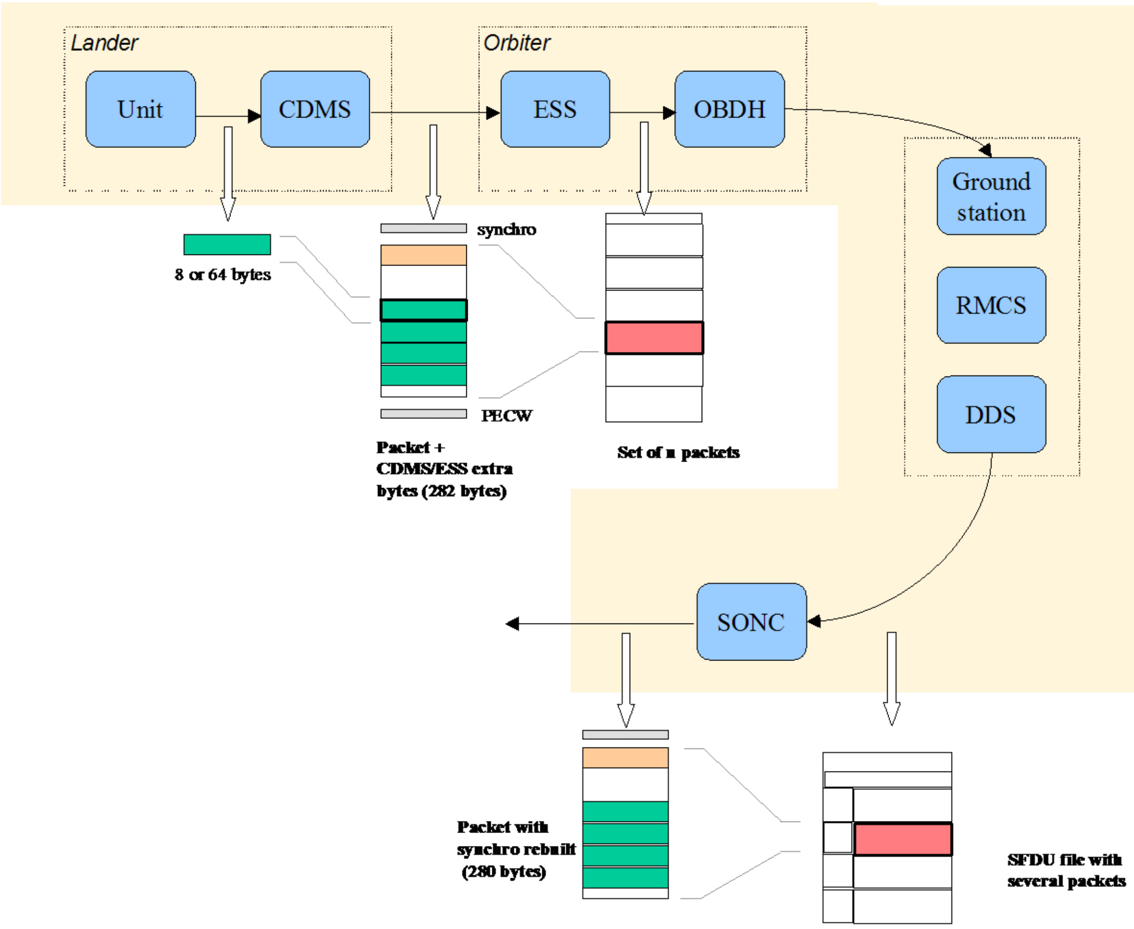

Figure 3-2 On board data flow

- Afterwards, SONC processes science raw packets in order to recompose the science measurement (e.g. an image, a spectrum, ...).

Figure 3-2 gives an overview of this data flow.

The following principles are applied :

- the packet wrapping is removed, and science frames that had to be split into several raw data packets are rebuilt. Basic error detection controls are applied, to recover from possible problems in the transmission chain.

- the Lander On-Board time (LOBT) (synchronised with OOBT) extracted from the packet, and corresponding UTC time are added.

- UTC time is calculated from the On-Board time taking into account the On-Board clock drift as following : UTC (seconds since 01/01/1970) = LOBT(seconds) * Gradient + Offset (these coefficients are extracted from TCP packets delivered by DDS).
LOBT is either the LOBTextracted from CDMS header or the Experiment internal clock when it exists (CIVA, COSAC, PTOLEMY, ROMAP, ROLIS, SESAME). In the last case, it must be taken into account that the Internal clock (32 bits) resets all 4 years, 4 months, 3 days (first reset : 03/04/2007 10 :42 :07).

UTC time-stamped Science and HK data are available in the SONC database and used to generate PDS format.

3.2.2.2 MUPUS Time standards

The time standards used in the MUPUS data products are:

- MUPUS Local Time,
- Lander On-Board Time,
- DDS header time correlated,
- Universal Time Coordinated (UTC).

3.2.2.2.1 MUPUS Local Time

MUPUS Local time is the only time available to the instrument during operation. It is synchronized with Lander On-board Time each time a CDMS RTIM message is received by MUPUS. MUPUS uses a timer with a resolution of 1 millisecond to update this time between two successive CDMS RTIM messages. The MUPUS Local Time at generation is written by the MUPUS flight software in the measurement header of each science measurement.

3.2.2.2.2 Lander On-Board Time (LOBT)

The instruments on board the spacecraft (Orbiter) generate telemetry source packets with an **Orbiter On-Board Time** (OOBT) time stamp in the header. This OOBT is the time of the start of measurement (cf.[AD6], § 2.3). The Orbiter On-Board Time is a linear binary counter having a resolution of 1/65536 sec stored in 3 16-bit words.

The Lander On-Board Time (LOBT) is a linear binary counter having a resolution of 1/32 sec, kept in 37 bits. Only the 32 least significant bits are distributed to the instruments, in 2 16-bit words. The 5 most significant bits are supposed constant during most of the mission, they are available through a specific service.

The LOBT is derived from the Orbiter On-Board Time: the 11 least significant bits of the OOBT are discarded to obtain the LOBT, hence the reduced resolution. A re-synchronization between OOBT and LOBT is performed regularly (see [AD6]).

3.2.2.2.3 The DDS header time correlated

The OOBT is converted to UTC (Coordinated Universal Time) by means of time correlation and included in the additional DDS packet header when the packets are distributed via the DDS server.

The **DDS header time correlated** (SCET field in the DDS header) is the UTC of the start of measurement derived from the OOBT by time correlation. Its format is the solar **Modified Julian Time** (MJT) i.e. two 32 bit integers. The first (MSB) contains the number of seconds since 00:00:00 on 1 January 1970 and the second (LSB) integer the number of micro-seconds from seconds in the first field.

3.2.2.2.4 Coordinated Universal Time

The **Coordinated Universal Time (UTC)** is used as a time stamp for SC and HK MUPUS data products (from level 2 to level 3). It is the DDS header time correlated.

3.2.2.2.5 Spacecraft Clock Count in PDS Labels

The PDS keywords SPACECRAFT_CLOCK_START_COUNT and SPACECRAFT_CLOCK_STOP_COUNT refer to LOBT.

The LOBT is represented in the following format:

SPACECRAFT_CLOCK_START/STOP_COUNT = "<reset number>/<unit seconds>.<fractional seconds>"

The unit seconds and the fractional seconds are separated by the full stop character. **Note that this is not a decimal point.** The fractional seconds are expressed as multiples of 2^{-5} = 0,03125. seconds and count from 0 to 2^5 -1 = 31. E.g. in SPACECRAFT_CLOCK_START_COUNT = "3/356281394.21" the 21 fractional seconds

correspond to 21 × 2^{-5} = 0.65625 decimal seconds.
The reset number is an integer starting at 1, i.e. "1/" means LOBT = 0 at 2003-01-01T00:00:00 UTC.

3.3 Data Validation

The MUPUS data products are delivered to PSA by SONC. The MUPUS PI or the MUPUS PDS responsible will validate the SC and HK data produced by SONC of all PDS CODMAC-levels. These data will be distributed via the W3-SONC server.

3.3.1 Data quality parameter

The quality of MUPUS data products will be defined by the DATA_QUALITY_ID keyword globally.

The values of the DATA_QUALITY_ID for CODMAC level 1 data are:
-1 Not yet qualified
0 No missing or corrupted packets
1 Corrupted packets
2 Missing packets
3 Corrupted and missing packets

The values of the DATA_QUALITY_ID for CODMAC level 2 data are (Note that this qualifier applies separately for the sensors PEN, TM/ANC-T, and ANC-M:

-1 Not yet qualified
0 Good data without disturbances or outliers
1 less than 1 % of disturbed data
2 less than 10 % of disturbed data
3 > 10% of disturbed data

For the TM/ANC-T data the DATA_QUALITY_ID applies separately for the 4 TM infrared channels and ANC-T, e.g. DATA_QUALITY_ID = ("channel A value","channel B value","channel C value","channel D value","ANC-T value")

The values of the DATA_QUALITY_ID for CODMAC level 3 data are (Note that this qualifier applies separately for the sensors PEN, TM/ANC-T, and ANC-M:

-1 Not yet qualified
0 Very good quality of calibration
1 Good quality of calibration
2 Acceptable quality of calibration
3 Bad quality of calibration
4 Calibration failed

For the TM/ANC-T data the DATA_QUALITY_ID applies separately for the 4 TM infrared channels and ANC-T, e.g. DATA_QUALITY_ID = ("channel A value","channel B value","channel C value","channel D value","ANC-T value")

3.4 Archive Content

3.4.1 Volume Set

One volume corresponds to one data set. The possible values of VOLUME keywords can be found in AD4. The volume keyword values for the cruise 4-1 mission phase are given in the following example.

Keyword	Value
VOLUME_NAME	“MUPUS RAW DATA FOR THE CR4A PHASE”
VOLUME_SERIES_NAME	"ROSETTA SCIENCE ARCHIVE"
VOLUME_SET_ID	"DE_DLR_PF_RLMUP_10XX"
VOLUME_SET_NAME	"ROSETTA MUPUS DATA"
VOLUME_ID	"RLMUP_1001"
VOLUME_VERSION_ID	"VERSION 1"
VOLUME_FORMAT	"ISO-9660"
MEDIUM_TYPE	"ELECTRONIC"
VOLUMES	1
PUBLICATION_DATE	YYYY-MM-DD
DESCRIPTION	"This volume contains Rosetta MUPUS level 2 data products and supporting documentation from the Cruise 4A mission phase"

Table 5 Volume set keyword values

3.4.2 Data Set

The MUPUS data will be archived in Data Sets corresponding to mission phase and data level processing. Data Sets will be named according to chapter 3.1.2. Each component of the name will match the corresponding component of the Data Set ID. The data set name components are defined in Table 6.

Name element	Data Set ID	Data Set Name
INSTRUMENT_HOST_ID / INSTRUMENT_HOST_NAME	RL (Rosetta Lander)	ROSETTA-LANDER
Target ID / Target name	See [AD4]	See [AD4]
INSTRUMENT_NAME	MULTI PURPOSE SENSORS FOR SURFACE AND SUBSURFACE SCIENCE	
INSTRUMENT_ID	MUPUS	
Data processing level number	Level 1 is delivered directly after the end of the proprietary period and contains level 1 Science and HK data Level 2 is delivered directly after the end of the proprietary period and contains level 2 Science data Level 3 is delivered after the stabilization of the calibration and contains level 3 science and HK data	
Mission phase abbreviation	See [AD4]	
Description	N/A	No description
Version	The first version of any Data Set is V1.0	

Table 6: Data Set designation parameters

3.4.3 Directories

The directory structure of MUPUS data sets is shown below.

Level 1 data sets:

```
                                           |-CATALOG--
                                           |-DATA-----
|-root directory-----------|
                                           |-DOCUMENT-
                                           |-INDEX----
                                           |-EXTRAS----
```

Level 2 data sets:

```
                                           |-CATALOG--
                                           |           |-ANCSHOT-
                                           |-DATA-----|-HAMMER--
|- root directory----------|           |-MAP-----
                                           |           |-PENEL---
                                           |-DOCUMENT-
                                           |-INDEX----
                                           |-LABEL----
```

Level 3 data sets:

```
                           |-CALIB--
                           |-CATALOG--
                           |          |-MAP-
                           |-DATA-----|-PENNEL—
                           |          |-HAMMER--
|- root directory----------|          |-HK-----
                           |
                           |-DOCUMENT-
                           |-INDEX----
                           |-LABEL----
```

3.4.3.1 Root Directory

Files in the Root Directory include an overview of the archive, i.e. a description of the volume for the PDS Catalog. The files are contained in the Root Directory are given in Table 7

File Name	File Contents
AAREADME.TXT	Volume content and format information
VOLDESC.CAT	A description of the contents of this volume in a PDS format readable by both humans and computers

Table 7 Root directory content

3.4.3.2 Calibration Directory

The information necessary for the calibration of data is given in the MUPUS User Manual in the DOCUMENT directory.

3.4.3.3 Catalog Directory

The files in the Catalog Directory provide a top-level understanding of the mission, spacecraft, instruments, and data sets. The files in this directory are coordinated with the PSA team, who is responsible for loading them into the PDS catalog. The following files are found in the Catalog Directory.

File Name	File Contents
CATINFO.TXT	A description of the contents of this directory
DATASET.CAT	Data Set description, one for each Data Set
INSTHOST.CAT	Instrument host (spacecraft) description, provided by the Project
INST.CAT	Instrument description
MISSION.CAT	Mission description, provided by the Project
PERSON.CAT	PDS personnel catalog information about the instrument team responsible for generating the data products. There will be one file for each instrument team providing data to this data set.
REF.CAT	Full citations for references mentioned in any and all of the catalog files, or in any associated label files
SOFTWARE.CAT	Information about the software (EGSE) included in the EXTRAS directory

Table 8 CATALOG directory content

3.4.3.4 Index directory

Files in the Index Directory are provided to help the user locate products on this archive volume and on previously released volumes in the archive. The following files are contained in the Index Directory.

File Name	File Contents
INDXINFO.TXT	A description of the contents of this directory
INDEX.TAB	A tabular listing all data products on this volume
INDEX.LBL	A PDS detached label that describes INDEX.TAB

Table 9 INDEX directory content

3.4.3.5 Software Directory

There is no software provided in the SOFTWARE directory since the requirements of the PDS standard are too difficult to meet.

Instead, the EGSE (Electrical Ground Support Equipment) quick-look software, which can be used for processing the raw telemetry data (rolbin files, level 1) is provided in the EXTRAS directory.

3.4.3.6 Label Directory

The label directory contains include files (.FMT files with label definitions) referenced by data files on the data set. The following files are included in the index directory:

File Name	Contents
LABINFO.TXT	A description of the contents of this directory (.FMT files)
ANC.FMT	Anchor accelerometer measurement values (level 2)
HAM.FMT	Hammer depth value measurement (level 2)
MAP.FMT	Thermal mapper measurement (level 2)
PEN.FMT	Temperatures of PENEL sensors (level 2)
HK.FMT	MUPUS housekeeping data (level 3)
MAP_3A.FMT	Thermal mapper measurement (level 3, mV)
MAP_3B.FMT	Thermal mapper measurement (level 3, K)
PEN_3A.FMT	Temperatures of PENEL sensors (level 3, mV)

PEN_3B.FMT	Temperatures of PENEL sensors (level 3, K)

3.4.3.7 Document Directory

This directory contains documentation to help the user to understand and use the archive data. The following files are contained in the document directory:

File Name	File Contents
DOCINFO.TXT	A description of the contents of this directory
EAICD_MUPUS.PDF	The MUPUS Experiment to Archive Interface Control Document (this document) as a PDF file
EAICD_MUPUS.LBL	A PDS detached label that describes EAICD.PDF
RO-LMU-SW-V74.PDF	MUPUS User Manual, version 2.0 as a PDF file
RO-LMU-SW-V74.LBL	PDS label for MUPUS User Manual
MUPUS_CALIBRATION_DESC.TXT	Description of the calibration ANC, PEN, MAP and HAM
MUPUS_CALIBRATION_DESC.LBL	PDS label for MUPUS_CALIBRATION_DESC.TXT
TIMELINE_*ph*.TXT	Timeline Ascii file with the PDS label attached for phase *ph*
TIMELINE_*ph*_DESC.TXT	Description of the timeline file for phase *ph*
TIMELINE_*ph_obty*.PNG	Timeline Image file for phase *ph* and observation type *obty*
TIMELINE_*ph_obty*.LBL	PDS label for image TIMELINE_*ph_obty*.PNG

3.4.3.8 Extras Directory

The Extras directory contains EGSE software to read and visualize raw telemetry data (CDMS rolbin files, CODMAC level 1). The content of the EXTRAS directory is shown below:

```
                                  |- MUPUS.EXE
                                  |- MUPUS.LBL
                                  |- MUPUS_EGSE_USER_MANUAL.PDF
|-EXTRAS----------|-MUPUS_EGSE---|- MUPUS_EGSE_USER_MANUAL.LBL
|                                 |- V74_FM_STRUCTURE.TXT
|                                 |- V74_FM_STRUCTURE.LBL
|-EXTRINFO.TXT
```

The MUPUS_EGSE Directory contains the following files:

File Name	Contents
MUPUS.EXE	EGSE software (PC MS Windows executable) for extracting data from the raw data product files (rolbin), calibration and visualization.
MUPUS.LBL	PDS label for MUPUS.EXE
MUPUS_EGSE_USER_MANUAL.PDF	EGSE software user manual
MUPUS_EGSE_USER_MANUAL.LBL	PDS label for MUPUS_EGSE_USER_MANUAL.PDF
V74_FM_STRUCTURE.TXT	File describing the data arrangement of the different frame types from the flight hardware. This file is used by MUPUS.EXE
V74_FM_STRUCTURE.LBL	PDS label for V73_FM_STRUCTURE.TXT
EXTRTINFO.TXT	A description of the contents of the Extras Directory

3.4.3.10 Data Directory

The structure and naming scheme of the data directory is described in chapter 3.4.3

4 Detailed Interface Specifications

4.1 Structure and Organization Overview

The data files are archived in a data set on the basis of the mission phase relative to the production of the data.

Each .ROL (rolbin) file containing the raw data (telemetry packets, CODMAC level 1) is placed in the DATA directory of the corresponding dataset (with level 1 data files, HK and SC mixed).

Each .TAB file containing uncalibrated SC data (CODMAC level 2) is archived in the DATA directory of the corresponding dataset (with level 2 SC data files).

Each .TAB file containing calibrated SC data (CODMAC level 3) and each .TAB file containing calibrated HK (CODMAC level 3) data is archived in the DATA directory of the corresponding datasets (with level 3 HK data files and level 3 SC data files).

The file names follows the rules explained in this document (§3.1.4).

4.2 Data Sets, Definition and Content

The following table gives the definition of the name and id of the foreseen data sets :

Data Set ID	Data Set Name
RL-CAL-MUPUS-1-CVP-V1.0	ROSETTA-LANDER CAL MUPUS 1 CVP V1.0
RL-CAL-MUPUS-1-CR2-V1.0	ROSETTA-LANDER CAL MUPUS 1 CR2 V1.0
RL-CAL-MUPUS-1-CR4A-V1.0	ROSETTA-LANDER CAL MUPUS 1 CR4A V1.0
RL-CAL-MUPUS-1-CR4B-V1.0	ROSETTA-LANDER CAL MUPUS 1 CR4B V1.0
RL-CAL-MUPUS-1-CR5-V1.0	ROSETTA-LANDER CAL MUPUS 1 CR5 V1.0
RL-CAL-MUPUS-1-RVM1-V1.0	ROSETTA-LANDER CAL MUPUS 1 RVM1 V1.0
RL-CAL-MUPUS-1-RVM2-V1.0	ROSETTA-LANDER CAL MUPUS 1 RVM2 V1.0
RL-E-MUPUS-1-EAR1-V1.0	ROSETTA-LANDER EARTH MUPUS 1 EAR1 V1.0
RL-E-MUPUS-1-EAR2-V1.0	ROSETTA-LANDER EARTH MUPUS 1 EAR2 V1.0
RL-E-MUPUS-1-EAR3-V1.0	ROSETTA-LANDER EARTH MUPUS 1 EAR3 V1.0
RL-M-MUPUS-1-MARS-V1.0	ROSETTA-LANDER MARS MUPUS 1 MARS V1.0
RL-A-MUPUS-1-AST1-V1.0	ROSETTA-LANDER STEINS MUPUS 1 AST1 V1.0
RL-CAL-MUPUS-1-PHC-V1.0	ROSETTA-LANDER 67P MUPUS 1 PHC V1.0
RL-CAL-MUPUS-1-SDL-V1.0	ROSETTA-LANDER 67P MUPUS 1 SDL V1.0
RL-C-MUPUS-1-RBD-V1.0	ROSETTA-LANDER 67P MUPUS 1 RBD V1.0
RL-C-MUPUS-1-FSS-V1.0	ROSETTA-LANDER 67P MUPUS 1 FSS V1.0
RL-CAL-MUPUS-2-CVP-V1.0	ROSETTA-LANDER CAL MUPUS 2 CVP V1.0
RL-CAL-MUPUS-2-CR2-V1.0	ROSETTA-LANDER CAL MUPUS 2 CR2 V1.0
RL-CAL-MUPUS-2-CR4A-V1.0	ROSETTA-LANDER CAL MUPUS 2 CR4A V1.0
RL-CAL-MUPUS-2-CR4B-V1.0	ROSETTA-LANDER CAL MUPUS 2 CR4B V1.0
RL-CAL-MUPUS-2-CR5-V1.0	ROSETTA-LANDER CAL MUPUS 2 CR5 V1.0
RL-CAL-MUPUS-2-RVM1-V1.0	ROSETTA-LANDER CAL MUPUS 2 RVM1 V1.0
RL-CAL-MUPUS-2-RVM2-V1.0	ROSETTA-LANDER CAL MUPUS 2 RVM2 V1.0
RL-E-MUPUS-2-EAR1-V1.0	ROSETTA-LANDER EARTH MUPUS 2 EAR1 V1.0
RL-E-MUPUS-2-EAR2-V1.0	ROSETTA-LANDER EARTH MUPUS 2 EAR2 V1.0
RL-E-MUPUS-2-EAR3-V1.0	ROSETTA-LANDER EARTH MUPUS 2 EAR3 V1.0
RL-M-MUPUS-2-MARS-V1.0	ROSETTA-LANDER MARS MUPUS 2 MARS V1.0

RL-A-MUPUS-2-AST1-V1.0	ROSETTA-LANDER STEINS MUPUS 2 AST1 V1.0
RL-CAL-MUPUS-2-PHC-V1.0	ROSETTA-LANDER 67P MUPUS 2 PHC V1.0
RL-CAL-MUPUS-2-SDL-V1.0	ROSETTA-LANDER 67P MUPUS 2 SDL V1.0
RL-C-MUPUS-2-RBD-V1.0	ROSETTA-LANDER 67P MUPUS 2 RBD V1.0
RL-C-MUPUS-2-FSS-V1.0	ROSETTA-LANDER 67P MUPUS 2 FSS V1.0
RL-CAL-MUPUS-3-CVP-V1.0	ROSETTA-LANDER CAL MUPUS 3 CVP V1.0
RL-CAL-MUPUS-3-CR2-V1.0	ROSETTA-LANDER CAL MUPUS 3 CR2 V1.0
RL-CAL-MUPUS-3-CR4A-V1.0	ROSETTA-LANDER CAL MUPUS 3 CR4A V1.0
RL-CAL-MUPUS-3-CR4B-V1.0	ROSETTA-LANDER CAL MUPUS 3 CR4B V1.0
RL-CAL-MUPUS-3-CR5-V1.0	ROSETTA-LANDER CAL MUPUS 3 CR5 V1.0
RL-CAL-MUPUS-3-RVM1-V1.0	ROSETTA-LANDER CAL MUPUS 3 RVM1 V1.0
RL-CAL-MUPUS-3-RVM2-V1.0	ROSETTA-LANDER CAL MUPUS 3 RVM2 V1.0
RL-E-MUPUS-3-EAR1-V1.0	ROSETTA-LANDER EARTH MUPUS 3 EAR1 V1.0
RL-E-MUPUS-3-EAR2-V1.0	ROSETTA-LANDER EARTH MUPUS 3 EAR2 V1.0
RL-E-MUPUS-3-EAR3-V1.0	ROSETTA-LANDER EARTH MUPUS 3 EAR3 V1.0
RL-M-MUPUS-3-MARS-V1.0	ROSETTA-LANDER MARS MUPUS 3 MARS V1.0
RL-A-MUPUS-3-AST1-V1.0	ROSETTA-LANDER STEINS MUPUS 3 AST1 V1.0
RL-CAL-MUPUS-3-PHC-V1.0	ROSETTA-LANDER 67P MUPUS 3 PHC V1.0
RL-CAL-MUPUS-3-SDL-V1.0	ROSETTA-LANDER 67P MUPUS 3 SDL V1.0
RL-C-MUPUS-3-RBD-V1.0	ROSETTA-LANDER 67P MUPUS 3 RBD V1.0
RL-C-MUPUS-3-FSS-V1.0	ROSETTA-LANDER 67P MUPUS 3 FSS V1.0

4.3 Data Product Design

All MUPUS data products have PDS detached labels.

4.3.1 Raw MUPUS data product design (Level 1)

Level 1 contains mixed raw housekeeping and science data packets delivered by the Rosetta Lander with detached PDS labels.

4.3.1.1 File Characteristics Data Elements

The raw files (level 1) are described by PDS minimal detached labels. The file characteristic data elements are RECORD_TYPE, PRODUCT_TYPE and FILE_NAME. The PRODUCT_TYPE is UDR. The RECORD_TYPE for raw data is UNDEFINED, i.e. the structure of records is not described in the PDS labels since these data are intended to be processed with the EGSE software available in the EXTRAS directory. The file contains telemetry packets which are described in [AD8].

4.3.1.2 Instrument and Detector Descriptive Data Elements

```
INSTRUMENT_HOST_NAME   = "ROSETTA-LANDER"
INSTRUMENT_HOST_ID     = RL
INSTRUMENT_ID          = MUPUS
INSTRUMENT_NAME        = "MULTI PURPOSE SENSORS FOR SURFACE AND
                          SUBSURFACE SCIENCE"
INSTRUMENT_TYPE        = "MATERIAL PROPERTY SENSOR"
INSTRUMENT_MODE_ID     = "N/A"
INSTRUMENT_MODE_DESC   = "N/A"
```

4.3.2 Science Data Product Design (Level 2)

The science data products are organized according to instrument operational modes listed in Table 1.

4.3.2.1 File Characteristics Data Elements

The PDS file characteristic data elements for MUPUS science data (level 2) are:

```
RECORD_TYPE    = FIXED_LENGTH
FILE_RECORDS
PROCESSING_LEVEL_ID
```

4.3.2.2 Data Object Pointers Identification Data Elements

The MUPUS SC data are organized as ASCII tables. The data object pointers (^TABLE) reference TAB files.

4.3.2.3 Data Object Definition

4.3.2.3.6 The description of the ANC table object

The ANC table contains fast anchor accelerator measurements during touch-down.

```
OBJECT                = ANC_TABLE
  NAME                = "ANC"
  INTERCHANGE_FORMAT = ASCII
  ROWS                =
  COLUMNS             = 5
  ROW_BYTES           = 72
  ^STRUCTURE          = "ANC.FMT"
END_OBJECT            = ANC_TABLE
```

The structure of the TABLE object is described in the file ANC.FMT (located in the LABEL directory) as follows:

```
OBJECT                = COLUMN
    NAME                = "UTC"
    DATA_TYPE           = TIME
    START_BYTE          = 1
    BYTES               = 23
    UNIT                = "N/A"
    DESCRIPTION         = "This column represents the UTC
                         in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT            = COLUMN

OBJECT                = COLUMN
    NAME                = "UTC_MSEC"
    DATA_TYPE           = ASCII_INTEGER
    START_BYTE          = 25
    BYTES               = 6
    FORMAT              = "I6"
    DESCRIPTION         = "UTC, microseconds part"
END_OBJECT            = COLUMN

OBJECT                = COLUMN
    NAME                = "MUPUS_TIME"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 33
    BYTES               = 8
    FORMAT              = "A8"
    DESCRIPTION         = "MUPUS On Board Time represented as a
                          32-bit integer (in hexadecimal format)
                          with 1 millisecond resolution.
```

```
                          It counts the time since the MUPUS boot and
                          overruns after 49.7 days (2^32 milliseconds)"
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
    NAME                = "ANC_MODE"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 44
    BYTES               = 14
    UNIT                = "N/A"
    DESCRIPTION         = "Possible values are:
                           MAIN
                           REDONDANT
                           MAIN TEST
                           REDONDANT TEST
                           "
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "ANC_ACC"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 60
    BYTES               = 11
    FORMAT              = "F11.6"
    UNIT                = "METER PER SECOND SQUARED"
    DESCRIPTION         = "Anchor accelerometer measurement values"
END_OBJECT            = COLUMN
```

4.3.2.3.7 The description of the HAM table object

The HAM table contains information obtained during the PEN insertion.

```
OBJECT                 = HAM_TABLE
  NAME                 = "HAM"
  INTERCHANGE_FORMAT   = ASCII
  ROWS                 =
  COLUMNS              = 11
  ROW_BYTES            = 81
  ^STRUCTURE           = "HAM.FMT"
END_OBJECT             = HAM_TABLE
```

The structure of the TABLE object is described in the file HAM.FMT (located in the LABEL directory) as follows:

```
OBJECT                 = COLUMN
    NAME                 = "UTC"
    DATA_TYPE            = TIME
    START_BYTE           = 1
    BYTES                = 23
    DESCRIPTION          = "This column represents the UTC
                          in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
    NAME                 = "MUPUS_TIME"
    DATA_TYPE            = CHARACTER
    START_BYTE           = 26
    BYTES                = 8
    FORMAT               = "A8"
    DESCRIPTION          = "MUPUS On Board Time represented as a
                            32-bit integer (in hexadecimal format)
                            with 1 millisecond resolution.
```

```
                          It counts the time since the MUPUS boot and
                          overruns after 49.7 days (2^32 milliseconds)"
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
    NAME                 = "TIME_DIFF1"
    DATA_TYPE            = ASCII_INTEGER
    START_BYTE           = 36
    BYTES                = 5
    FORMAT               = "I5"
    UNIT                 = "MILLISECOND"
    DESCRIPTION          = "Time difference for hammer stroke 1"
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
    NAME                 = "TIME_DIFF2"
    DATA_TYPE            = ASCII_INTEGER
    START_BYTE           = 42
    BYTES                = 5
    FORMAT               = "I5"
    UNIT                 = "MILLISECOND"
    DESCRIPTION          = "Time difference for hammer stroke 2"
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
    NAME                 = "TIME_DIFF3"
    DATA_TYPE            = ASCII_INTEGER
    START_BYTE           = 48
    BYTES                = 5
    FORMAT               = "I5"
    UNIT                 = "MILLISECOND"
    DESCRIPTION          = "Time difference for hammer stroke 3"
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
    NAME                 = "TIME_DIFF4"
    DATA_TYPE            = ASCII_INTEGER
    START_BYTE           = 54
    BYTES                = 5
    FORMAT               = "I5"
    UNIT                 = "MILLISECOND"
    DESCRIPTION          = "Time difference for hammer stroke 4"
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
    NAME                = "DEPTH_REF"
    DATA_TYPE           = ASCII_INTEGER
    START_BYTE          = 60
    BYTES               = 5
    FORMAT              = "I5"
    UNIT                = "N/A"
    DESCRIPTION         = "Reference depth measure at begin of insertion"
END_OBJECT            = COLUMN


OBJECT                 = COLUMN
    NAME                = "HAMMER_CYCLE_NUMBER"
    DATA_TYPE           = ASCII_INTEGER
    START_BYTE          = 66
    BYTES               = 5
    FORMAT              = "I5"
    UNIT                = "N/A"
    DESCRIPTION         = "Counter of hammer cycles, 4 strokes each"
END_OBJECT            = COLUMN
```

```
OBJECT                    = COLUMN
    NAME                   = "HAMMER_ENERGY_LEVEL"
    DATA_TYPE              = ASCII_INTEGER
    START_BYTE             = 72
    BYTES                  = 1
    FORMAT                 = "I1"
    UNIT                   = "N/A"
    DESCRIPTION            = "Hammer energy level.
                              Possible values are:
                              0, 1, 2, 3"
END_OBJECT               = COLUMN

OBJECT                    = COLUMN
    NAME                   = "NSAF"
    DATA_TYPE              = ASCII_INTEGER
    START_BYTE             = 74
    BYTES                  = 3
    FORMAT                 = "I3"
    UNIT                   = "N/A"
    DESCRIPTION            = "Hammer cycles at current
                              energy (mod 256)"
END_OBJECT               = COLUMN

OBJECT                    = COLUMN
    NAME                   = "DEPTH_VALUE"
    DATA_TYPE              = ASCII_INTEGER
    START_BYTE             = 78
    BYTES                  = 5
    FORMAT                 = "I5"
    UNIT                   = "N/A"
    DESCRIPTION            = "Current depth value measurement"
END_OBJECT               = COLUMN
```

4.3.2.3.8 The description of the MAP table object

The MAP table contains fast anchor accelerator measurements during touch-down.

```
OBJECT                    = MAP_TABLE
  NAME                    = "MAP"
  INTERCHANGE_FORMAT      = ASCII
  ROWS                    =
  COLUMNS                 = 16
  ROW_BYTES               = 136
  ^STRUCTURE              = "MAP.FMT"
END_OBJECT                = MAP_TABLE
```

The structure of the TABLE object is described in the file MAP.FMT (located in the LABEL directory) as follows:

```
OBJECT                    = COLUMN
    NAME                    = "UTC"
    DATA_TYPE               = TIME
    START_BYTE              = 1
    BYTES                   = 23
    DESCRIPTION             = "This column represents the UTC
                             in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                    = "MUPUS_TIME"
    DATA_TYPE               = CHARACTER
    START_BYTE              = 26
```

```
     BYTES                = 8
     FORMAT               = "A8"
     DESCRIPTION          = "MUPUS On Board Time represented as a
                             32-bit integer (in hexadecimal format)
                             with 1 millisecond resolution.
                             It counts the time since the MUPUS boot and
                             overruns after 49.7 days (2^32 milliseconds)"
END_OBJECT              = COLUMN

OBJECT                  = COLUMN
     NAME                = "PEN_DATA_FLAG"
     DATA_TYPE           = CHARACTER
     START_BYTE          = 37
     BYTES               = 3
     FORMAT              = "A3"
     UNIT                = "N/A"
     DESCRIPTION         = "Availability of PEN data.
                            Possible values are YES or NO"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
     NAME                = "TM_MODE"
     DATA_TYPE           = CHARACTER
     START_BYTE          = 43
     BYTES               = 8
     FORMAT              = "A8"
     UNIT                = "N/A"
     DESCRIPTION         = "Possible values are:
                            LONGTERM
                            TEM
                            THC
                            MAPPER
                            CMAPPER "
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
     NAME                = "TM_CHANNEL_A"
     DATA_TYPE           = CHARACTER
     START_BYTE          = 54
     BYTES               = 4
     FORMAT              = "A4"
     UNIT                = "ADC"
     DESCRIPTION         = "Thermal mapper thermopile channel A"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
     NAME                = "TM_CHANNEL_B"
     DATA_TYPE           = CHARACTER
     START_BYTE          = 61
     BYTES               = 4
     FORMAT              = "A4"
     UNIT                = "ADC"
     DESCRIPTION         = "Thermal mapper thermopile channel B"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
     NAME                = "TM_CHANNEL_C"
     DATA_TYPE           = CHARACTER
     START_BYTE          = 68
     BYTES               = 4
     FORMAT              = "A4"
     UNIT                = "ADC"
     DESCRIPTION         = "Thermal mapper thermopile channel C"
END_OBJECT             = COLUMN
```

```
OBJECT                     = COLUMN
    NAME                    = "TM_CHANNEL_D"
    DATA_TYPE               = CHARACTER
    START_BYTE              = 75
    BYTES                   = 4
    FORMAT                  = "A4"
    UNIT                    = "ADC"
    DESCRIPTION             = "Thermal mapper thermopile channel D"
END_OBJECT                = COLUMN

OBJECT                     = COLUMN
    NAME                    = "TM_BLACKBODY"
    DATA_TYPE               = CHARACTER
    START_BYTE              = 82
    BYTES                   = 4
    FORMAT                  = "A4"
    UNIT                    = "ADC"
    DESCRIPTION             = "Thermal mapper blackbody Pt-100"
END_OBJECT                = COLUMN

OBJECT                     = COLUMN
    NAME                    = "TM_CH_A_REF"
    DATA_TYPE               = CHARACTER
    START_BYTE              = 89
    BYTES                   = 4
    FORMAT                  = "A4"
    UNIT                    = "ADC"
    DESCRIPTION             = "Thermal mapper reference channel A Pt-1000"
END_OBJECT                = COLUMN

OBJECT                     = COLUMN
    NAME                    = "TM_CH_B_REF"
    DATA_TYPE               = CHARACTER
    START_BYTE              = 96
    BYTES                   = 4
    FORMAT                  = "A4"
    UNIT                    = "ADC"
    DESCRIPTION             = "Thermal mapper reference channel B Pt-1000"
END_OBJECT                = COLUMN

OBJECT                     = COLUMN
    NAME                    = "TM_CH_C_REF"
    DATA_TYPE               = CHARACTER
    START_BYTE              = 103
    BYTES                   = 4
    FORMAT                  = "A4"
    UNIT                    = "ADC"
    DESCRIPTION             = "Thermal mapper reference channel C Pt-1000"
END_OBJECT                = COLUMN

OBJECT                     = COLUMN
    NAME                    = "TM_CH_D_REF"
    DATA_TYPE               = CHARACTER
    START_BYTE              = 110
    BYTES                   = 4
    FORMAT                  = "A4"
    UNIT                    = "ADC"
    DESCRIPTION             = "Thermal mapper reference channel D Pt-1000"
END_OBJECT                = COLUMN

OBJECT                     = COLUMN
    NAME                    = "TM_ANCT1"
    DATA_TYPE               = CHARACTER
```

```
    START_BYTE        = 117
    BYTES             = 4
    FORMAT            = "A4"
    UNIT              = "ADC"
    DESCRIPTION       = "Anchor 1 temperature sensor Pt-100"
END_OBJECT          = COLUMN

OBJECT                = COLUMN
    NAME              = "TM_ANCT2"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 124
    BYTES             = 4
    FORMAT            = "A4"
    UNIT              = "ADC"
    DESCRIPTION       = "Anchor 2 temperature sensor Pt-100"
END_OBJECT          = COLUMN

OBJECT                = COLUMN
    NAME              = "POWER_STATUS_FLAGS"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 131
    BYTES             = 4
    FORMAT            = "A4"
    UNIT              = "N/A"
    DESCRIPTION       = "Power Status Flags"
END_OBJECT          = COLUMN
```

4.3.2.3.9 The description of the PEN table object

The PEN table contains fast anchor accelerator measurements during touch-down.

```
OBJECT               = PEN_TABLE
  NAME               = "PEN"
  INTERCHANGE_FORMAT = ASCII
  ROWS               =
  COLUMNS            = 38
  ROW_BYTES          = 271
  ^STRUCTURE         = "PEN.FMT"
END_OBJECT           = PEN_TABLE
```

The structure of the TABLE object is described in the file PEN.FMT (located in the LABEL directory) as follows:

```
OBJECT               = COLUMN
    NAME               = "UTC"
    DATA_TYPE          = TIME
    START_BYTE         = 1
    BYTES              = 23
    DESCRIPTION        = "This column represents the UTC
                          in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME               = "MUPUS_TIME"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 26
    BYTES              = 8
    FORMAT             = "A8"
    DESCRIPTION        = "MUPUS On Board Time represented as a
                           32-bit integer (in hexadecimal format)
                           with 1 millisecond resolution.
```

```
                          It counts the time since the MUPUS boot and
                          overruns after 49.7 days (2^32 milliseconds)"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME              = "TM_DATA_FLAG"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 37
    BYTES             = 3
    FORMAT            = "A3"
    UNIT              = "N/A"
    DESCRIPTION       = "Availability of TM data.
                         Possible values are YES or NO"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "PEN_T1"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 43
    BYTES             = 4
    FORMAT            = "A4"
    UNIT              = "ADC"
    DESCRIPTION       = "Temperature of PENEL sensor 1 "
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "HEAT_FLAG_1"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 50
    BYTES             = 3
   FORMAT            = "A3"
    UNIT              = "N/A"
    DESCRIPTION       = "Flag indicating if temperature sensor 1
                         was heated
                         Possible values are YES or NO"
END_OBJECT          = COLUMN


OBJECT               = COLUMN
    NAME              = "PEN_T2"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 56
    BYTES             = 4
    FORMAT            = "A4"
    UNIT              = "ADC"
    DESCRIPTION       = "Temperature of PENEL sensor 2 "
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "HEAT_FLAG_2"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 63
    BYTES             = 3
    FORMAT            = "A3"
    UNIT              = "N/A"
    DESCRIPTION       = "Flag indicating if temperature sensor 2
                         was heated
                         Possible values are YES or NO"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "PEN_T3"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 69
```

```
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "ADC"
    DESCRIPTION         = "Temperature of PENEL sensor 3"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HEAT_FLAG_3"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 76
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 3
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "PEN_T4"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 82
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "ADC"
    DESCRIPTION         = "Temperature of PENEL sensor 4 "
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HEAT_FLAG_4"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 89
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 4
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "PEN_T5"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 95
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "ADC"
    DESCRIPTION         = "Temperature of PENEL sensor 5 "
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HEAT_FLAG_5"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 102
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 5
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "PEN_T6"
```

```
    DATA_TYPE          = CHARACTER
    START_BYTE         = 108
    BYTES              = 4
    FORMAT             = "A4"
    UNIT               = "ADC"
    DESCRIPTION        = "Temperature of PENEL sensor 6"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "HEAT_FLAG_6"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 115
    BYTES              = 3
    FORMAT             = "A3"
    UNIT               = "N/A"
    DESCRIPTION        = "Flag indicating if temperature sensor 6
                          was heated
                          Possible values are YES or NO"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "PEN_T7"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 121
    BYTES              = 4
    FORMAT             = "A4"
    UNIT               = "ADC"
    DESCRIPTION        = "Temperature of PENEL sensor 7"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "HEAT_FLAG_7"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 128
    BYTES              = 3
    FORMAT             = "A3"
    UNIT               = "N/A"
    DESCRIPTION        = "Flag indicating if temperature sensor 7
                          was heated
                          Possible values are YES or NO"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "PEN_T8"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 134
    BYTES              = 4
    FORMAT             = "A4"
    UNIT               = "ADC"
    DESCRIPTION        = "Temperature of PENEL sensor 8 "
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "HEAT_FLAG_8"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 141
    BYTES              = 3
    FORMAT             = "A3"
    UNIT               = "N/A"
    DESCRIPTION        = "Flag indicating if temperature sensor 8
                          was heated
                          Possible values are YES or NO"
END_OBJECT           = COLUMN
```

```
OBJECT                   = COLUMN
    NAME                  = "PEN_T9"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 147
    BYTES                 = 4
    FORMAT                = "A4"
    UNIT                  = "ADC"
    DESCRIPTION           = "Temperature of PENEL sensor 9"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_9"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 154
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 9
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "PEN_T10"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 160
    BYTES                 = 4
    FORMAT                = "A4"
    UNIT                  = "ADC"
    DESCRIPTION           = "Temperature of PENEL sensor 10"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_10"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 167
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 10
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "PEN_T11"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 173
    BYTES                 = 4
    FORMAT                = "A4"
    UNIT                  = "ADC"
    DESCRIPTION           = "Temperature of PENEL sensor 11"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_11"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 180
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 11
                             was heated
                             Possible values are YES or NO"
```

```
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "PEN_T12"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 186
    BYTES             = 4
    FORMAT            = "A4"
    UNIT              = "ADC"
    DESCRIPTION       = "Temperature of PENEL sensor 12"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "HEAT_FLAG_12"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 193
    BYTES             = 3
    FORMAT            = "A3"
    UNIT              = "N/A"
    DESCRIPTION       = "Flag indicating if temperature sensor 12
                         was heated
                         Possible values are YES or NO"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "PEN_T13"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 199
    BYTES             = 4
    FORMAT            = "A4"
    UNIT              = "ADC"
    DESCRIPTION       = "Temperature of PENEL sensor 13"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "HEAT_FLAG_13"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 206
    BYTES             = 3
    FORMAT            = "A3"
    UNIT              = "N/A"
    DESCRIPTION       = "Flag indicating if temperature sensor 13
                         was heated
                         Possible values are YES or NO"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "PEN_T14"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 212
    BYTES             = 4
    FORMAT            = "A4"
    UNIT              = "ADC"
    DESCRIPTION       = "Temperature of PENEL sensor 14"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "HEAT_FLAG_14"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 219
    BYTES             = 3
    FORMAT            = "A3"
    UNIT              = "N/A"
    DESCRIPTION       = "Flag indicating if temperature sensor 14
```

```
                          was heated
                          Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "PEN_T15"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 225
    BYTES                 = 4
    FORMAT                = "A4"
    UNIT                  = "ADC"
    DESCRIPTION           = "Temperature of PENEL sensor 15"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_15"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 232
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 15
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "PEN_T16"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 238
    BYTES                 = 4
    FORMAT                = "A4"
    UNIT                  = "ADC"
    DESCRIPTION           = "Temperature of PENEL sensor 16"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_16"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 245
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 16
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

 OBJECT                   = COLUMN
    NAME                  = "HK1"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 251
    BYTES                 = 4
    FORMAT                = "A4"
    UNIT                  = "ADC"
    DESCRIPTION           = "Shortcut in holder for sensors 1-8"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HK2"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 258
    BYTES                 = 4
    FORMAT                = "A4"
```

```
    UNIT                = "ADC"
    DESCRIPTION         = "PT100 holder inset (outside)"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HK3"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 265
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "ADC"
    DESCRIPTION         = "TT100 holder ring (outside, uncalibrated)"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HK4_PENTS_ASSIST"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 272
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "ADC"
    DESCRIPTION         = "PT100 detector, temperature control
                           sensor inside PENEL"
END_OBJECT            = COLUMN

 OBJECT                 = COLUMN
    NAME                = "HK5"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 279
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "ADC"
    DESCRIPTION         = "TT100 holder (inside, uncalibrated)"
END_OBJECT            = COLUMN
OBJECT                 = COLUMN
    NAME                = "HK6"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 286
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "ADC"
    DESCRIPTION         = "100 Ohms reference resistor"
END_OBJECT            = COLUMN


OBJECT                 = COLUMN
    NAME                = "HK7"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 293
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "ADC"
    DESCRIPTION         = " Shortcut in holder for sensors 9-16"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HK8"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 300
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "ADC"
    DESCRIPTION         = "20 Ohms reference resistor"
```

```
END_OBJECT          = COLUMN
```

Science Data Product Design (Level 3)

The science data products are organized according to instrument operational modes listed in Table 1.

4.3.2.4 File Characteristics Data Elements

The PDS file characteristic data elements for MUPUS science data (level 3) are:

```
RECORD_TYPE    = FIXED_LENGTH
FILE_RECORDS
PROCESSING_LEVEL_ID
```

4.3.2.5 Data Object Pointers Identification Data Elements

The MUPUS SC data are organized as ASCII tables. The data object pointers (^TABLE) reference TAB files.

4.3.2.6 Data Object Definition

4.3.2.6.10 The description of the MAP_3A table object

The MAP_3A table contains ADC readings converted to mV of TM surface temperature and ANC-T measurements.

```
OBJECT               = MAP_3A_TABLE
  NAME               = "MAP_3A"
  INTERCHANGE_FORMAT = ASCII
  ROWS               =
  COLUMNS            = 16
  ROW_BYTES          = 178
  ^STRUCTURE         = "MAP_3A.FMT"
END_OBJECT           = MAP_3A_TABLE
```

The structure of the TABLE object is described in the file MAP_3A.FMT (located in the LABEL directory) as follows:

```
OBJECT               = COLUMN
    NAME               = "UTC"
    DATA_TYPE          = TIME
    START_BYTE         = 1
    BYTES              = 23
    DESCRIPTION        = "This column represents the UTC
                        in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME               = "MUPUS_TIME"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 26
    BYTES              = 8
    FORMAT             = "A8"
    DESCRIPTION        = "MUPUS On Board Time represented as a
                         32-bit integer (in hexadecimal format)
                         with 1 millisecond resolution.
                         It counts the time since the MUPUS boot and
                         overruns after 49.7 days (2^32 milliseconds)"
END_OBJECT           = COLUMN
```

```
OBJECT                    = COLUMN
    NAME                   = "PEN_DATA_FLAG"
    DATA_TYPE              = CHARACTER
    START_BYTE             = 37
    BYTES                  = 3
    FORMAT                 = "A3"
    UNIT                   = "N/A"
    DESCRIPTION            = "Availability of PEN data.
                              Possible values are YES or NO"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "TM_MODE"
    DATA_TYPE              = CHARACTER
    START_BYTE             = 43
    BYTES                  = 8
    FORMAT                 = "A8"
    UNIT                   = "N/A"
    DESCRIPTION            = "Possible values are:
                              LONGTERM
                              TEM
                              THC
                              MAPPER
                              CMAPPER "
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "TM_CHANNEL_A"
    DATA_TYPE              = ASCII_REAL
    START_BYTE             = 53
    BYTES                  = 9
    FORMAT                 = "F9.3"
    UNIT                   = "MILLIVOLT"
    DESCRIPTION            = "Thermal mapper thermopile channel A
                              ADC readings converted to mV"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "TM_CHANNEL_B"
    DATA_TYPE              = ASCII_REAL
    START_BYTE             = 63
    BYTES                  = 9
    FORMAT                 = "F9.3"
    UNIT                   = "MILLIVOLT"
    DESCRIPTION            = "Thermal mapper thermopile channel B
                              ADC readings converted to mV"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "TM_CHANNEL_C"
    DATA_TYPE              = ASCII_REAL
    START_BYTE             = 73
    BYTES                  = 9
    FORMAT                 = "F9.3"
    UNIT                   = "MILLIVOLT"
    DESCRIPTION            = "Thermal mapper thermopile channel C
                              ADC readings converted to mV"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "TM_CHANNEL_D"
    DATA_TYPE              = ASCII_REAL
    START_BYTE             = 83
    BYTES                  = 9
```

```
    FORMAT              = "F9.3"
    UNIT                = "MILLIVOLT"
    DESCRIPTION         = "Thermal mapper thermopile channel D
                            ADC readings converted to mV"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "TM_BLACKBODY"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 93
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIVOLT"
    DESCRIPTION         = "Thermal mapper blackbody Pt-100
                            ADC readings converted to mV"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "TM_CH_A_REF"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 103
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIVOLT"
    DESCRIPTION         = "Thermal mapper reference channel A Pt-1000
                            ADC readings converted to mV"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "TM_CH_B_REF"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 113
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIVOLT"
    DESCRIPTION         = "Thermal mapper reference channel B Pt-1000
                            ADC readings converted to mV"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "TM_CH_C_REF"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 123
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIVOLT"
    DESCRIPTION         = "Thermal mapper reference channel C Pt-1000
                            ADC readings converted to mV"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "TM_CH_D_REF"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 133
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIVOLT"
    DESCRIPTION         = "Thermal mapper reference channel D Pt-1000
                            ADC readings converted to mV"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "TM_ANCT1"
    DATA_TYPE           = ASCII_REAL
```

```
    START_BYTE        = 143
    BYTES             = 9
    FORMAT            = "F9.3"
    UNIT              = "MILLIVOLT"
    DESCRIPTION       = "Anchor 1 temperature sensor Pt-100
                         ADC readings converted to mV"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "TM_ANCT2"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 153
    BYTES             = 9
    FORMAT            = "F9.3"
    UNIT              = "MILLIVOLT"
    DESCRIPTION       = "Anchor 2 temperature sensor Pt-100
                         ADC readings converted to mV"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "POWER_STATUS_FLAGS"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 164
    BYTES             = 12
    FORMAT            = "A12"
    UNIT              = "N/A"
    DESCRIPTION       = "Power Status Flags
                         The possible values are
                           1: true
                           0: false
                         The 12 flags are the following.
                           Heater
                           Low Power Mode
                           Nominal Power Mode
                           Calibration Mode
                           Last heat time > 1h40min
                           TM powered
                           Calibration mode (sub-mode) refused
                           PEN_EL Heater
                           Mode Flag
                           Mean Flag
                           Last Heat Time > 1h
                           PEN powered"
END_OBJECT          = COLUMN
```

4.3.2.6.11 The description of the MAP_3B table object

The MAP_3B table contains ADC readings converted to K of TM surface temperature and ANC-T measurements.

```
OBJECT               = MAP_3B_TABLE
  NAME               = "MAP_3B"
  INTERCHANGE_FORMAT = ASCII
  ROWS               =
  COLUMNS            = 16
  ROW_BYTES          = 155
  ^STRUCTURE         = "MAP_3B.FMT"
END_OBJECT           = MAP_3B_TABLE
```

The structure of the TABLE object is described in the file MAP_3B.FMT (located in the LABEL directory) as follows:

```
OBJECT                    = COLUMN
    NAME                    = "UTC"
    DATA_TYPE               = TIME
    START_BYTE              = 1
    BYTES                   = 23
    DESCRIPTION             = "This column represents the UTC
                             in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                    = "MUPUS_TIME"
    DATA_TYPE               = CHARACTER
    START_BYTE              = 27
    BYTES                   = 8
    FORMAT                  = "A8"
    DESCRIPTION             = "MUPUS On Board Time represented as a
                              32-bit integer (in hexadecimal format)
                              with 1 millisecond resolution.
                              It counts the time since the MUPUS boot and
                              overruns after 49.7 days (2^32 milliseconds)"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "PEN_DATA_FLAG"
    DATA_TYPE              = CHARACTER
    START_BYTE             = 38
    BYTES                  = 3
    FORMAT                 = "A3"
    UNIT                   = "N/A"
    DESCRIPTION            = "Availability of PEN data.
                             Possible values are YES or NO"
END_OBJECT               = COLUMN

OBJECT                    = COLUMN
    NAME                   = "TM_MODE"
    DATA_TYPE              = CHARACTER
    START_BYTE             = 44
    BYTES                  = 8
    FORMAT                 = "A8"
    UNIT                   = "N/A"
    DESCRIPTION            = "Possible values are:
                             LONGTERM
                             TEM
                             THC
                             MAPPER
                             CMAPPER "
END_OBJECT               = COLUMN

OBJECT                    = COLUMN
    NAME                   = "TM_CHANNEL_A"
    DATA_TYPE              = ASCII_REAL
    START_BYTE             = 55
    BYTES                  = 7
    FORMAT                 = "F7.2"
    UNIT                   = "KELVIN"
    DESCRIPTION            = "Thermal mapper thermopile channel A
                             ADC readings converted to KELVIN"
END_OBJECT               = COLUMN

OBJECT                    = COLUMN
    NAME                   = "TM_CHANNEL_B"
    DATA_TYPE              = ASCII_REAL
    START_BYTE             = 63
    BYTES                  = 7
```

```
    FORMAT                = "F7.2"
    UNIT                  = "KELVIN"
    DESCRIPTION           = "Thermal mapper thermopile channel B
                             ADC readings converted to KELVIN"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "TM_CHANNEL_C"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 71
    BYTES                 = 7
    FORMAT                = "F7.2"
    UNIT                  = "KELVIN"
    DESCRIPTION           = "Thermal mapper thermopile channel C
                             ADC readings converted to KELVIN"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "TM_CHANNEL_D"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 79
    BYTES                 = 7
    FORMAT                = "F7.2"
    UNIT                  = "KELVIN"
    DESCRIPTION           = "Thermal mapper thermopile channel D
                             ADC readings converted to KELVIN"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "TM_BLACKBODY"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 87
    BYTES                 = 7
    FORMAT                = "F7.2"
    UNIT                  = "KELVIN"
    DESCRIPTION           = "Thermal mapper blackbody Pt-100
                             ADC readings converted to KELVIN"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "TM_CH_A_REF"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 95
    BYTES                 = 7
    FORMAT                = "F7.2"
    UNIT                  = "KELVIN"
    DESCRIPTION           = "Thermal mapper reference channel A Pt-1000
                             ADC readings converted to KELVIN"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "TM_CH_B_REF"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 103
    BYTES                 = 7
    FORMAT                = "F7.2"
    UNIT                  = "KELVIN"
    DESCRIPTION           = "Thermal mapper reference channel B Pt-1000
                             ADC readings converted to KELVIN"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "TM_CH_C_REF"
    DATA_TYPE             = ASCII_REAL
```

```
    START_BYTE        = 111
    BYTES             = 7
    FORMAT            = "F7.2"
    UNIT              = "KELVIN"
    DESCRIPTION       = "Thermal mapper reference channel C Pt-1000
                         ADC readings converted to KELVIN"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "TM_CH_D_REF"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 119
    BYTES             = 7
    FORMAT            = "F7.2"
    UNIT              = "KELVIN"
    DESCRIPTION       = "Thermal mapper reference channel D Pt-1000
                         ADC readings converted to KELVIN"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "TM_ANCT1"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 127
    BYTES             = 7
    FORMAT            = "F7.2"
    UNIT              = "KELVIN"
    DESCRIPTION       = "Anchor 1 temperature sensor Pt-100
                         ADC readings converted to KELVIN"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "TM_ANCT2"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 135
    BYTES             = 7
    FORMAT            = "F7.2"
    UNIT              = "KELVIN"
    DESCRIPTION       = "Anchor 2 temperature sensor Pt-100
                         ADC readings converted to KELVIN"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "POWER_STATUS_FLAGS"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 145
    BYTES             = 8
    FORMAT            = "A8"
    UNIT              = "N/A"
    DESCRIPTION       = "Power Status Flags
                         The possible values are
                           1: true
                           0: false
                         The 8 flags are the following.
                           Heater ON
                           Low Power Mode
                           Nominal Power Mode
                           Calibration Mode
                           TM powered
                           Ops Heater ON
                           PEN_EL Heater ON
                           PEN powered"
END_OBJECT          = COLUMN
```

4.3.2.6.12 The description of the PEN_3A table object

The PEN_3A table contains ADC readings converted to mV of PENEL temperature sensors.

```
OBJECT               = PEN_3A_TABLE
  NAME               = "PEN_3A"
  INTERCHANGE_FORMAT = ASCII
  ROWS               =
  COLUMNS            = 38
  ROW_BYTES          = 328
  ^STRUCTURE         = "PEN_3A.FMT"
END_OBJECT           = PEN_3A_TABLE
```

The structure of the TABLE object is described in the file PEN_3A.FMT (located in the LABEL directory) as follows:

```
OBJECT               = COLUMN
    NAME               = "UTC"
    DATA_TYPE          = TIME
    START_BYTE         = 1
    BYTES              = 23
    DESCRIPTION        = "This column represents the UTC
                        in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME               = "MUPUS_TIME"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 26
    BYTES              = 8
    FORMAT             = "A8"
    DESCRIPTION        = "MUPUS On Board Time represented as a
                          32-bit integer (in hexadecimal format)
                          with 1 millisecond resolution.
                          It counts the time since the MUPUS boot and
                          overruns after 49.7 days (2^32 milliseconds)"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME              = "TM_DATA_FLAG"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 37
    BYTES             = 3
    FORMAT            = "A3"
    UNIT              = "N/A"
    DESCRIPTION       = "Availability of TM data.
                         Possible values are YES or NO"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "PEN_T1"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 42
    BYTES             = 9
    FORMAT            = "F9.3"
    UNIT              = "MILLIVOLT"
    DESCRIPTION       = "Temperature of PENEL sensor 1 "
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "HEAT_FLAG_1"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 53
    BYTES             = 3
```

```
     FORMAT               = "A3"
     UNIT                 = "N/A"
     DESCRIPTION          = "Flag indicating if temperature sensor 1
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN


OBJECT                   = COLUMN
     NAME                 = "PEN_T2"
     DATA_TYPE            = ASCII_REAL
     START_BYTE           = 58
     BYTES                = 9
     FORMAT               = "F9.3"
     UNIT                 = "MILLIVOLT"
     DESCRIPTION          = "Temperature of PENEL sensor 2 "
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
     NAME                 = "HEAT_FLAG_2"
     DATA_TYPE            = CHARACTER
     START_BYTE           = 69
     BYTES                = 3
     FORMAT               = "A3"
     UNIT                 = "N/A"
     DESCRIPTION          = "Flag indicating if temperature sensor 2
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
     NAME                 = "PEN_T3"
     DATA_TYPE            = ASCII_REAL
     START_BYTE           = 74
     BYTES                = 9
     FORMAT               = "F9.3"
     UNIT                 = "MILLIVOLT"
     DESCRIPTION          = "Temperature of PENEL sensor 3"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
     NAME                 = "HEAT_FLAG_3"
     DATA_TYPE            = CHARACTER
     START_BYTE           = 85
     BYTES                = 3
     FORMAT               = "A3"
     UNIT                 = "N/A"
     DESCRIPTION          = "Flag indicating if temperature sensor 3
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
     NAME                 = "PEN_T4"
     DATA_TYPE            = ASCII_REAL
     START_BYTE           = 90
     BYTES                = 9
     FORMAT               = "F9.3"
     UNIT                 = "MILLIVOLT"
     DESCRIPTION          = "Temperature of PENEL sensor 4 "
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
     NAME                 = "HEAT_FLAG_4"
```

```
    DATA_TYPE           = CHARACTER
    START_BYTE          = 101
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 4
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "PEN_T5"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 106
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIVOLT"
    DESCRIPTION         = "Temperature of PENEL sensor 5 "
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HEAT_FLAG_5"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 117
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 5
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "PEN_T6"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 122
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIVOLT"
    DESCRIPTION         = "Temperature of PENEL sensor 6"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HEAT_FLAG_6"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 133
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 6
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "PEN_T7"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 138
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIVOLT"
    DESCRIPTION         = "Temperature of PENEL sensor 7"
END_OBJECT            = COLUMN
```

```
OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_7"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 149
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 7
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "PEN_T8"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 154
    BYTES                 = 9
    FORMAT                = "F9.3"
    UNIT                  = "MILLIVOLT"
    DESCRIPTION           = "Temperature of PENEL sensor 8 "
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_8"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 165
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 8
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "PEN_T9"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 170
    BYTES                 = 9
    FORMAT                = "F9.3"
    UNIT                  = "MILLIVOLT"
    DESCRIPTION           = "Temperature of PENEL sensor 9"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_9"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 181
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 9
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "PEN_T10"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 186
    BYTES                 = 9
    FORMAT                = "F9.3"
    UNIT                  = "MILLIVOLT"
    DESCRIPTION           = "Temperature of PENEL sensor 10"
```

```
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "HEAT_FLAG_10"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 197
    BYTES              = 3
    FORMAT             = "A3"
    UNIT               = "N/A"
    DESCRIPTION        = "Flag indicating if temperature sensor 10
                          was heated
                          Possible values are YES or NO"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "PEN_T11"
    DATA_TYPE          = ASCII_REAL
    START_BYTE         = 202
    BYTES              = 9
    FORMAT             = "F9.3"
    UNIT               = "MILLIVOLT"
    DESCRIPTION        = "Temperature of PENEL sensor 11"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "HEAT_FLAG_11"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 213
    BYTES              = 3
    FORMAT             = "A3"
    UNIT               = "N/A"
    DESCRIPTION        = "Flag indicating if temperature sensor 111
                          was heated
                          Possible values are YES or NO"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "PEN_T12"
    DATA_TYPE          = ASCII_REAL
    START_BYTE         = 218
    BYTES              = 9
    FORMAT             = "F9.3"
    UNIT               = "MILLIVOLT"
    DESCRIPTION        = "Temperature of PENEL sensor 12"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "HEAT_FLAG_12"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 229
    BYTES              = 3
    FORMAT             = "A3"
    UNIT               = "N/A"
    DESCRIPTION        = "Flag indicating if temperature sensor 12
                          was heated
                          Possible values are YES or NO"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "PEN_T13"
    DATA_TYPE          = ASCII_REAL
    START_BYTE         = 234
    BYTES              = 9
    FORMAT             = "F9.3"
```

```
    UNIT                  = "MILLIVOLT"
    DESCRIPTION           = "Temperature of PENEL sensor 13"
END_OBJECT              = COLUMN

OBJECT                    = COLUMN
    NAME                  = "HEAT_FLAG_13"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 245
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 13
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                    = COLUMN
    NAME                  = "PEN_T14"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 250
    BYTES                 = 9
    FORMAT                = "F9.3"
    UNIT                  = "MILLIVOLT"
    DESCRIPTION           = "Temperature of PENEL sensor 14"
END_OBJECT              = COLUMN

OBJECT                    = COLUMN
    NAME                  = "HEAT_FLAG_14"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 261
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 14
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                    = COLUMN
    NAME                  = "PEN_T15"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 266
    BYTES                 = 9
    FORMAT                = "F9.3"
    UNIT                  = "MILLIVOLT"
    DESCRIPTION           = "Temperature of PENEL sensor 15"
END_OBJECT              = COLUMN

OBJECT                    = COLUMN
    NAME                  = "HEAT_FLAG_15"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 277
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 15
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                    = COLUMN
    NAME                  = "PEN_T16"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 282
```

```
    BYTES                = 9
    FORMAT               = "F9.3"
    UNIT                 = "MILLIVOLT"
    DESCRIPTION          = "Temperature of PENEL sensor 16"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "HEAT_FLAG_16"
    DATA_TYPE            = CHARACTER
    START_BYTE           = 293
    BYTES                = 3
    FORMAT               = "A3"
    UNIT                 = "N/A"
    DESCRIPTION          = "Flag indicating if temperature sensor 16
                            was heated
                            Possible values are YES or NO"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "HK2"
    DATA_TYPE            = ASCII_REAL
    START_BYTE           = 298
    BYTES                = 9
    FORMAT               = "F9.3"
    UNIT                 = "MILLIVOLT"
    DESCRIPTION          = "PT100 holder inset (outside)"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "HK3"
    DATA_TYPE            = ASCII_REAL
    START_BYTE           = 308
    BYTES                = 9
    FORMAT               = "F9.3"
    UNIT                 = "MILLIVOLT"
    DESCRIPTION          = "PT100 holder ring (outside)"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "HK4_PENTS_ASSIST"
    DATA_TYPE            = ASCII_REAL
    START_BYTE           = 318
    BYTES                = 9
    FORMAT               = "F9.3"
    UNIT                 = "MILLIVOLT"
    DESCRIPTION          = "PT100 detector, temperature control
                            sensor inside PENEL"
END_OBJECT             = COLUMN
```

4.3.2.6.13 The description of the PEN_3B table object

The PEN_3B table contains temperature of PENEL sensors in K.

```
OBJECT                  = PEN_3B_TABLE
  NAME                  = "PEN_3B"
  INTERCHANGE_FORMAT    = ASCII
  ROWS                  =
  COLUMNS               = 35
  ROW_BYTES             = 266
  ^STRUCTURE            = "PEN_3B.FMT"
END_OBJECT              = PEN_3B_TABLE
```

The structure of the TABLE object is described in the file PEN_3B.FMT (located in the LABEL directory) as follows:

```
OBJECT                  = COLUMN
    NAME                  = "UTC"
    DATA_TYPE             = TIME
    START_BYTE            = 1
    BYTES                 = 23
    DESCRIPTION           = "This column represents the UTC
                           in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT              = COLUMN

OBJECT                  = COLUMN
    NAME                  = "MUPUS_TIME"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 26
    BYTES                 = 8
    FORMAT                = "A8"
    DESCRIPTION           = "MUPUS On Board Time represented as a
                             32-bit integer (in hexadecimal format)
                             with 1 millisecond resolution.
                             It counts the time since the MUPUS boot and
                             overruns after 49.7 days (2^32 milliseconds)"
END_OBJECT              = COLUMN

OBJECT                  = COLUMN
    NAME                 = "TM_DATA_FLAG"
    DATA_TYPE            = CHARACTER
    START_BYTE           = 37
    BYTES                = 3
    FORMAT               = "A3"
    UNIT                 = "N/A"
    DESCRIPTION          = "Availability of TM data.
                            Possible values are YES or NO"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "PEN_T1"
    DATA_TYPE            = ASCII_REAL
    START_BYTE           = 42
    BYTES                = 7
    FORMAT               = "F7.2"
    UNIT                 = "KELVIN"
    DESCRIPTION          = "Temperature of PENEL sensor 1 "
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "HEAT_FLAG_1"
    DATA_TYPE            = CHARACTER
    START_BYTE           = 51
    BYTES                = 3
```

```
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 1
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN


OBJECT                 = COLUMN
    NAME                = "PEN_T2"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 56
    BYTES               = 7
    FORMAT              = "F7.2"
    UNIT                = "KELVIN"
    DESCRIPTION         = "Temperature of PENEL sensor 2 "
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HEAT_FLAG_2"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 65
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 2
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "PEN_T3"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 70
    BYTES               = 7
    FORMAT              = "F7.2"
    UNIT                = "KELVIN"
    DESCRIPTION         = "Temperature of PENEL sensor 3"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HEAT_FLAG_3"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 79
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 3
                           was heated
                           Possible values are YES or NO"
```

```
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "PEN_T4"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 84
    BYTES             = 7
    FORMAT            = "F7.2"
    UNIT              = "KELVIN"
    DESCRIPTION       = "Temperature of PENEL sensor 4 "
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "HEAT_FLAG_4"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 93
    BYTES             = 3
    FORMAT            = "A3"
    UNIT              = "N/A"
    DESCRIPTION       = "Flag indicating if temperature sensor 4
                         was heated
                         Possible values are YES or NO"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "PEN_T5"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 98
    BYTES             = 7
    FORMAT            = "F7.2"
    UNIT              = "KELVIN"
    DESCRIPTION       = "Temperature of PENEL sensor 5 "
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "HEAT_FLAG_5"
    DATA_TYPE         = CHARACTER
    START_BYTE        = 107
    BYTES             = 3
    FORMAT            = "A3"
    UNIT              = "N/A"
    DESCRIPTION       = "Flag indicating if temperature sensor 5
                         was heated
                         Possible values are YES or NO"
END_OBJECT          = COLUMN

OBJECT               = COLUMN
    NAME              = "PEN_T6"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 112
```

```
    BYTES              = 7
    FORMAT             = "F7.2"
    UNIT               = "KELVIN"
    DESCRIPTION        = "Temperature of PENEL sensor 6"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "HEAT_FLAG_6"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 121
    BYTES              = 3
    FORMAT             = "A3"
    UNIT               = "N/A"
    DESCRIPTION        = "Flag indicating if temperature sensor 6
                          was heated
                          Possible values are YES or NO"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "PEN_T7"
    DATA_TYPE          = ASCII_REAL
    START_BYTE         = 126
    BYTES              = 7
    FORMAT             = "F7.2"
    UNIT               = "KELVIN"
    DESCRIPTION        = "Temperature of PENEL sensor 7"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "HEAT_FLAG_7"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 135
    BYTES              = 3
    FORMAT             = "A3"
    UNIT               = "N/A"
    DESCRIPTION        = "Flag indicating if temperature sensor 7
                          was heated
                          Possible values are YES or NO"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "PEN_T8"
    DATA_TYPE          = ASCII_REAL
    START_BYTE         = 140
    BYTES              = 7
    FORMAT             = "F7.2"
    UNIT               = "KELVIN"
    DESCRIPTION        = "Temperature of PENEL sensor 8 "
END_OBJECT           = COLUMN
```

```
OBJECT                  = COLUMN
    NAME                 = "HEAT_FLAG_8"
    DATA_TYPE            = CHARACTER
    START_BYTE           = 149
    BYTES                = 3
    FORMAT               = "A3"
    UNIT                 = "N/A"
    DESCRIPTION          = "Flag indicating if temperature sensor 8
                            was heated
                            Possible values are YES or NO"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "PEN_T9"
    DATA_TYPE            = ASCII_REAL
    START_BYTE           = 154
    BYTES                = 7
    FORMAT               = "F7.2"
    UNIT                 = "KELVIN"
    DESCRIPTION          = "Temperature of PENEL sensor 9"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "HEAT_FLAG_9"
    DATA_TYPE            = CHARACTER
    START_BYTE           = 163
    BYTES                = 3
    FORMAT               = "A3"
    UNIT                 = "N/A"
    DESCRIPTION          = "Flag indicating if temperature sensor 9
                            was heated
                            Possible values are YES or NO"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "PEN_T10"
    DATA_TYPE            = ASCII_REAL
    START_BYTE           = 168
    BYTES                = 7
    FORMAT               = "F7.2"
    UNIT                 = "KELVIN"
    DESCRIPTION          = "Temperature of PENEL sensor 10"
END_OBJECT             = COLUMN

OBJECT                  = COLUMN
    NAME                 = "HEAT_FLAG_10"
    DATA_TYPE            = CHARACTER
    START_BYTE           = 177
    BYTES                = 3
    FORMAT               = "A3"
```

```
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 10
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "PEN_T11"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 182
    BYTES               = 7
    FORMAT              = "F7.2"
    UNIT                = "KELVIN"
    DESCRIPTION         = "Temperature of PENEL sensor 11"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HEAT_FLAG_11"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 191
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 111
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "PEN_T12"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 196
    BYTES               = 7
    FORMAT              = "F7.2"
    UNIT                = "KELVIN"
    DESCRIPTION         = "Temperature of PENEL sensor 12"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "HEAT_FLAG_12"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 205
    BYTES               = 3
    FORMAT              = "A3"
    UNIT                = "N/A"
    DESCRIPTION         = "Flag indicating if temperature sensor 12
                           was heated
                           Possible values are YES or NO"
END_OBJECT            = COLUMN
```

```
OBJECT                    = COLUMN
    NAME                   = "PEN_T13"
    DATA_TYPE              = ASCII_REAL
    START_BYTE             = 210
    BYTES                  = 7
    FORMAT                 = "F7.2"
    UNIT                   = "KELVIN"
    DESCRIPTION            = "Temperature of PENEL sensor 13"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "HEAT_FLAG_13"
    DATA_TYPE              = CHARACTER
    START_BYTE             = 219
    BYTES                  = 3
    FORMAT                 = "A3"
    UNIT                   = "N/A"
    DESCRIPTION            = "Flag indicating if temperature sensor 13
                              was heated
                              Possible values are YES or NO"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "PEN_T14"
    DATA_TYPE              = ASCII_REAL
    START_BYTE             = 224
    BYTES                  = 7
    FORMAT                 = "F7.2"
    UNIT                   = "KELVIN"
    DESCRIPTION            = "Temperature of PENEL sensor 14"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "HEAT_FLAG_14"
    DATA_TYPE              = CHARACTER
    START_BYTE             = 233
    BYTES                  = 3
    FORMAT                 = "A3"
    UNIT                   = "N/A"
    DESCRIPTION            = "Flag indicating if temperature sensor 14
                              was heated
                              Possible values are YES or NO"
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
    NAME                   = "PEN_T15"
    DATA_TYPE              = ASCII_REAL
    START_BYTE             = 238
    BYTES                  = 7
    FORMAT                 = "F7.2"
```

```
    UNIT                  = "KELVIN"
    DESCRIPTION           = "Temperature of PENEL sensor 15"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_15"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 247
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 15
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "PEN_T16"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 252
    BYTES                 = 7
    FORMAT                = "F7.2"
    UNIT                  = "KELVIN"
    DESCRIPTION           = "Temperature of PENEL sensor 16"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HEAT_FLAG_16"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 261
    BYTES                 = 3
    FORMAT                = "A3"
    UNIT                  = "N/A"
    DESCRIPTION           = "Flag indicating if temperature sensor 16
                             was heated
                             Possible values are YES or NO"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HK2"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 266
    BYTES                 = 7
    FORMAT                = "F7.2"
    UNIT                  = "KELVIN"
    DESCRIPTION           = "PT100 holder inset (outside)"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "HK4_PENTS_ASSIST"
    DATA_TYPE             = ASCII_REAL
    START_BYTE            = 277
    BYTES                 = 7
```

```
    FORMAT            = "F7.2"
    UNIT              = "KELVIN"
    DESCRIPTION       = "PT100 detector, temperature control
                         sensor inside PENEL"
END_OBJECT          = COLUMN
```

4.3.2.6.14 The description of the HAM_3B table object

The HAM_3B table contains the depth sensor readings in mm (relative to initial position) counted positive downwards.

```
OBJECT                = HAM_3B_TABLE
  NAME                = "HAM_3B"
  INTERCHANGE_FORMAT  = ASCII
  ROWS                = 216
  COLUMNS             = 11
  ROW_BYTES           = 84
  ^STRUCTURE          = "HAM_3B.FMT"
END_OBJECT            = HAM_3B_TABLE
```

The structure of the TABLE object is described in the file HAM_3B.FMT (located in the LABEL directory) as follows:

```
OBJECT                = COLUMN
  NAME                = "UTC"
  DATA_TYPE           = TIME
  START_BYTE          = 1
  BYTES               = 23
  DESCRIPTION         = "This column represents the UTC
                        in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT            = COLUMN

OBJECT                = COLUMN
  NAME                = "MUPUS_TIME"
  DATA_TYPE           = CHARACTER
  START_BYTE          = 27
  BYTES               = 8
  FORMAT              = "A8"
  DESCRIPTION         = "MUPUS On Board Time represented as a
                         32-bit integer (in hexadecimal format)
                         with 1 millisecond resolution.
                         It counts the time since the MUPUS boot and
                         overruns after 49.7 days (2^32 milliseconds)"
END_OBJECT            = COLUMN

OBJECT                = COLUMN
  NAME                = "TIME_DIFF1"
  DATA_TYPE           = ASCII_INTEGER
  START_BYTE          = 38
  BYTES               = 5
  FORMAT              = "I5"
  UNIT                = "MILLISECOND"
  DESCRIPTION         = "Time difference for hammer stroke 1"
END_OBJECT            = COLUMN

OBJECT                = COLUMN
  NAME                = "TIME_DIFF2"
  DATA_TYPE           = ASCII_INTEGER
  START_BYTE          = 44
  BYTES               = 5
  FORMAT              = "I5"
  UNIT                = "MILLISECOND"
  DESCRIPTION         = "Time difference for hammer stroke 2"
END_OBJECT            = COLUMN
```

```
OBJECT                     = COLUMN
  NAME                     = "TIME_DIFF3"
  DATA_TYPE                = ASCII_INTEGER
  START_BYTE               = 50
  BYTES                    = 5
  FORMAT                   = "I5"
  UNIT                     = "MILLISECOND"
  DESCRIPTION              = "Time difference for hammer stroke 3"
END_OBJECT                 = COLUMN

OBJECT                     = COLUMN
  NAME                     = "TIME_DIFF4"
  DATA_TYPE                = ASCII_INTEGER
  START_BYTE               = 56
  BYTES                    = 5
  FORMAT                   = "I5"
  UNIT                     = "MILLISECOND"
 DESCRIPTION              = "Time difference for hammer stroke 4"
 END_OBJECT                  = COLUMN

OBJECT                     = COLUMN
NAME                    = "DEPTH_REF"
  DATA_TYPE               = ASCII_INTEGER
  START_BYTE              = 62
  BYTES                   = 5
  FORMAT                  = "I5"
  UNIT                    = "N/A"
 DESCRIPTION             = "Reference depth measure at begin of
                            insertion"
END_OBJECT                = COLUMN

OBJECT                     = COLUMN
  NAME                    = "HAMMER_CYCLE_NUMBER"
  DATA_TYPE               = ASCII_INTEGER
  START_BYTE              = 68
  BYTES                   = 5
  FORMAT                  = "I5"
  UNIT                    = "N/A"
  DESCRIPTION             = "Counter of hammer cycles, 4 strokes each"
END_OBJECT                = COLUMN

OBJECT                     = COLUMN
  NAME                    = "HAMMER_ENERGY_LEVEL"
  DATA_TYPE               = ASCII_INTEGER
  START_BYTE              = 74
  BYTES                   = 1
  FORMAT                  = "I1"
  UNIT                    = "N/A"
  DESCRIPTION             = "Hammer energy level.
                             Possible values are
                             0, 1, 2, 3"
END_OBJECT                = COLUMN

OBJECT                     = COLUMN
  NAME                    = "NSAF"
  DATA_TYPE               = ASCII_INTEGER
  START_BYTE              = 76
  BYTES                   = 3
  FORMAT                  = "I3"
  UNIT                    = "N/A"
  DESCRIPTION             = "Hammer cycles at current
                             energy (mod 256)"
 END_OBJECT                = COLUMN
```

```
OBJECT                = COLUMN
  NAME               = "DEPTH_VALUE"
  DATA_TYPE          = ASCII_INTEGER
  START_BYTE         = 80
  BYTES              = 3
  FORMAT             = "I3"
  UNIT               = "MILLIMETER"
  DESCRIPTION        = "Current depth value measurement"
END_OBJECT           = COLUMN
```

4.3.3 Housekeeping Calibrated Data Product Design (Level 3)

4.3.3.1 File Characteristics Data Elements

The PDS file characteristic data elements for MUPUS HK calibrated data are:

```
RECORD_TYPE           = FIXED_LENGTH
RECORD_BYTES          = 324
PROCESSING_LEVEL_ID
```

4.3.3.2 Data Object Pointers Identification Data Elements

The MUPUS HK data are organized as ASCII tables. The data object pointers (^TABLE) reference TAB files.

4.3.3.3 Data Object Definition

4.3.3.3.15 The description of the HK table object

The HK table contains calibrated housekeeping data.

```
OBJECT                = HK_TABLE
  NAME                = "HK"
  INTERCHANGE_FORMAT  = ASCII
  ROWS                =
  COLUMNS             = 35
  ROW_BYTES           = 324
  ^STRUCTURE          = "HK.FMT"
END_OBJECT            = HK_TABLE
```

The structure of the TABLE object is described in the file HK.FMT (located in the LABEL directory) as follows:

```
OBJECT                = COLUMN
    NAME                = "UTC"
    DATA_TYPE           = TIME
    START_BYTE          = 1
    BYTES               = 23
    DESCRIPTION         = "This column represents the UTC
                         in PDS standard format YYYY-MM-DDThh:mm:ss.sss"
END_OBJECT            = COLUMN

OBJECT                = COLUMN
    NAME               = "LOBT_HIGH"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 26
    BYTES              = 4
```

```
    FORMAT                = "A4"
    DESCRIPTION           = "Lander On Board Time high word (hex)"
END_OBJECT               = COLUMN

OBJECT                   = COLUMN
    NAME                  = "LOBT_LOW"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 33
    BYTES                 = 4
    FORMAT                = "A4"
    DESCRIPTION           = "Lander On Board Time Low word (hex)"
END_OBJECT               = COLUMN

OBJECT                   = COLUMN
    NAME                  = "MUPUS_ID"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 40
    BYTES                 = 2
    FORMAT                = "A2"
    UNIT                  = "N/A"
    DESCRIPTION           = "MUPUS identifier.
                             Default value = 07 (x87 for Version 7.0)"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "DPU_STATUS_FLAGS"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 45
    BYTES                 = 2
    FORMAT                = "A2"
    UNIT                  = "N/A"
    DESCRIPTION           = "2 characters which can take the values 1 or 0
                            -DPU power mode (1=low/0=normal); should always be
0
                            -Power consumption overflow (1=Yes/0=Not)
                                Set 1, if at least one of the h/k power supply
                                currents/voltages  is  outside  of  range  (see
below):
                                0 < -12I < 100 mA
                                -12.5 V < -12U < -10.5 V
                                0 < -5I < 300 mA
                                -5.4 < -5U < -4.4 V
                                0 < 5I < 400 mA
                                4.5 < 5U < 5.5 V
                                0 < 12I < 300 mA
                                11.1 < 12U < 13.1 V
                                No   further   consequences   if   out-of-range
condition
                                detected (ignored by flight s/w)"
END_OBJECT              = COLUMN

OBJECT                   = COLUMN
    NAME                  = "EPROM_CHECKSUM"
    DATA_TYPE             = CHARACTER
    START_BYTE            = 50
    BYTES                 = 4
    FORMAT                = "A4"
    UNIT                  = "N/A"
    DESCRIPTION           = "EPROM checksum in hexadecimal format"
END_OBJECT              = COLUMN


OBJECT                   = COLUMN
    NAME                  = "HK_MUPUS_MODE"
```

```
    DATA_TYPE          = CHARACTER
    START_BYTE         = 57
    BYTES              = 2
    FORMAT             = "A2"
    UNIT               = "N/A"
    DESCRIPTION        = "Current MUPUS mode (lower byte of 71xx mode
                          telecommand, when mode is running, =0 otherwise)"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME               = "CDMS_ERROR_FLAGS"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 62
    BYTES              = 8
    FORMAT             = "A8"
    UNIT               = "N/A"
    DESCRIPTION        = "Last received CDMS error code;
                          Ver7.1: reset after every HK update
                          8 values (1=Yes/0=No)
                          Illegal Request Code
                          Illegal Unit, Pointer, Offset, Length
                          Request Code Undue
                          Mass-memory Full
                          Allocated SC Data Vol. Exhausted
                          Destination unit Off
                          Cdms (TCmd) request error
                          Cdms (RCmd) request error
                         "
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME               = "RCMD_W1"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 73
    BYTES              = 4
    FORMAT             = "A4"
    UNIT               = "N/A"
    DESCRIPTION        = "Last received RCMD command (word 1, hex)"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME               = "RCMD_W2"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 80
    BYTES              = 4
    FORMAT             = "A4"
    UNIT               = "N/A"
    DESCRIPTION        = "Last received RCMD command (word 2, hex)"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME               = "RCMD_W3"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 87
    BYTES              = 4
    FORMAT             = "A4"
    UNIT               = "N/A"
    DESCRIPTION        = "Last received RCMD command (word 3, hex)"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
    NAME               = "RSST"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 94
```

```
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "N/A"
    DESCRIPTION         = "Last received RSST message (hex)"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "RMOD"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 101
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "N/A"
    DESCRIPTION         = "Last received RMOD message (hex)"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "CMD_POINTER"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 108
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "N/A"
    DESCRIPTION         = "Last Command Buffer Pointer word (offset, hex)"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "BRAM_POINTER"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 115
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "N/A"
    DESCRIPTION         = "last Backup RAM Pointer word (hex)"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "I-12V"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 121
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIAMPERE"
    DESCRIPTION         = "-12V current (power supply) "
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "U-12V"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 131
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "VOLT"
    DESCRIPTION         = "-12V voltage (power supply)"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "I-5V"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 141
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "MILLIAMPERE"
    DESCRIPTION         = "-5V current (power supply) "
```

```
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME              = "U-5V"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 151
    BYTES             = 9
    FORMAT            = "F9.3"
    UNIT              = "VOLT"
    DESCRIPTION       = "-5V voltage (power supply)"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME              = "I+5V"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 161
    BYTES             = 9
    FORMAT            = "F9.3"
    UNIT              = "MILLIAMPERE"
    DESCRIPTION       = "+5V current (power supply)"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME              = "U+5V"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 171
    BYTES             = 9
    FORMAT            = "F9.3"
    UNIT              = "VOLT"
    DESCRIPTION       = "+5V voltage (power supply)"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME              = "I+12V"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 181
    BYTES             = 9
    FORMAT            = "F9.3"
    UNIT              = "MILLIAMPERE"
    DESCRIPTION       = "+12V current (power supply)"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME              = "U+12V"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 191
    BYTES             = 9
    FORMAT            = "F9.3"
    UNIT              = "VOLT"
    DESCRIPTION       = "+12V voltage (power supply)"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME              = "PENTS_ASSIST"
    DATA_TYPE         = ASCII_REAL
    START_BYTE        = 201
    BYTES             = 9
    FORMAT            = "F9.3"
    UNIT              = "VOLT"
    DESCRIPTION       = "PEN-EL Pt-100 voltage when PEN-EL switched ON"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME              = "HK3"
```

```
    DATA_TYPE          = ASCII_REAL
    START_BYTE         = 211
    BYTES              = 9
    FORMAT             = "F9.3"
    UNIT               = "VOLT"
    DESCRIPTION        = "Temperature detector TT100 external
                          HK3 when PEN-EL switched on"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "PENTS"
    DATA_TYPE          = ASCII_REAL
    START_BYTE         = 221
    BYTES              = 7
    FORMAT             = "F7.3"
    UNIT               = "KELVIN"
    DESCRIPTION        = " PEN-EL electronics temperature (only valid
                           when PENEL OFF)"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "DPU U+5V"
    DATA_TYPE          = ASCII_REAL
    START_BYTE         = 229
    BYTES              = 9
    FORMAT             = "F9.3"
    UNIT               = "VOLT"
    DESCRIPTION        = "DPU +5V voltage"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
    NAME               = "TM_STATUS"
    DATA_TYPE          = CHARACTER
    START_BYTE         = 240
    BYTES              = 8
    FORMAT             = "A8"
    UNIT               = "N/A"
    DESCRIPTION        = "Termal Map Flags
                     Heater (On/Off)
                        in version 7.0 : 1 if the TM not operating;
                                             heater is working (pre-heating)
                     Low Power Mode (On/Off)
                        in version 7.0: 1 if TM is operating in low power
                        mode
                     Nominal Power Mode (On/Off)
                        in version 7.0: 1 if TM is operating in nominal
                        power mode
                     Calibration Mode (On/Off)
                        in version 7.0: 1 if TM blackbody is heated
                     Last Heat Time > 1h40min (Yes/Not)
                        not used for MUPUS version 7.0
                     TM powered (Yes/Not)
                        in version 7.0: 1 if TM is powered
                     Calibration mode (sub-mode) refused (Yes/Not)
                        in version 7.0: 1 if the initial blackbody
                        temperature was too low for calibration (< -110°C)
                        and therefore, heating of the blackbody for
                        calibration was refused
                     TM refused (yes/no)
                        in version 7.0: 1 if preheating was not successful
                        (still below switch-ON temperature) and therefore,
                        TM was not switched ON"
END_OBJECT           = COLUMN
```

```
OBJECT                    = COLUMN
    NAME                   = "DD_STATUS"
    DATA_TYPE              = CHARACTER
    START_BYTE             = 251
    BYTES                  = 14
    FORMAT                 = "A15"
    UNIT                   = "N/A"
    DESCRIPTION            = "Deployment Device Status Flags (values 1 or 0)
                             Hammer release END flag (set after Depth
                                     Sensor Release)
                             Deployment START flag (set when starting motor
                                     deployment (forward)
                             Deployment END flag (set after stopping motor
                                     deployment forward; same as Mupus status
                                     flag, bit 4)
                             Balcony release END flag (set after finishing 2nd
                                     balcony release (same as Mupus status
                                     flag, bit 3)
                             Retracting START flag (set when starting motor
                                     retraction backward)
                             Balcony release START flag (set before starting 1st
                                     balcony release)
                             Hammer release START flag (set when starting Depth
                                     Sensor Release)
                             Retracting END flag (set after stopping motor
                                     retraction backward; same as Mupus status
                                     flag, bit 7)
                             Inserting START flag (set when starting insertion -
                                     hammering)
                             Inserting END flag (set after finishing insertion -
                                     hammering;  same  as  Mupus  status  flag,  bit
5)
                             DSB2 power ON flag (set if DSB2 powered,
                                     unset if not)
                             Penel power ON flag (set if PENEL powered, unset if
                                     not; same as Penel status flag, bit 5)
                             Penel  heating  ON  flag  (set  if  DSB2  powered,  unset
if

                                     not; same as Penel status flag, bit 0)
                             Penel continous heating ON flag (set/unset during
                                    Penel background heating)"
END_OBJECT               = COLUMN

OBJECT                    = COLUMN
    NAME                   = "PEN_STATUS"
    DATA_TYPE              = CHARACTER
    START_BYTE             = 268
    BYTES                  = 6
    FORMAT                 = "A6"
    UNIT                   = "N/A"
    DESCRIPTION            = "PEN status flags (values 1 or 0)
                          PEN_EL Heater (On/Off)
                             in version 7.0: 1 if the PENEL heater is
                             working (either pre-heating or background
                             heating)
                          Mode Flag (On/Off)
                             not used for MUPUS version 7.0
                          Mean Flag (On/Off)
                             not used for MUPUS version 7.0
                          Last Heat Time > 1 h (Yes/Not)
                             not used for MUPUS version 7.0
                          PEN powered (Yes/Not)
                             in version 7.0: 1 if PENEL is powered
                          PEN refused (Yes/Not)
```

```
                          in version 7.0: 1 if preheating was not
                          successful (still below switch-ON temperature)
                          and therefore, PENEL was not switched ON"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "ANC_STATUS"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 277
    BYTES               = 4
    FORMAT              = "A4"
    UNIT                = "N/A"
    DESCRIPTION         = "Anchor Status Flags (values 1 or 0)
                      ANCM1 sampled (Yes/Not)
                          in version 7.0: 1 if accelerometer ANCM1 was
                          sampled (since MUPUS ON)
                      ANCM2 sampled (Yes/Not)
                          in version 7.0: 1 if accelerometer ANCM2 was
                          sampled (since MUPUS ON)
                      Anchor 1 powered (Yes/Not)
                          in version 7.0: 1 if ANC-1 electronics is powered
                      Anchor 2 powered (Yes/Not)
                          in version 7.0: 1 if ANC-2 electronics is powered"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "CDMS_ERROR_COUNT"
    DATA_TYPE           = ASCII_INTEGER
    START_BYTE          = 283
    BYTES               = 5
    FORMAT              = "I5"
    UNIT                = "N/A"
    DESCRIPTION         = "CDMS error messages number"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "TIMEOUT_ERROR"
    DATA_TYPE           = ASCII_INTEGER
    START_BYTE          = 289
    BYTES               = 5
    FORMAT              = "I5"
    UNIT                = "N/A"
    DESCRIPTION         = "MUPUS internal error counter"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "RES1"
    DATA_TYPE           = ASCII_REAL
    START_BYTE          = 295
    BYTES               = 9
    FORMAT              = "F9.3"
    UNIT                = "KELVIN"
    DESCRIPTION         = "TM electronics temperature Pt-1000,
                           jumps by about +25 Ohms (+6.4 K) when
                           TM is switched ON"
END_OBJECT            = COLUMN

OBJECT                 = COLUMN
    NAME                = "MUPUS_STATUS"
    DATA_TYPE           = CHARACTER
    START_BYTE          = 306
    BYTES               = 16
    FORMAT              = "A16"
    UNIT                = "N/A"
```

```
    DESCRIPTION       = "MUPUS Status Flags (values are 1 or 0)
               TM calibrated (Yes/Not)
                   in version 7.0: set after successful calibration,
                   reset after calibration refused
               ANC-M 1 sampled (Yes/Not)
                   in version 7.0: set after INT4 reception for
                   anchor 1, never reset, same as AncStatusFlags:Bit0
               ANC-M 2 sampled (Yes/Not)
                   in version 7.0:Set after INT4 reception for
                   anchor 2, never reset, same as AncStatusFlags:Bit1
               PEN released (Yes/Not)
                  in version 7.0: Same as DdStatusFlags:bit3
               PEN deployed (Yes/Not)
                  in version 7.0: Set after complete PENEL deployment,
                  same as DdStatusFlags:bit2
               PEN inserted (Yes/Not)
                  in version 7.0: Set after complete PENEL insertion,
                  same as DdStatusFlags:bit10
               DD released (Yes/Not)
                  in version 7.0: Set after Deployment device release,
                  same as DdStatusFlags:bit0
               DD retracted (Yes/Not)
                  in version 7.0: Set after Deployment device retraction,
                  same as DdStatusFlags:bit8
               Read Alloc. RAM error (Yes/Not)
                  not used for MUPUS version 7.0
               Read STCB error (Yes/Not)
                   not used for MUPUS version 7.0
               Read Alloc. Mem. Error (Yes/Not)
                   not used for MUPUS version 7.0
               MUPUS Setup loaded from BRAM(Yes/Not)
                   not used for MUPUS version 7.0
               PEN Set-up loaded from STCB (Yes/Not)
                   not used for MUPUS version 7.0
               TM Set-up loaded from STCB (Yes/Not)
                   not used for MUPUS version 7.0
               Read BRAM error (Yes/Not)
                   not used for MUPUS version 7.0,
                   see HK#53 instead
               Write BRAM error (Yes/Not)
                    not used for MUPUS version 7.0,
                    see HK#54 instead"
END_OBJECT           = COLUMN
```

5 Appendix 1: Available Software to read PDS files

The level housekeeping and science PDS files can be read with the PDS table verifier tool “tbtool” and “readpds” (Small Bodies Node tool).

6 Appendix 2: MUPUS operations at the comet

6.1 Overview

This section shall give a short overview about then MUPUS operations performed and the data gathered at comet CG/67. MUPUS was switched on at 12-NOV-2014 07:26:00 UTC about 1 h before separation of Philae from Rosetta and shortly after at 07:36:43 MAPPER mode was started, thereafter acquiring measurement data from the 9 TM and the 2 ANC-T channels at a measurement rate of ~5 s. The TM and ANC-T sensors were then operated continuously in MAPPER mode during the whole SDL and RBD mission phases until the final touchdown of the Lander at Abydos (defining the end of the RBD phase). As part of the MUPUS-TM inflight calibration at 12:57:36 (during descent) a 20 min long heating phase of the TM blackbody was started where a maximum blackbody temperature of 405 K was reached at the end of the heating phase. During the subsequent “Safe Blocks” MUPUS was again operated in MAPPER mode during 4 individual blocks of 2 h length each. Note that due to the operational implementation of these safe blocks MUPUS was switched off at the end of each block and switched on again at the start of the next block which caused a considerably disturbance of the thermal equilibrium of the TM sensor head, with the consequence that the data acquired during the first 20 min of each safe block cannot be interpreted quantitatively.

During the execution of FSS Block 6 MUPUS was commanded to TEM mode (aimed at measuring all MUPUS temperature sensors of PEN, TM, and ANC-T) on 13-NOV-2014 22:00:36 while the PEN was still at rest at its nominal cruise location on the Philae balcony. Because the PEN electronics needed to be warmed-up to the minimum operational temperature of -55°C first, the actual PEN measurements started at 22:54:33. The balcony measurement phase lasted until 23:30:58 when the deployment of the PEN was commanded. After extraction of the MUPUS boom to the programmed distance of 585 mm (measured horizontally and perpendicular to the outer edge of the balcony) the TEM measurements resumed again at 23:39:35. This measurement phase finished at 14-NOV-2014 00:20:44 with the start of the PEN insertion using HAMMER mode. Due to the unexpected high penetration resistance of the comet surface the PEN was not able to penetrate into the ground and hammering continued for about 3,5 h without success. Because the hammering progress required for release of the PEN from the boom was never reached during the whole hammering phase the PEN was still connected to the deployment device boom. Furthermore, during HAMMER mode no temperature measurements could be performed. After HAMMER mode was finished because the configured maximum number of strokes was reached the PEN was released from the DD boom and the boom was retracted to allow further rotations of the Lander. The state and location of the PEN after retraction is not known. Temperature measurements in TEM mode were then re-started on 14-NOV-2014 03:50:33 and continuously performed until 10:12:39 when the last MUPUS measurement in the FSS was taken.

Table 10 Overview of MUPUS operations and acquired data on comet 67P

Mission phase	Date / time [UTC]	MUPUS activity	Active sensors	Remarks
SDL	2014/11/12 07:25:00	MUPUS ON	h/k	
SDL	2014/11/12 07:35:01	Start MAPPER mode	TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	Measurement interval 5 s
Separation	2014/11/12 08:35:02			
SDL	2014/11/12 12:57:36	TM blackbody ON	TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	
SDL	2014/11/12 13:17:36	TM blackbody OFF	TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	
SDL	2014/11/12 14:48:34	TM to STANDBY	h/k	Philae switched to “Touchdown mode”, TM commanded to standby to minimize the load on CDMS
Touchdown	2014/11/12 15:34:04			1st touchdown at Agilkia
RBD	2014/11/12 15:34:36	MAPPER restart	TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	Measurement interval 15 s
RBD	2014/11/12 16:33:50	MAPPER reconfiguration	TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	Measurement interval 60 s
Touchdown	2014/11/12 17:30:21			Final touchdown at Abydos
FSS	2014/11/13 06:33:27	Start MAPPER mode		1st safe block Starts with pre-heating of sensor head to switch-on temperature of -90°C
	2014/11/13 06:42:53	1st TM measurement	TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	Switch-on temperature reached, TM measurements start with interval of 30 s

FSS	2014/11/13 08:28:41	MUPUS OFF		End of 1st safe block
FSS	2014/11/13 08:35:26	Start MAPPER mode		2nd safe block Starts with pre-heating of sensor head to switch-on temperature of -90°C
FSS	2014/11/13 08:39:37	1st TM measurement	TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	2nd safe block
FSS	2014/11/13 10:29:28	MUPUS OFF		End of 2nd safe block
FSS	2014/11/13 10:37:31	Start MAPPER mode		3rd safe block
FSS	2014/11/13 10:41:12	1st TM measurement	TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	
FSS	2014/11/13 12:31:03	MUPUS OFF		End of 3rd safe block
FSS	2014/11/13 12:39:29	Start MAPPER mode		4th safe block
FSS	2014/11/13 12:43:19	1st TM measurement	TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	
FSS	2014/11/13 14:33:09	MUPUS OFF		End of 4th safe block
FSS	2014/11/13 21:49:26	MUPUS ON	h/k	Preparation for PEN deployment to a horizontal distance of 585 mm from edge of balcony
FSS	2014/11/13 22:00:56	Start TEM mode	h/k	Starts with pre-heating of sensor heads to -50°C (PEN-EL) and -90°C (TM)
FSS	2014/11/13 22:54:27	1st TEM measurement	PEN1-16, TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	Perform temperature measurements with PEN still on the balcony
FSS	2014/11/13 23:30:58	Start GEAR mode	h/k	Deployment of PEN to the selected distance
FSS	2014/11/13 23:39:54	Restart TEM measurements	PEN1-16, TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	Perform temperature measurements before start of insertion
FSS	2014/11/14 00:20:44	Start HAMMER mode	DS, h/k	Start insertion of PEN. Downward movement of PEN

				only for ~20 mm with 1st stroke sequence, too hard layer prevented further insertion (bouncing back observed). At the end of the mode (timeout) PEN was released and DD boom was successfully retracted
FSS	2014/11/14 03:50:29	Restart TEM measurements	PEN1-16, TM_A-D, TM_REF_A-D, TM_BB, ANC-T1/2, h/k	Perform temperature measurements after failed insertion of PEN.
FSS	2014/11/14 10:12:36	MUPUS OFF		

6.1 TM measurements during descent

The TM measurements conducted during Philae descent to the surface of comet 67P were mainly aimed at re-calibration of the TM sensor head. It was detected during the first inflight calibration sequence in cruise that all IR sensors had suffered a significant loss of sensitivity compared to the ground calibration of the order of 20-40%. Further regular checkouts performed during cruise then showed that the sensitivity remained constant thereafter. Therefore, the most probable explanation for this problem is the intrusion of humidity already on the ground which then triggered a chemical reaction of the silver smoke absorber of the thermopiles that ultimately lead to a significant degradation in absorptance.

The overall thermal state of MUPUS-TM and its environment on the Lander balcony is plotted in Figure 6-1 where t=0 is chosen to be the separation time of Philae from Rosetta. Note that the 4 TM reference sensors show the same temperature readings within +/-0.2 K, and, therefore, plot on a single line in this plot. After separation, a general trend of slowly increasing temperatures on Philae is observed (here indicated by the TCU Baseplate temperature) which is probably mostly due to the additional solar energy the Lander received after separation. This general trend of increasing temperatures with time is also reflected in the MUPUS anchor temperature measurements (ANC-T1/2 correspond to TM-5/6 in the plot). For the thermal state of MUPUS-TM especially the strong temperature increase of the Tx/Rx antenna after separation is important because TM is mounted at a short distance of only a few cm below the antenna plate.

The rise of the TM temperatures before separation is due to the warmup heating of TM until the switch-on temperature of -90°C was reached. After separation the radiative interface of TM to its environment suddenly changed. There is now additional cooling by radiating heat into deep space, but on the other hand, the Tx/Rx antenna is now acting as a heat source on TM. The combined effect is that the TM sensor head temperature still rises during the whole descent with an approximately constant gradient of about 2K/h until at t=4.3 h the TM blackbody was heated for 20 min as part of the inflight calibration. Though the blackbody is conductively decoupled from the sensor head as much as possible, some heat input into the sensor head cannot be avoided which causes a further temperature increase of about 8 K, before the temperature slowly decays again after blackbody heating was finished. A closer look to the measured temperatures reveals also periodic component of the temperatures during descent with a period between 8:20 min (after separation) and 9:23 (at end of MUPUS SDL measurements) and an amplitude of +/-0.2 K on the reference temperature sensors and +/-1.5 K on the blackbody. The period indicates the slow rotation of the Lander around its z-axis during descent and the measured temperature variation is probably caused by direct Sun light falling onto the sensor head for some time during each rotation.

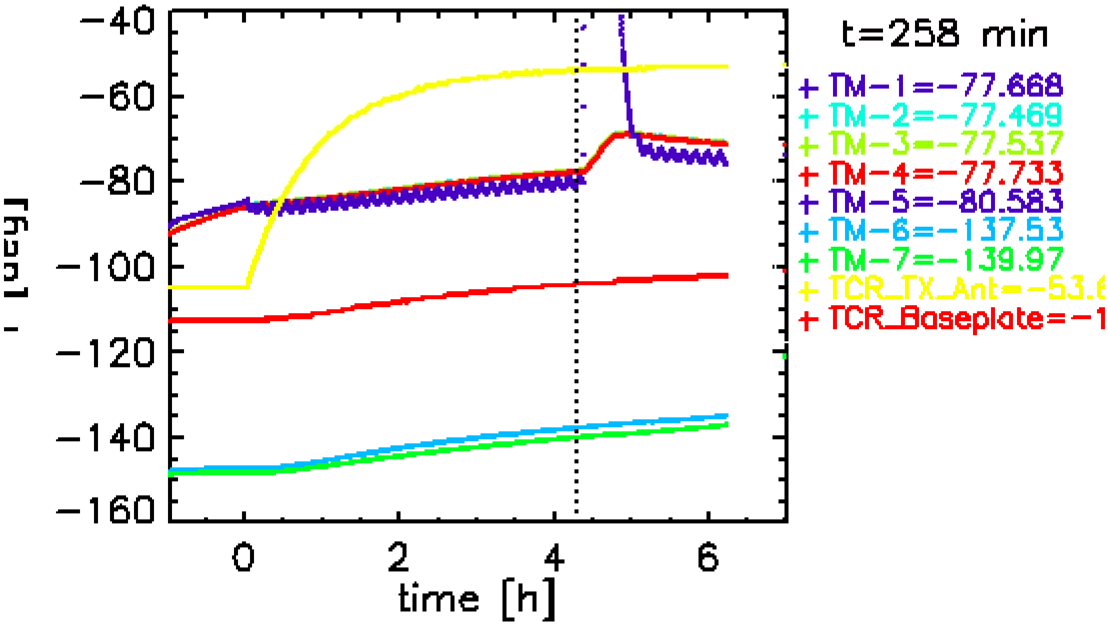

Figure 6-1 Temperatures of TM reference sensors (TM-1-4), blackbody (TM-5), ANC-T1/2 (TM-5/6) and some lander h/k temperatures measured on the Philae balcony during SDL

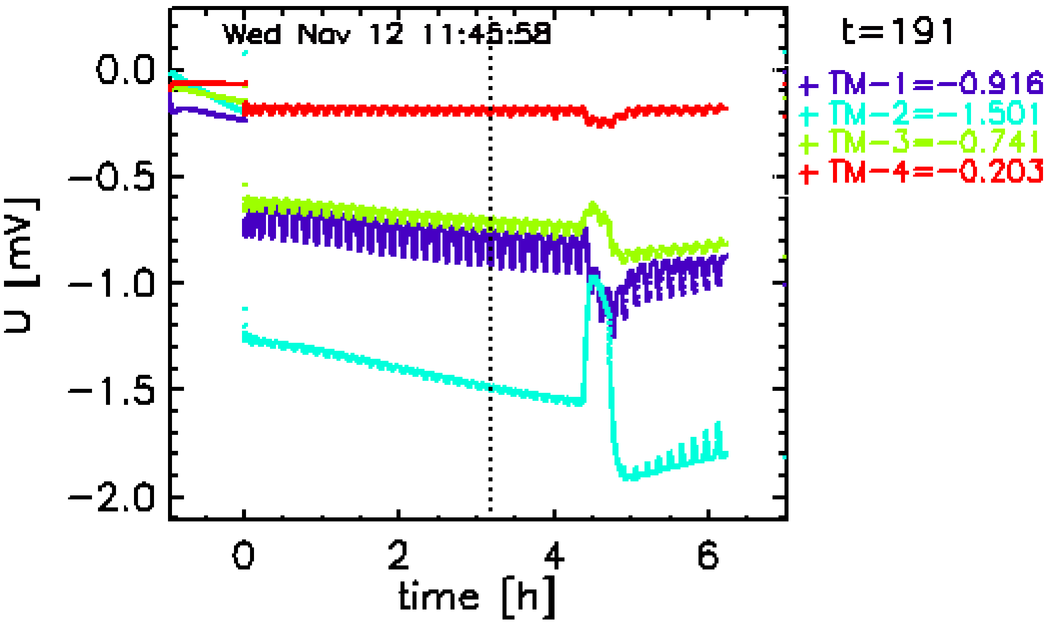

Figure 6-2 TM thermopile signals measured during descent.

The thermopile signals measured during SDL are given in Figure 6-2. Separation is clearly indicated by a jump to lower values in all TM infrared channels which is caused by the appearance of deep space in the sensors FOV. Due to the differential measurement principle of a thermopile (signal voltage is approximately proportional between the sensors reference junction temperature and the object temperature) the approximately linear increase of the reference sensor temperatures gives rise to an approximately linear decrease of the thermopile signal while looking constantly into deep space.The different slopes are due to the different sensitivities caused by the different filter passbands of the four TM channels. The periodic sensor temperature variation caused by the rotating Lander is also clearly reflected in the signal voltages. This disturbance is especially strong in channels A (8-14 µm) and C (13-15 µm). The blackbody heating started at t=4.3 h then gives rise to another change of the thermopile signals. The blackbody which is covering about 1-2% of the sensor FOV is heated to a maximum temperature of 400 K increases the object flux considerably which then rises the signal by a few 100 µV for channels B (6-15 µm) and C, as can be expected. The behaviour of channels A and D is different. Here, the blackbody heating even leads to a lowering of the thermopile signal despite of the increased object flux falling onto the sensor. This is due to the rather strong thermal non-equilibrium of the sensors caused by the unavoidable conductive heat input into the sensor housing where the reference junction is heated up more strongly than the sensor housing. During the last 1.5 h of TM measurements the rotational signal in the TM-B channel changes its appearance. Here, we see the comet surface coming slowly into the FOV of the sensor.

Note on TM calibration:

The original baseline of operating the TM was to operate at a constant sensor head temperature setpoint (set by hardware) of about -105°C which should have been stabilized by an internal heater. At the time this setpoint was defined it was assumed that the sensor head would cool down during descent to -105°C and reach the thermally stabilized state. Possible changes in sensitivity of the infrared sensors during flight should then be detected by different responses to the heated TM blackbody ny comparison to a reference measurement taken before launch under the same conditions. This concept was proven pre-launch on ground to work with a precision of 2-5% (depending on IR channel, highest precision for the longwave passband 6-25 µm of channel B) but this precision requires the sensor head to be in the thermally stabilized and equilibrated state before the blackbody heating starts in both comparison measurements. The real thermal environment was warmer than assumed before launch (during cruise as well as during SDL) which strongly reduces the precision of this approach although the inflight calibration sequences executed during cruise clearly showed a significant loss of sensitivity compared to the ground calibration. For the same reason the quantitative evaluation of the blackbody heating sequence during SDL turned out not to be feasible with the required accuracy. Therefore, the final recalibration of TM was done by evaluating the thermopile signals as a function of reference temperature while looking at a constant zero (deep space) background in terms of sensitivity S (in units of [V/W] and temperature coefficient of sensitivity TCS (in units of [%/K]) from the data acquired between t=0.3 h and t=4.3 h. This approach worked well for the 6-25 µm channel B but ***failed for channels A,C, and D*** because of the lower signal (shorter wavelength and narrower passbands) and larger disturbance by the rotational signal induced by the Sun.

For the reasons described above***, only TM channel B shall be considered to be calibrated well enough for further quantitative analysis*** (this is also reflected in the quality IDs provided for the delivered data).

The unavoidable errors in the calibration together with the zero thermal flux from the sky can lead to a failure of the conversion from measured signal to brightness temperature (resulting in NAN values). In these cases the NANs are replaced by an arbitrary brightness temperature less than 50 K.