esac

European Space Astronomy Centre
P.O. Box 78
28691 Villanueva de la Cañada
Madrid
Spain
Tel. (34) 91 813 1100
Fax (34) 91 813 1139
www.esa.int

BepiColombo SGS

Mercury Planetary Orbiter (MPO)

MGNS Experiment to Archive Interface Control Document (MGNS EAICD)

BC-MGN-ICD-001_MGNS_EAICD.docx

Prepared by	**MGNS Team**
Reference	**BC-MGN-ICD-001**
Issue	**D**
Revision	**1**
Date of Issue	**3/6/2021**
Status	**Draft**
Document Type	**ICD**

APPROVAL

Title MGNS Experiment to Archive Interface Control Document (MGNS EAICD)	
Issue D	**Revision** 1
Date 3/6/2021	
Approved by	**Signature**
Igor Mitrofanov (MGNS PI)	
Johannes Benkhoff (BepiColombo MPO Project Scientist)	
Santa Martinez (BepiColombo Mission Manager)	
Mark Bentley (BepiColombo SGS Archive Scientist)	
Authorised by	
Igor Mitrofanov (MGNS PI)	**Signature**

CHANGE LOG

Reason for change	Issue	Revision	Date
First draft created for the SGS Design Review	D	1	20/05/2014
Initial Release	1	1	15/03/2020

CHANGE RECORD

Issue D	Revision 1		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
First draft created for the SGS Design Review	20/05/2014	All	All
First draft of the document produced by MGNS team	15/03/2020	All	All

DISTRIBUTION LIST

Recipient	Organisation	Recipient	Organisation
I.Mitrofanov	IKI (MGNS PI)	J. Benkhoff	ESA (SRE-SM)
A.Kozyrev	IKI (MGNS PM)	J. Zender	ESA (SRE-SM)
A.Malakhov	IKI (MGNS Team)	M. Casale	ESA (SRE-OD)
D.Lisov	IKI (MGNS Team)	D. Heather	ESA (SRE-OS)
N.Lukyanov	IKI (MGNS Team)	P. Osuna	ESA (SRE-OE)
		BepiColombo SGS	ESA (SRE-OD)
		BepiColombo SAT	ESA (SRE-OE)

Table of contents:

1 INTRODUCTION

1.1 Purpose and Scope

This Experiment-to-Archive Interface Control Document (EAICD) describes the format and content of the Mercurial Gamma-ray and Neutron Spectrometer (MGNS) archived data. It includes descriptions of the data products and associated metadata, including the data format, content, and generation pipeline.

The specifications described in this EAICD apply to all MGNS products submitted for archive to ESA's BepiColombo Science Ground Segment (SGS), for all phases of the BepiColombo mission. This document includes descriptions of archive products that are produced by both the MGNS team and by the SGS.

1.2 Applicable Documents

The following documents, of the issue given hereunder, are pertinent to the extent specified herein and impose requirements to the SGS or the SGS schedule. They are referenced in the form [AD XX]:

[AD.01] ESDC-PSA-TN-0002 PSA PDS4 Archiving Guide
[AD.02] BC-SGS-TN-081 BepiColombo Annex to the PSA PDS4 Archiving Guide for MGNS
[AD.03] PDS4 Standards Reference (SR)
[AD.04] PDS4 Data Dictionary (DDDB)
[AD.05] PDS4 Information Model Specification (IM)
[AD.06] BC-SGS-ICD-029, MGNS - ESA/SGS Interface Control Document

1.3 Reference Documents

The following documents, of the issue given hereunder, although not part of this document, amplify or clarify its contents. If no issue given, the most recent issue should be used. They are referenced in the form [RD.XX]:

[RD.01] BC-SGS-TN-042, BepiColombo Data Handling and Archiving Concept
[RD.02] PDS4 Data Providers Handbook (DPH)
[RD.03] PDS4 Concepts
[RD.04] BC-SGS-LI-014, SGS Glossary

1.4 Abbreviations and Acronyms

See BepiColombo online Glossary [RD.04].

2 MGNS INSTRUMENT DESCRIPTION

The Mercurial Gamma-ray and Neutron Spectrometer (MGNS) instrument measures fluxes of gamma-rays and neutrons from the surface of Mercury, which are produced by Galactic Cosmic Rays or by natural radioactivity of specific elements. This is an instrument placed onboard the Mercury Planetary Orbiter (MPO) of the ESA-JAXA *BepiColombo* interplanetary mission.

2.1 Science Objectives

The instrument MGNS has to accomplish the following Objectives:

- Objective (I): To determine the elemental compositions for distinguishable regions over the entire Mercury by the measurements of nuclear lines of major soil-composing elements, of the leakage flux of neutrons and of the lines of natural radioactive elements with the accuracy about 10-30 % and with a surface resolution of about 400 km at pericentre of MPO orbit.

- Objective (II): To determine the regional distribution of volatile depositions on the polar areas of Mercury, which are permanently shadowed from the Sun, and to provide a map of column density of this depositions with the accuracy of 0.1 g cm^{-2} and with the surface resolution of about 400 km.

2.2 Physical principles

The instrument is aimed to collect data on the flux of neutrons from Mercurial soil. This allows estimation of hydrogen content in the soil at up to 1 meter depth. The instrument's basic functionality principles are explained below

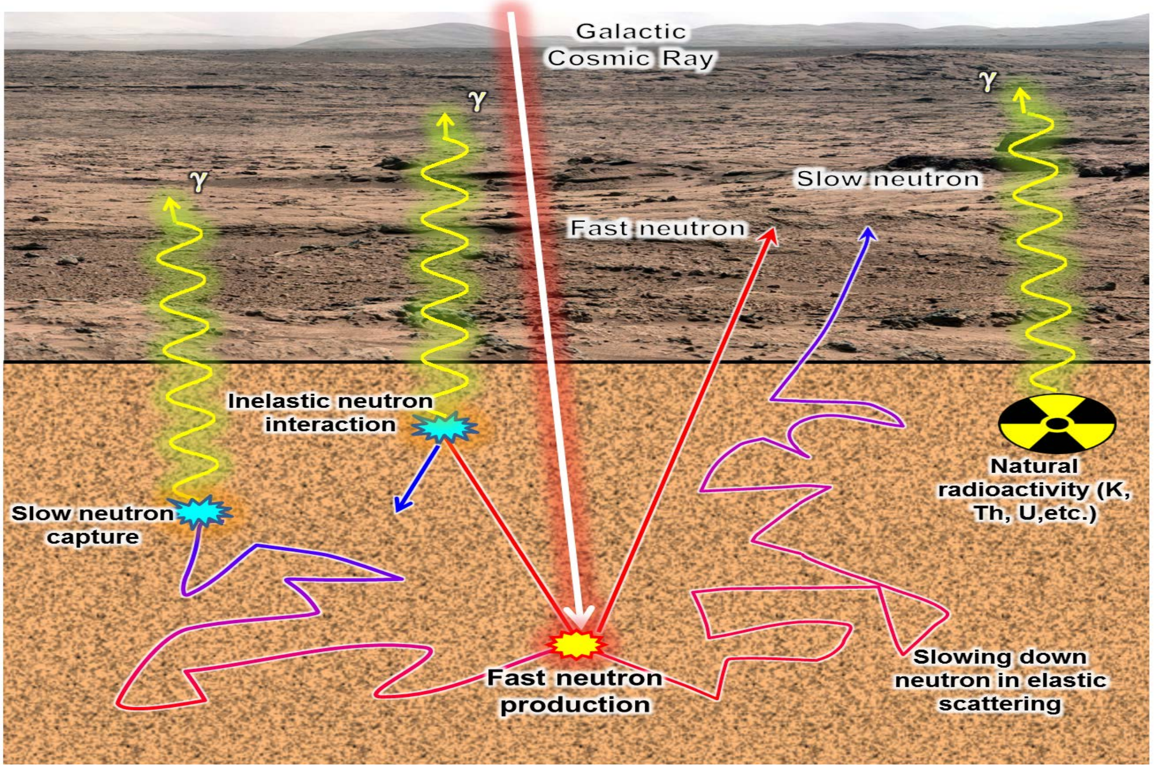

Figure 2-1: MGNS measurement physical principle

The figure above shows physical processes involved in measurements of MGNS. Because Mercury lacks atmosphere and has a weak magnetic field, cosmic rays propagate to and interact with its surface. Due to the cosmic ray bombardment, a large number of secondary neutrons are produced within a subsurface layer of 1 to 2 meters thick (*Figure* 2-1). These neutrons interact with nuclei of atoms of the subsurface material, producing emission of gamma ray lines. Each chemical element has a unique set of these lines, so that gamma-ray spectroscopy can identify the composition of the Mercury subsurface.

Lines of natural radioactive isotopes of K, Th and U are produced without relation with the bombardment by galactic cosmic rays. But photons of nuclear gamma-ray lines from the major elements of the soil are emitted by inelastic scattering reactions of high energy neutrons and by capture reactions of low energy neutrons. Therefore, the intensity of gamma-ray lines depends both on the elemental compositions of the subsurface and on the spectrum and flux of neutrons. Thus, knowledge of the spectral density of neutrons is a necessary condition for the determination of the elemental abundance by the method of gamma-ray spectroscopy. That is why the nuclear science experiment MGNS include gamma-ray spectrometer for detection of gamma-ray lines together with neutron spectrometer for measurement of the spectral density of leakage flux of neutrons of Mercury.

The energy spectrum of leakage neutrons also depends on the composition of subsurface material. A neutron with mass m loses on average a small fraction of energy ~ m/(M+ m) in a collision with heavy nucleus with mass M, but the fraction is ½ when it collides with nuclei of hydrogen with the same mass m. Even a little addition of hydrogen distinctly decreases the leakage flux of epithermal and high energy neutrons and increases the flux of thermal neutrons.

2.3 Instrument and Subsystems

The main component parts and subsystems of MGNS instrument and their functions are presented in Table 2-1 and *Figure* 2-2 and *Figure* 2-3.

Name of units of IFE	Function of the unit
Sensor of Thermal Neutrons (STN).	Thermal & epithermal neutrons detection, analog signal STN provision from sensor counts.
STN/FRE: Front-end/read-out electronics for signal for thermal neutrons with controlling amplitude discrimination.	Analog signal STN amplification and shaping, STN signal discrimination in windowed comparator.
Sensor of Epi-Thermal Neutron (SETN).	Epithermal neutrons detection, analogy signal SETN provision from sensor counts.
SETN/FRE: Front-end/read-out electronics for signal for epithermal neutrons with controlling amplitude discrimination.	Primary signal SETN amplification and shaping, SETN signal discrimination in windowed comparator.
Sensor of Fast Neutron (SFN).	Fast neutrons detection, analogy signal SFN provision from sensor counts.
SFN/FRE: Front-end/read-out electronics for signal for fast neutrons with controlling amplitude discrimination.	Primary signal SFN amplification and shaping, signal SFN discrimination in windowed comparator.
High voltage HV/S12: High voltage power provision for STN, SETN and SFN with controlling levels.	HV provision with controlling levels for STN, SETN and SFN sensors.
Sensor of High Energy of Neutron (SHEN).	High energy neutrons detection, analogy signal SEHN provision from scintillator counts.

Name of units of IFE	Function of the unit
SHEN-PART/FRE&S: Front-end/read-out electronics with controlling amplitude discriminator and separation signals of high energy neutrons (SHEN) from gamma-ray and charge particles (PART).	Primary signal SC amplification and shaping, signal SC discrimination in windowed comparator, signal SC separation into SHEN from neutrons and PART from gamma-rays and charged particles by using signal shape.
SHEN-PART/SA: Signal pulse height analyser.	Signals SHEN and PART amplitude measurement, holding & analogy-to-digital conversion with 16 energy channels.
High voltage HV/SHEN-PART: High voltage power provision for SHEN and PART with controlling levels.	HV provision with controlling levels for SHEN and PART sensor
ACS: Anticoincidence system for discrimination of signals SHEN and PART.	Generation of veto signals according to logic of ACS.
Scintillator sensor of gamma-ray (SC/G).	Gamma-ray photons detection, analogy signal SC/G provision from scintillator counts.
SC/G/FRE: Front-end/read-out electronics for signal for gamma-rays SGR with controlling amplitude discrimination	Primary signal SC/G amplification and shaping, SC/G signal discrimination in windowed comparator
SC/G/SA: Analyzer for signal of gamma-rays SGR	Signals SC/G amplitude measurement, holding & analogy-to-digital conversion with 4096 energy channels
LVP: Low voltage power provision/distribution	Low level voltage provision for digital/analogy electronics
TCS: Temperature control system	Temperature measurements for instrument sub-systems
IC: Instrument controller	Main digital unit for instrument logic, data processing, commanding and interfacing
SWI: SpaceWire interface	Providing interface with onboard TM-system accordingly with ESA requirements

Table 2-1: The main units and subsystems of MGNS

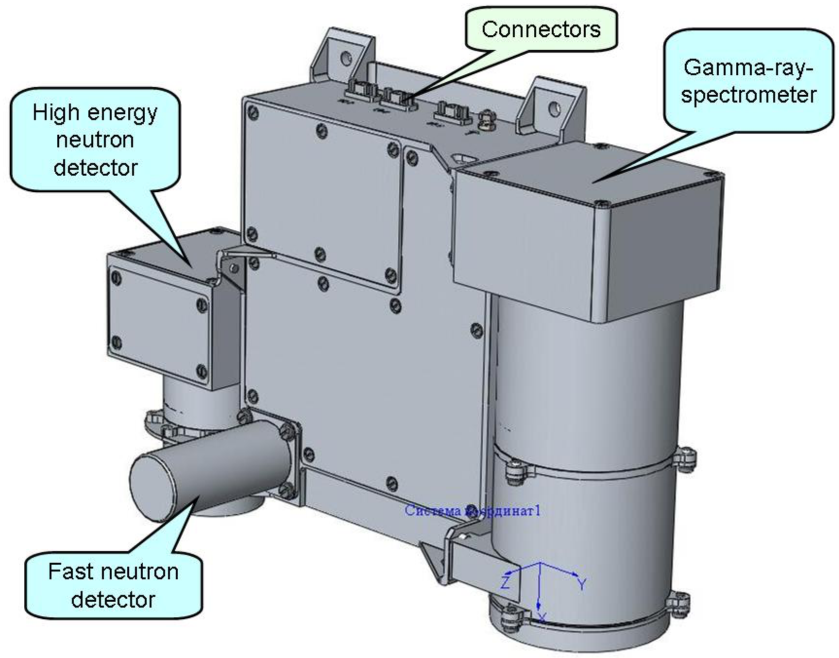

Figure 2-2: MGNS concept design

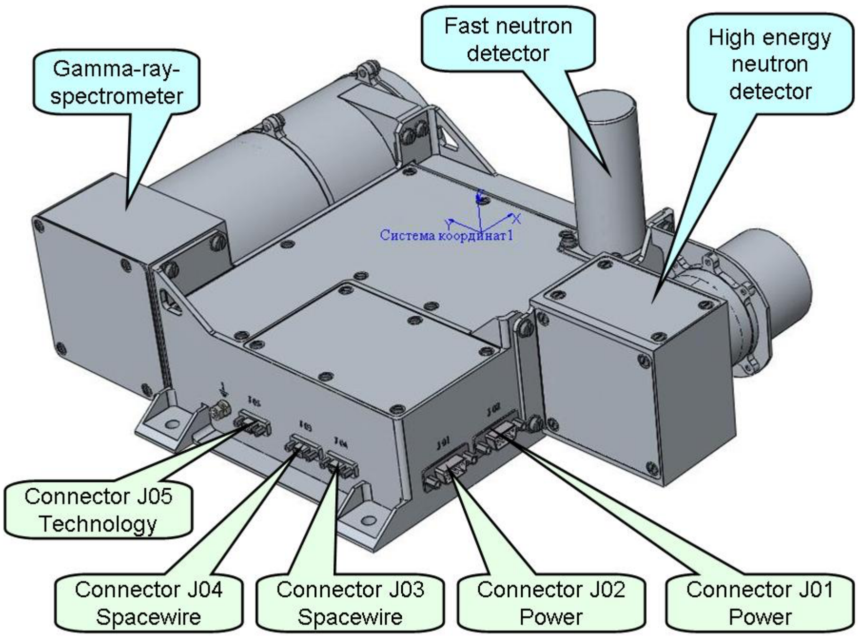

Figure 2-3: MGNS concept design

2.4 MGNS Detectors and Measurement Principle

The MGNS instrument measures fluxes of gamma-rays and neutrons from the surface of Mercury, which are produced by Galactic Cosmic Rays or by natural radioactivity of specific elements.

2.4.1 Measurements of thermal and epithermal neutrons in MGNS

Detectors for thermal and epithermal neutrons are made with three sensors with ^{3}He proportional counters STN, SETN and SFN. All three have identical counters and electronics. STN detects thermal and low energy epithermal neutrons due to capture reaction in the ^{3}He.
The counts of this detection reaction are produced by two particles: triton and proton, which share the energy in the ratio ¼ to ¾ (*Figure* 2-4). The right peak of counts spectrum corresponds to the full energy deposition (*Figure* 2-4), the left peak corresponds to the deposition by Triton only, when proton escapes due to the wall effect (*Figure* 2-4).

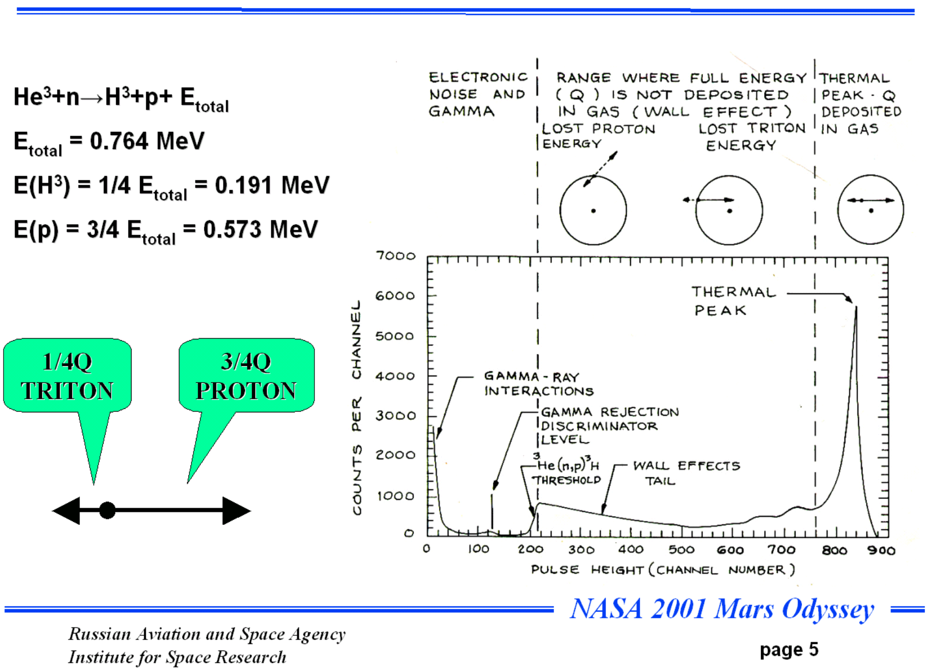

Figure 2-4: Reaction of neutrons detection by ^{3}He counters of MGNS sensors STN, SETN and SFN

The detectors *SFN, STN and SETN concept presented on* Figure 2-5.

SETN has Cd enclosure which effectively rejects neutrons with energies below 0.4 eV. The difference of counts between STN and SETN equals to thermal neutrons (E_n<0.4 eV).

Detector SFN for high energy epithermal neutrons has thick polyethylene moderating enclosure inside the internal Cd shield. High energy neutrons are moderated in the polyethylene down to thermal energy, which are detected by 3He counter inside. External thermal neutrons are rejected by Cd shield. Efficiency of moderation determines the energy dependence of effective cross-section of SFN.

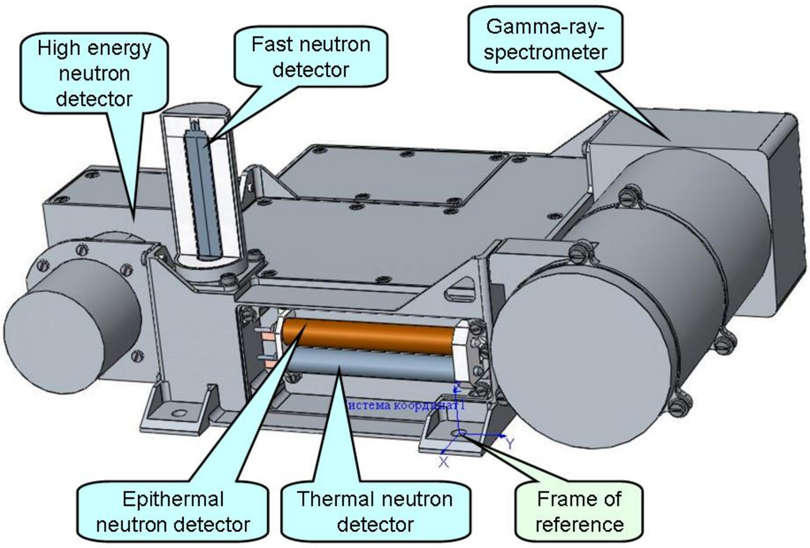

Figure 2-5: Neutron detectors based on ^{3}He proportional counter (SFN, STN and SETN) concept design in assemble

2.4.2 Measurements of high energy neutrons

Detectors for high energy neutrons are made by high energy neutron spectrometer SC. The most efficient sensor of high energy neutrons 0.6-10.0 MeV is stylbene scintillator. Neutron detection is based on reaction n + H –> n' + p. The recoil proton gets the energy from 0 up to E_n with equal probability and produce proportional scintillation light in the stylbene. The low energy cut-off of the SHEN detector is determined as 800 keV. The high energy cut-off is produced by the decreasing cross section of the recoil reaction with increasing energy of neutron. We use the cylindrical stylbene crystal of size Ø40×40 cm. The effective peak-like cross section of SC has a maximum around 2-3 MeV.

External electrons and electrons from gamma-rays produce the scintillation light in the stylbene crystal as well as protons. The shape of light peak is quite different from electrons and protons, and we have developed the proton-from-electron separation electronic board.

External protons are another problem for detection of neutrons by stylbene because there is no opportunity to separate them from the recoil protons produced by neutrons. In MGNS instrument used plastic scintillator to reject external protons.

The detector SHEN *concept presented on Figure* 2-6.

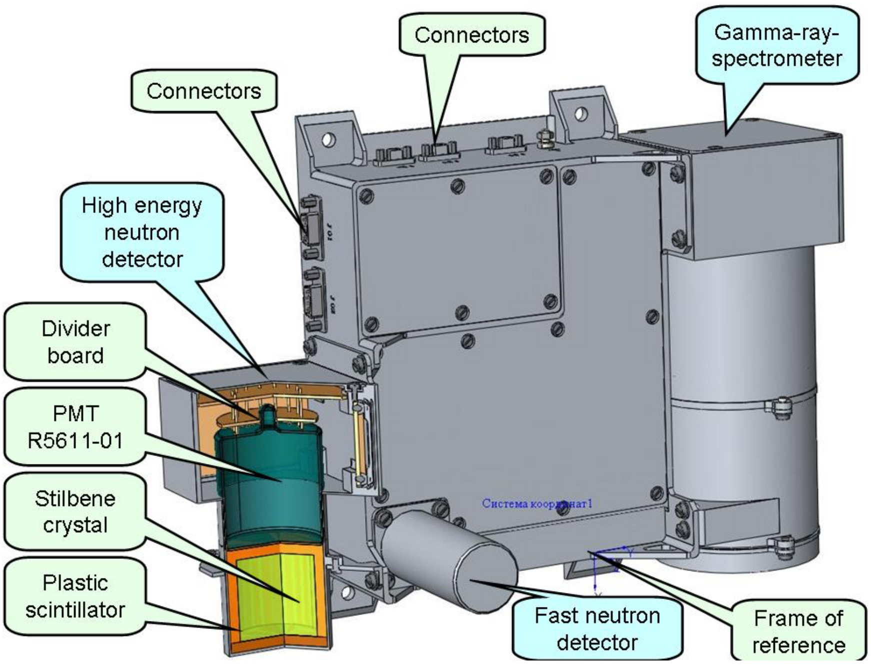

Figure 2-6: Spectrometer of high energy neutron (SHEN) concept design in assemble

2.4.3 Measurements of high energy photons

High energy photons are detected by scintillation crystals $CeBr_3$. We do not plan using anti-coincidence shield for this detector because it is not important for detection of nuclear lines. The mass of anti-coincidence system is better to use for the larger mass of the main crystal of MGNS.

The spectrometer GRS *concept presented on Figure* 2-7.

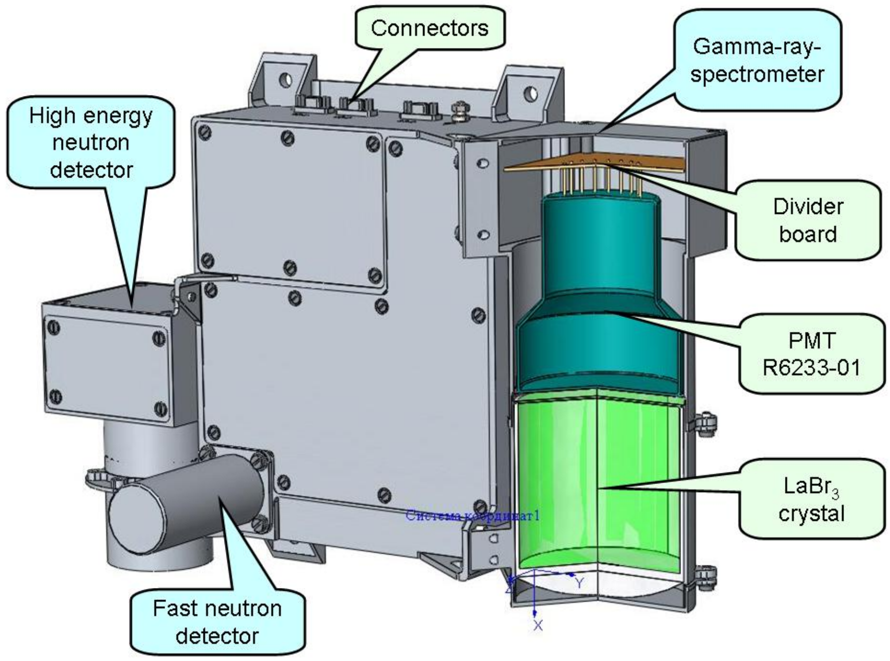

Figure 2-7: Gamma-ray spectrometer (GRS) concept design in assemble

2.5 Operational Modes

This chapter describes MGNS operations, explaining possible measurement modes of the instrument and how they are related to scientific observations that are performed by the instrument.

2.5.1 Normal operations

MGNS has 2 main operation modes: STANDBY mode and SCIENTIFIC mode. MGNS will switch between these two modes by command.

In the case of STANDBY mode, only low voltage is generated inside MGNS and only the main digital electronics is powered. In this mode, only housekeeping telemetry is generated and MGNS has its minimum power consumption.

In the case of SCIENTIFIC mode, both housekeeping and science telemetry are generated. In this mode, one, two or all three HV converters can be turned on and in the last case MGNS has its maximum power consumption.

After each power on MGNS automatically enters STANDBY mode by default.

#	Mode	Description	Telemetry	Power, W	Data rate, bits/sec
1	STANDBY	Standby regime Digital electr. = ON All HV = OFF	housekeeping	5.04	36.8
2	SCIENTIFIC	Scientific measurements for neutron and gamma ray spectroscopy Digital electr. = ON	Housekeeping + science	5.60 – 6.44	3316.8

Table 2-2: Operational modes

2.5.2 Operational support at space commissioning stage, operations at the cruise flight

During the cruise flight, all tested sequences could be used from the set of MGNS STANDARD SEQUENCES. The second flight instrument with Ground Support Equipment (GSE) will be used for testing and verifications any new sequences before its submission to the MPO.

The optimal settings of the instrument should be determined during the cruise phase, and their parameters should be loaded into the OPERATION sequence before Mercury orbit insertion.

Instrument could have regular sessions of testing operations during the cruise flight with duration of about 2-4 hours and frequency about one session every 6 months or more frequently. These measurements will provide to the team the regular data for instrument conditions and for local background variations.

2.5.3 Operational support during the approaching to Mercury and at the science operations phase

There are no special requirements to the instrument operations during the approaching stage and orbit insertion.

2.5.4 Other modes

To save power, the MGNS team suggests two additional modes which are variations of STANDBY and SCIENTIFIC modes: partial operational mode and duty cycle mode.

Partial operation mode

For partial operation mode MGNS instrument can switch OFF one, two or three HV during apoapsis part of the MPO elliptical orbit around Mercury (about 20% of orbit). For this mode average power consumption equal about (5.60 – 6.44) W and power saving about (0 – 1.4) W. The description of power saving presented in Table 2-2.

#	Mode	Description	Power, W	Science measurements
1	SCIENTIFIC/ GAMMA	HV/GAMMA -ON HV/Neutron1-OFF HV/Neutron2-OFF	5.60	One measurement will be provided -Gamma-ray spectroscopy
2	SCIENTIFIC/ NEUTRON	HV/Neutron1-ON HV/Neutron2-ON HV/GAMMA – OFF	5.88	Two measurements will be provided -Neutrons (10-3eV – 1MeV) -Neutrons (1Mev – 15 MeV)
3	SCIENTIFIC/ TOTAL	HV/GAMMA -ON HV/Neutron1-ON HV/Neutron2-ON	6.44	All of measurements will be provided -Gamma-ray spectroscopy -Neutrons (10-3eV – 1MeV) -Neutrons (1Mev – 15 MeV)

Table 2-3: Operational mode – Partial Operations

Duty cycle mode

For larger power saving we suggest using duty cycle mode with an off-duty factor of DF = T_{off}/T_{all}, where T_{off} - time when power is switched OFF, and T_{all} – total time of flight. Average power consumption is about [6.44- (DF x 6.44)] W and the power saving about (DF x 6.44) W.

2.6 Calibration

2.6.1 On-ground Calibration

The plan of MGNS ground calibrations includes the following measurements for the 1st and 2nd flight units of the instrument:

1) Measurements of neutron reference sources and neutron monochromatic beams for testing the angular reference functions of Signal for thermal neutrons (STN), Signal for epithermal neutrons (SETN), Signal for fast neutrons (SFN) and Signal from high energy neutrons (SHEN) at the broad energy range from thermal energy up to 15 MeV.
2) Measurements of the reference sources of gamma-ray lines with calibrated intensities from 300 keV up to 8 MeV.
3) Comparison and verification of the neutron and gamma-ray data with results of numerical simulations, conversion of these data to the conditions of MGNS and MPO mass distribution around sensors.

2.6.2 In-flight Calibration

MGNS operates continuously (with the exception of some periods of time when the instrument is switched off due to spacecraft limitation reasons) during the cruise flight to the Mercury. The data from these measurements will be compared with the instrument numerical model (generated for interplanetary flight conditions), and a model of the spacecraft background will be developed both for neutrons and for gamma-rays.

These data will allow the accumulation profile of induced radioactivity to be determined and the development of an engineering model of spacecraft local background in neutrons and gamma-rays for conditions of the orbital flight.

After orbit insertion MGNS will work continuously with varying distance to the planet. The variation of signals for neutrons and for gamma-rays will allow the background on the orbiter to be separated from the emission from the planet. The heritage of Mars Odyssey has proved that measurements in elliptical orbit are very useful for data analysis and interpretation. The orbit of MPO will have different altitudes, which will be taken into account for the mapping process: therefore, the data for different orbital conditions would be quite useful.

3 DATA GENERATION AND ANALYSIS PROCESS

The MGNS science products are produced by the MGNS Instrument Team in accordance with MGNS - ESA/SGS Interface Control Document [AD.06].

3.1 Scientific Measurements

MGNS data type consist of follow information:

- MGNS Housekeeping (data of the instrument status);
- MGNS Neutron Science data for application process PID90 and PID91;
- MGNS Gamma-ray Science data for application process PID90 and PID91.

The tables below summarise the data types generated by MGNS instrument:

Data Type	Description	Volume [Mbytes/day]	Operational Usage
HK	Housekeeping data	0.57	Instrument status
Science (PID90)	Science data. Low time resolution	34.85	Regular downlink science data
Science (PID91)	Science data. High time resolution	Up to 696.92 (TBC by ESA)	Selective downlink science data

Table 3-1: MGNS data type

3.2 Data Flow Overview

This section provides an overview of the data flow for the MGNS data, from on-board acquisition by the MGNS instrument to ingestion into the ESA's Planetary Science Archive (PSA).

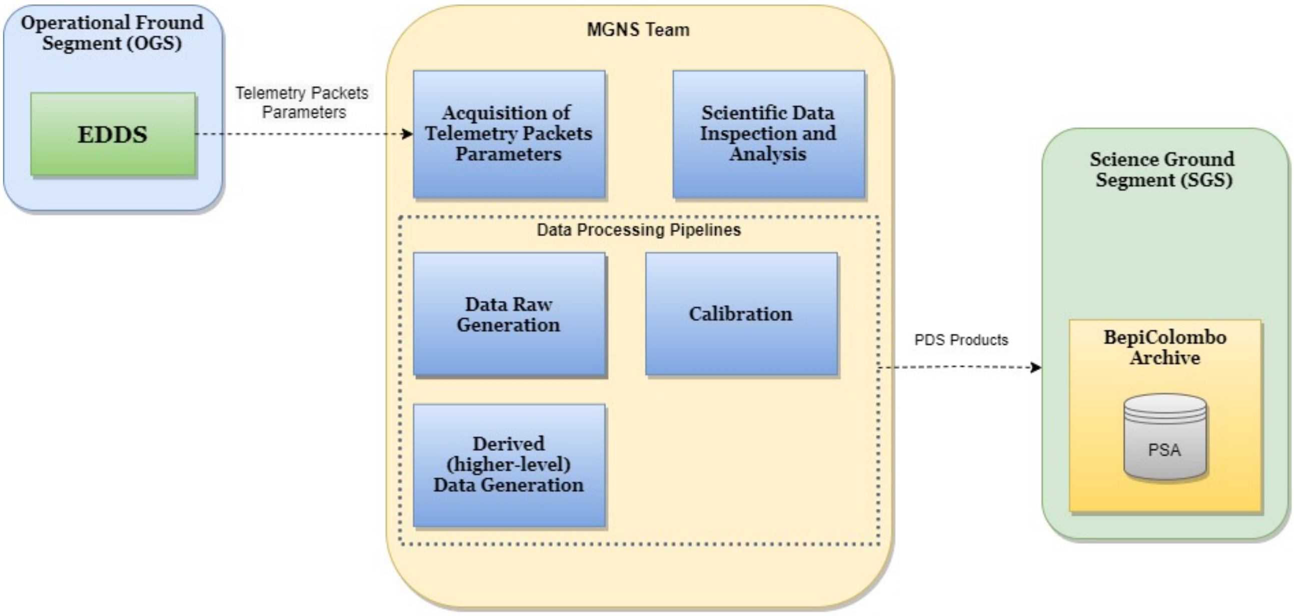

Figure 3-1: Science Data Flow

3.3 Data Generation

The following sections describe the process by which data products in each of the MGNS described in section 5 are produced. All required products are delivered according to the schedule mentioned in Section 3.5 and [AD.06], by uploading (FTP / SCP) to the BepiColombo Science Ground Segment (SGS) from where they will be delivered to the PSA.

3.3.1 Raw Data Generation

This data type contains decoded telemetry data, no unit conversion has been performed.

Telemetry is the binary stream that is generated by the instrument and later downlinked to Earth. Raw data product contents are described in section 5.1.1. Raw products are generated directly from the telemetry streams without cropping. Only conversion from binary data to PDS4 compatible XML labels and tabbed data files is performed.

3.3.2 Calibrated Data Generation

The composition of the calibrated product is described in section 5.1.2. The main purpose of this product is to switch to physical units and remove the last 8 channels from the gamma spectrum as they are not physical channels, as well as to remove instrument engineering effects from the measured data (exclusion of warm-up intervals after switching on). To create this dataset, the MGNS team uses the previously obtained raw products and then processes them and creates products at a calibrated level.

Calibration curves are used for processes that convert raw values to technical values. The calibrations in these sections only apply to the flight model that is flown aboard the BepiColombo.

Temperature conversions. Conversion formula:

$$degC = a * rawX + b,$$

where a and b are coefficients from the table below, X is the original value from MGNS frames, degC is the engineering value in degrees Celsius.

Parameter	a	b
TEMP_PSU1	0.126695	-275.045
TEMP_PSU2	0.126463	-274.544
TEMP_PSU3	0.126001	-275.158
TEMP_PSU4	0.125851	-274.17
TEMP_HV_HE	0.125789	-276.601
TEMP_HV_SC	0.126516	-276.508
TEMP_HV_GA	0.126414	-275.923
TEMP_ACTEL	0.125746	-276.822
TEMP_ GRS	0.126762	-275.691
TEMP_MNT_PNT	0.126025	-275.647
TEMP_ACTEL_PLATA	0.126676	-275.902
ANALOG_REFERENCE	0	0

Voltage conversions. Conversion formula:

$$volt = a * rawX,$$

where a and b are coefficients from the table below, X is the original value from the MGNS frames, volts are the engineering value in volts.

Parameter	a
VOLTAGE_5V	0.00246921
VOLTAGE_3_3V	0.00246921
VOLTAGE_1_5V	0.00246921
VOLTAGE_6V	0.00246921

3.3.2.1 Housekeeping Raw to Calibrated Algorithm

This section describes how housekeeping raw parameters, described in Table 5-1 are converted to Calibrated housekeeping parameters described in Table 5-5. We will describe conversions based on the target parameter names:

UTC_TIME This field contains time information of the frame. It is converted from source **ONBOARD_TIME_*** fields, which are spacecraft time, by applying the SPICE library.

HK_PERIOD. Copied from raw values without calibrations applied.

TEMP and **VOLTAGE** fields. There is a total of 12 temperatures and 4 voltages present in the dataset. These are converted from the corresponding raw units by applying simple $y = ax + b$ conversion (see tables in Section 3.3.2 for details).

***_MIN, *_MAX fields**. A total of 14 fields that are copied from raw data (number of counts limits, needs no conversion).

***_TOTAL** fields. A total of 7 fields that are copied from raw data (number of counts in each detector, in UINTs, needs no conversion).

AC_TIME_PID90, AC_TIME_PID91 fields. Accumulation time for PID90/PID91, showing number of seconds to accumulate (copied from raw data, needs no conversion).

ONBOARD_TIME_SEC, ONBOARD_TIME_SUBSEC BepiColombo onboard time, format is the same as SC format. Sampled at HK counter expiration (copied from raw data, needs no conversion).

INSTRUMENT_MODE_PID90, INSTRUMENT_MODE_PID91 fields. Indicates the status of the MGNS instrument (scientific/standby mode). When the MGNS instrument is powered on, if both of these fields are set to 0 (OFF), then the MGNS instrument is in standby mode. If one of the values is 1 (ON), scientific data will be generated (copied from raw data, needs no conversion).

HV_*, DSC_*, HV_FAIL_* fields. These are status fields that are extracted from the source bit fields and saved as arrays in the calibrated product, for simplicity of access. No conversion is performed.

CMD*_STATUS. Execution status of command (copied from raw data, needs no conversion).

CMD*_PID. PID of command (copied from raw data, needs no conversion).
CMD*_TYPE. Command type (copied from raw data, needs no conversion).

CMD*_OPCODE. MGNS Private Command, byte 1 (copied from raw data, needs no conversion).

CMD*_PARAM1. MGNS Private Command, byte 2 (copied from raw data, needs no conversion).

CMD*_PARAM2. MGNS Private Command, byte 3 (copied from raw data, needs no conversion).

CMD*_TIME fields. A total of 4 integers representing instrument time of last command receipt, copied from source raw data.

3.3.2.2 Science Data Raw to Calibrated Algorithm

This section describes algorithms applied to data defined in Table 5-2 and Table 5-3 (raw science neutron) to convert it to calibrated science product defined in Table 5-4 and Table 5-5. We will describe the steps taken following the parameters enumerated in the target data structure, calibrated product describing how they were obtained from the source data structure, the raw product. Removal of instrument engineering effects from measured data (exclusion of warm-up intervals after switching on) is performed by an algorithm that finds the switch-on of the instrument and cuts out the data set (by approximately 2 hours) after switching on. Also excluded from the calibrated dataset are science frames that were generated by the instrument while one of the three high voltages was off. This is determined by the following fields: HV_*.

UTC_TIME. This field contains time information of the frame. It is converted from source **ONBOARD_TIME_***fields, which are spacecraft time, by applying the SPICE library.

ONBOARD_TIME_SEC, ONBOARD_TIME_SUBSEC. BepiColombo onboard time sampled at accumulation time counter expiration (copied from raw data, needs no conversion).

HV_*, DSC_* fields. These are status fields that are extracted from the source bit fields and saved as arrays in the calibrated product, for simplicity of access. No conversion is performed.

ACC_TIME. This parameter is copied from raw data without conversion and is a number of seconds current measurement lasted.

STN_PROFILE. This parameter represents a normalized count rate of STN detector. In the source raw data these counts are represented by 16-element arrays representing amplitude spectra in each counter. The resulting parameter provided in calibrated dataset is a result of converting each of the 16-element arrays to a single float number representing neutron counts. (In current deliveries, this parameter is forced to 0.0 in all values of the 16-element array)

SETN_PROFILE. This parameter represents a normalized count rate of SETN detector. In the source raw data these counts are represented by 16-element arrays representing amplitude spectra in each counter. The resulting parameter provided in calibrated dataset is a result of converting each of the 16-element arrays to a single float number representing neutron counts. (In current deliveries, this parameter is forced to 0.0 in all values of the 16-element array)

SFN_PROFILE. This parameter represents a normalized count rate of SFN detector. In the source raw data these counts are represented by 16-element arrays representing amplitude spectra in each counter. The resulting parameter provided in calibrated dataset is a result of converting each of the 16-element arrays to a single float number representing neutron counts. (In current deliveries, this parameter is forced to 0.0 in all values of the 16-element array)

SHEN_SPECTRA. Spectra for the SHEN detector (copied from the original data, no conversion required). A data set in a 16-element array of integers representing the number of neutrons is provided as the resulting parameter.

GRS_SPECTRA. Spectra for the GRS detector. Two blocks of 2043 channels are combined one after the other. The last 8 channels are removed from the spectrum because they are not physical channels. Thus, a final gamma spectrum is provided as the resulting parameter, which contains 4078 channels consisting of integers representing the number of gamma-rays.

3.3.3 Derived Data Generation

Derived product structure is described in section 5.1.3. This product contains neutron and gamma-rays science data, plotted on a map instead of time series (as it was in the calibrated product level).

This section describes algorithms applied to data defined in Table 5-4 and Table 5-5 (calibrated science neutron and gamma-rays products) to convert it to science neutron and gamma-rays product defined in Table 5-. We will describe the steps taken following the parameters enumerated in the target data structure, derived product describing how they were obtained from the source data structure, the calibrated product.

Derived products are essentially neutron or gamma-ray count rate maps; hence they are 2D arrays of pixels. Each pixel contains the number of neutrons or gamma-ray lines intensity accumulated when MPO/BepiColombo was flying above it, summed up for all the fly over incidents. Each pixel is accompanied by the exposition time and statistical error. In case MPO/BepiColombo ground track during calibrated product's accumulation frame crosses pixel boundary, then count rate is distributed between pixels proportionally to the track's length.

START_TIME, END_TIME – start and end UTC times between which this map was accumulated.
MAP [X],[Y] – 2D array of pixels containing neutron count rate or gamma-ray lines intensity of this pixel.

MAP_EXPOSURE [X],[Y] – 2D array of pixels containing exposition time – total number of seconds MPO/BepiColombo spent over this pixel.

MAP_ERR [X],[Y] – 2D array of pixels, containing neutron count rate or gamma-ray lines intensity statistical errors. These errors are taken from the calibrated product and propagated to the derived product, considering all the manipulations performed with the neutron count rate or gamma-ray lines intensity.

Array dimensions [X],[Y] will be selected at time of delivery considering statistical certainty level of each pixel: the more the exposure time of each pixel is, the lesser the error of that pixel is, hence it is possible to bin the map into smaller pixels (but with higher spatial resolution). At each delivery, an assessment of adequate binning size will be performed based on the length of period delivered and the statistics accumulated.

3.4 Validation

Prior to the delivery of the data to the archive, every data product is validated to check that it conforms to a basic set of requirements, as defined in the PSA PDS4 Archiving Guide

[AD.01] and [AD.02]. This is done using the PDS4 packager tool (provided by ESA/SGS), and a set of XML Schema and Schematron files.

In addition, the SGS performs completeness and integrity checks on the MGNS science data to ensure that they comply with the specifications described in this EAICD. Visual inspection is used as necessary to check the content. In parallel to SGS archive validation activities, the MGNS Team routinely assesses archive products as part of the operational quality control.

3.4.1 Peer Review

The SGS will conduct a full peer review of all of the data types that the MGNS team intends to archive. The review data will consist of fully formed bundles populated with candidate final versions of the data and other products and the associated metadata. The number and schedule of peer reviews are presented in the document [AD.06].

3.5 Data Delivery Schedule

Delivery dates and their order are indicated in the document [AD.06].

4 DATA ORGANISATION AND CONTENTS

This section describes the basic organization of a MGNS bundle, and the naming conventions used for the products, collections and bundle, collection, and basic product filenames.

4.1 Format and Conventions

MGNS science data are compatible with version 4 of the NASAs Planetary Data System (PDS) standards, so-called PDS4 [RD.02], and follow the organization, format, content and documentation requirements described in the PSA PDS4 Archiving Guide [AD.01] and BepiColomo Annex to the PSA PDS4 Archiving Guide for MGNS [AD.02].

All data from the MGNS instrument for the entire mission is stored in a top-level structure (root directory) called bundle. The bundle is subdivided into a set of collections (sub-directories) aiming to separate different types of data and information into an easy to navigate manner, so the bundle contains separate collections for instrument science data, documentation, etc.

For the instrument science data, there are separate collections for each processing level and this is standardized by PDS4 to four levels: raw, calibrated and derived.

The structure of the bundle is outlined in Figure 4-1.

Details of the structure and content of the MGNS bundle are provided in the following sections.

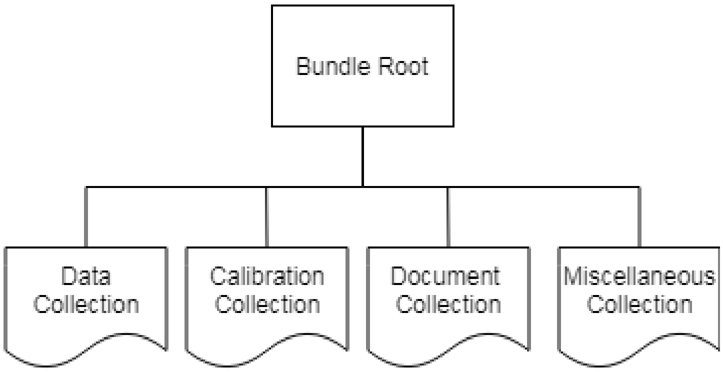

Figure 4-1: Structure of Bundle Root

4.2 Logical Identifier Formation

Bundle and collection logical identifiers are as indicated in Table 4-2 and *Table* 4-3. General conventions can be found in section 3 of the PSA PDS4 Archiving Guide **Error! Reference source not found.**. Specific conventions can be found in the BepiColombo Annex to the PSA PDS4 Archiving Guide for MGNS [AD.02].

4.3 File Naming Convention

This section describes file naming conventions of products delivered to PSA as proposed by the MGNS team. These are currently TBC and may be updated.

Level	Product	Reference	Naming convention
Raw	Housekeeping	Table 5-1	mgn_raw_hk_<start_time>
	Science Neutron and Gamma PID 90	Table 5-2	mgn_raw_sc_pid90_<start_time>
	Science Neutron and Gamma PID 91	Table 5-3	mgn_raw_sc_pid91_<start_time>
Calibrated	Housekeeping	Table 5-54	mgn_cal_hk_<start_time>
	Science Neutron and Gamma PID 90	Table 5-45	mgn_cal_sc_pid90_<start_time>
	Science Neutron and Gamma PID 91	Table 5-46	mgn_cal_sc_pid91_<start_time>
Derived	Science Neutron	Table 5-7	mgn_der_sc_<start_time>-<end_time>
Supplementary	Science Neutron		mgn_sup_<label>_<start_time>-<end_time>

Table 4-1: PSA Files Naming Convention

In the table above <start_time> and <end_time> are UTC times, e.g. 20180208t180000; <label> is a label describing the supplementary product to be defined at time of delivery of such product.

4.4 Bundle Content and Structure

The complete set of MGNS data is archived in one single instrument bundle (root directory). A top-level description of the bundle is provided below. A more detailed description of its contents and format is provided in the following sub-sections.

Bundle Title	Bundle Logical Identifier	Description
MGNS instrument bundle	urn:esa:psa:bc_mpo_mgns	This bundle contains the data collected by the MGNS instrument on-board the BepiColombo Mercury Planetary Orbiter (MPO), along with documents and other information necessary for the data interpretation

Table 4-2: MGNS instrument bundles

Inside the bundle, the data are organized in a directory structure as follows:

Directory Name	Collection Logical Identifier (LID)	Description
data_raw	urn:esa:psa:bc_mpo_mgns:data_raw	Contains MGNS raw data products, see section 4.4.1.
data_calibrated	urn:esa:psa:bc_mpo_mgns:data_calibrated	Contains MGNS calibrated data products, see section 4.4.1.
data_derived	urn:esa:psa:bc_mpo_mgns:data_derived	Contains MGNS maps, see section 4.4.1.
calibration_files	urn:esa:psa:bc_mpo_mgns:calibration_files	Contains MGNS calibration files, see section 4.4.2.
document	urn:esa:psa:bc_mpo_mgns:document	Documents related to the bundle; necessary for the use and interpretation of the MGNS data. See section 4.4.3.

Table 4-3: MGNS data collections

4.4.1 Products Data directory

Product catalogs (data_raw, data_calibrated, data_ derived) include the following structure:

data_raw/	data_calibrated/	data_ derived/
*.xml	*.xml	*.xml
*.tab	*.tab	*.tab

Table 4-4: MGNS data products structure

The names of the files in the bundle are described in section 4.3 of this document in Table 4-1.

4.4.2 Calibrations files directory

Data from calibration measurements of the instrument are delivered. These are time-series, having the same format (PSA labels) as Calibrated MGNS Science data type. They are delivered once only. Calibration data are from in-flight calibration measurements.

calibration_files /
*.xml

Table 4-5: MGNS calibration files

The composition of the calibration file is described in section 3.3.2.

4.4.3 Document directory

By default, they are delivered only once; if changes are made, they can be delivered again. The structure of the document collection is as follows:

document/	
BC-MGN-ICD-001-007.pdf	This document;
BC-SGS-ICD-029.pdf	MGNS - ESA/SGS Interface Control Document

Table 4-6: MGNS documents structure

4.4.4 Folder structure

Each collection of these products should use the format folder structure:

Folder structure
<mission_phase>/<year>/<year+month>

Table 4-7. MGNS folder structure

5 DATA PRODUCT FORMATS

MGNS data products are formatted in accordance with the PDS4 specifications (see **Error! Reference source not found.**, [AD.02] and [AD.03]) following the rules in the PSA PDS4 Archiving Guide and its BepiColombo Annex for MGNS. Clause 5.1 lists different levels of data processing that MGNS delivers to the PSA.

5.1 Primary Products Formats

This section will provide details on the format and content of each of the products included in the MGNS science data.

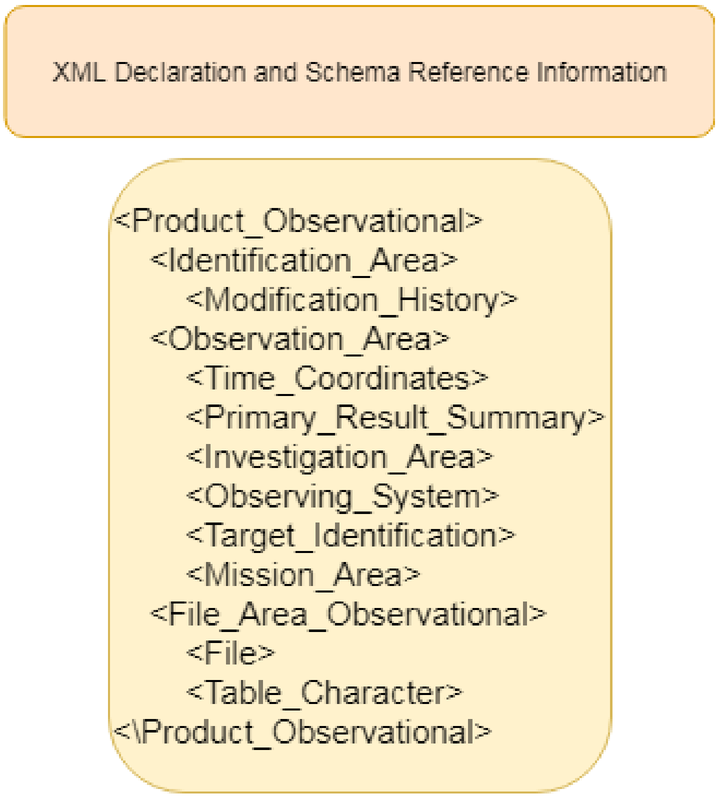

Figure 5-1: Simplified PDS4 label example

5.1.1 Raw Data Products

Raw data as read from the instrument. MGNS generates three parallel time series of the data: Housekeeping data, Main science data (PID90) and Selective science data (PID91, higher time resolution and is mainly intended to be used for Solar events or cosmic gamma-ray burst monitoring). Time series contain spectra (of counts per energy channel) for all five sensors, for the Gamma-ray sensor or for the Neutron sensors. The integration time interval can be set between 1s - 131071s (standard: 20s/low-resolution and 2s/high-resolution).

Raw products contain all instrument data converted from binary stream to fixed format ASCII files and their labels, according to PDS formats. The following types of Raw product are generated:

- mgn_raw_hk corresponds to MGNS Housekeeping data, containing instrument engineering telemetry;
- mgn_raw_sc_pid90 corresponds to MGNS Science Neutron and Gamma-ray data containing measurements of STN, SETN, SFN, SHEN, PART and GRS detectors when MGNS is in Scientific Mode;
- mgn_raw_sc_pid91 corresponds to MGNS Science Neutron and Gamma-ray data containing measurements of STN, SETN, SFN, SHEN, PART and GRS detectors when MGNS is in Scientific Mode.

The three ASCII table (Table Character) that follow contain labels and description of data contained within them.

Label	Type	Description
ACTIVE_CLOCK	ASCII_NonNegative_Integer	Shows active clock generator for Actel: 0 = clk0 1 = clk1
ACTIVE_SPW_LINK	ASCII_NonNegative_Integer	Shows active MGNS SpW link: 0 = link 0 active 1 = link 1 active
INS_ID	ASCII_NonNegative_Integer	Instrument id: 0 = ESA EM 1 = Russian EM 2 = QM 3 = FM1 4 = FM2
UTC_TIME	ASCII_Date_Time_YMD_UTC	UTC time of this frame, derived from SC time through SPICE.
HK_PERIOD	ASCII_ASCII_Real	Copy of HK period as commanded per TC (3, 129)
TEMP_PSU1	ASCII_NonNegative_Integer	Values of 16 MGNS analog parameters each: - Temp PSU1 - Temp PSU2 - Temp HV HE - Temp HV SC - Temp HV Gamma - Temp Actel - Temp GRS
TEMP_PSU2	ASCII_NonNegative_Integer	
TEMP_HV_HE	ASCII_NonNegative_Integer	
TEMP_HV_SC	ASCII_NonNegative_Integer	
TEMP_HV_GA	ASCII_NonNegative_Integer	
TEMP_ACTEL	ASCII_NonNegative_Integer	
TEMP_GRS	ASCII_NonNegative_Integer	

Label	Type	Description
TEMP_MNT_PNT	ASCII_NonNegative_Integer	- Temp Mount Point - Temp PSU3 - Temp PSU4 - Analog Reference - Temp Actel PCB - Voltage +5 - Voltage +3.3 - Voltage +1.5 - Voltage +6
TEMP_PSU3	ASCII_NonNegative_Integer	
TEMP_PSU4	ASCII_NonNegative_Integer	
ANALOG_REFERENCE	ASCII_NonNegative_Integer	
TEMP_ACTEL_PLATA	ASCII_NonNegative_Integer	
VOLTAGE_U5V	ASCII_NonNegative_Integer	
VOLTAGE_U3_3V	ASCII_NonNegative_Integer	
VOLTAGE_U1_5V	ASCII_NonNegative_Integer	
VOLTAGE_U6V	ASCII_NonNegative_Integer	
STN_MIN	ASCII_NonNegative_Integer	Spectra total counts limits for STN detector. These parameters show spectral limits, where total counts accumulated.
STN_MAX	ASCII_NonNegative_Integer	
SETN_MIN	ASCII_NonNegative_Integer	Spectra total counts limits for SETN detector.
SETN_MAX	ASCII_NonNegative_Integer	
SFN_MIN	ASCII_NonNegative_Integer	Spectra total counts limits for SFN detector.
SFN_MAX	ASCII_NonNegative_Integer	
SHEN_MIN	ASCII_NonNegative_Integer	Spectra total counts limits for SHEN detector.
SHEN_MAX	ASCII_NonNegative_Integer	
PART_MIN	ASCII_NonNegative_Integer	Spectra total counts limits for PART detector.
PART_MAX	ASCII_NonNegative_Integer	
GW1_MIN	ASCII_NonNegative_Integer	Spectra total counts limits for GRS detector, window1. Function of these parameters are the same as for He sensors, the only difference is the size.
GW1_MAX	ASCII_NonNegative_Integer	
GW2_MIN	ASCII_NonNegative_Integer	Spectra total counts limits for GRS detector, window 2.
GW2_MAX	ASCII_NonNegative_Integer	
STN_TOTAL	ASCII_NonNegative_Integer	Total counts for STN detector. MGNS instrument allows to monitor total counts per each sensor, here accumulation time is housekeeping interval.
SETN_TOTAL	ASCII_NonNegative_Integer	Total counts for SETN detector.
SFN_TOTAL	ASCII_NonNegative_Integer	Total counts for SFN detector.
SHEN_TOTAL	ASCII_NonNegative_Integer	Total counts of neutrons for SHEN detector. MGNS instrument allows to monitor total counts per each sensor, where accumulation time is housekeeping interval.
PART_TOTAL	ASCII_NonNegative_Integer	Total counts of gamma for PART detector.

Label	Type	Description
GW1_TOTAL	ASCII_NonNegative_Integer	Total counts for GRS detector accumulated within GW1_MIN and GW1_MAX channel.
GW2_TOTAL	ASCII_NonNegative_Integer	Total counts for GRS detector accumulated within GW2_MIN and GW2_MAX channel.
AC_TIME_ PID90	ASCII_NonNegative_Integer	Accumulation time for PID90, regular science data, showing number of seconds to accumulate.
AC_TIME_ PID91	ASCII_NonNegative_Integer	Accumulation time for PID91, selective downlink science data, showing number of seconds to accumulate.
PACKET_NUM	ASCII_NonNegative_Integer	This value is an incremental counter, increments by 1 each time HK frame is sent.
ONBOARD_TIME_SEC	ASCII_NonNegative_Integer	BepiColombo onboard time, format is the same as SC format. Sampled at HK counter expiration.
ONBOARD_TIME_SUBSEC	ASCII_NonNegative_Integer	
HV_FAIL_GAMMA	ASCII_NonNegative_Integer	Flags of MGNS HV failures, showing state of HV DC-DC converters: 0 = OK 1 = Failure observed
HV_FAIL_SC	ASCII_NonNegative_Integer	
HV_FAIL_HE	ASCII_NonNegative_Integer	
INSTRUMENT_MODE_PID90	ASCII_NonNegative_Integer	MGNS Mode (Standby/Scientific) If one of the parameters is '1', then the MGNS instrument is in scientific mode, if both are '0', then it is in standby mode.
INSTRUMENT_MODE_PID91	ASCII_NonNegative_Integer	
INT_TIME	ASCII_NonNegative_Integer	MGNS internal time. One tick per 1/10 of second. Sampled at HK counter expiration.
HV_GAMMA	ASCII_NonNegative_Integer	HV values, shows commanded state for HV: 0 = OFF 3 = Low 2 = High
HV_SC	ASCII_NonNegative_Integer	
HV_HE	ASCII_NonNegative_Integer	
DSC_SC	ASCII_NonNegative_Integer	Discriminators values. (Discriminators SC = SHEN and PART) 0 = OFF 1 = ON
DSC_SFN	ASCII_NonNegative_Integer	
DSC_SETN	ASCII_NonNegative_Integer	
DSC_STN	ASCII_NonNegative_Integer	
CMD1_STATUS	ASCII_NonNegative_Integer	Execution status of command:

Label	Type	Description
		0 = Failed 1 = OK
CMD1_PID	ASCII_NonNegative_Integer	PID of command: 0 = PID 90 1 = PID 91
CMD1_TYPE	ASCII_NonNegative_Integer	0 = Set HK Generation Interval 1 = Accept Time update 2 = Connection test request 3 = Maximum length TC test 4 = Enable Science packet generation 5 = Disable Science generation 6 = Reset output buffer 7 = MGNS Private CMD
CMD1_OPCODE	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command OpCode, byte 1 of TC Data Field otherwise
CMD1_PARAM1	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param1, byte 2 of TC Data Field otherwise
CMD1_PARAM2	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param2, byte 3 of TC Data Field otherwise
CMD1_TIME	ASCII_NonNegative_Integer	Command receipt time (MGNS Internal Time first 4 bytes)
CMD2_STATUS	ASCII_NonNegative_Integer	Commands 2, 3 and 4 history with structures identical to Cmd1
CMD2_PID	ASCII_NonNegative_Integer	
CMD2_TYPE	ASCII_NonNegative_Integer	
CMD2_OPCODE	ASCII_NonNegative_Integer	
CMD2_PARAM1	ASCII_NonNegative_Integer	
CMD2_PARAM2	ASCII_NonNegative_Integer	
CMD2_TIME	ASCII_NonNegative_Integer	
CMD3_STATUS	ASCII_NonNegative_Integer	
CMD3_PID	ASCII_NonNegative_Integer	
CMD3_TYPE	ASCII_NonNegative_Integer	
CMD3_OPCODE	ASCII_NonNegative_Integer	
CMD3_PARAM1	ASCII_NonNegative_Integer	
CMD3_PARAM2	ASCII_NonNegative_Integer	
CMD3_TIME	ASCII_NonNegative_Integer	
CMD4_STATUS	ASCII_NonNegative_Integer	
CMD4_PID	ASCII_NonNegative_Integer	
CMD4_TYPE	ASCII_NonNegative_Integer	
CMD4_OPCODE	ASCII_NonNegative_Integer	

Label	Type	Description
CMD4_PARAM1	ASCII_NonNegative_Integer	
CMD4_PARAM2	ASCII_NonNegative_Integer	
CMD4_TIME	ASCII_NonNegative_Integer	
CHSUM	ASCII_NonNegative_Integer	Checksum calculated as an arithmetical sum over entire Data Field without Checksum field.

Table 5-1: MGNS Raw Housekeeping Product (mgn_raw_hk) label definitions

Label	Type	Description
UTC_TIME	ASCII_Date_Time_YMD_UTC	UTC time of this frame, derived from SC time through SPICE.
PACKET_NUM	ASCII_NonNegative_Integer	This value is an incremental counter.
ONBOARD_TIME_SEC	ASCII_NonNegative_Integer	BepiColombo onboard time sampled at accumulation time counter expiration.
ONBOARD_TIME_SUBSEC	ASCII_NonNegative_Integer	
INT_TIME	ASCII_NonNegative_Integer	MGNS internal time.
HV_GAMMA	ASCII_NonNegative_Integer	HV values, shows commanded state for HV: 0 = OFF 3 = Low 2 = High
HV_SC	ASCII_NonNegative_Integer	
HV_HE	ASCII_NonNegative_Integer	
DSC_SC	ASCII_NonNegative_Integer	Discriminators values. (Discriminators SC = SHEN and PART) 0 = OFF 1 = ON
DSC_SFN	ASCII_NonNegative_Integer	
DSC_SETN	ASCII_NonNegative_Integer	
DSC_STN	ASCII_NonNegative_Integer	
ACC_TIME	ASCII_NonNegative_Integer	Current MGNS accumulation time.
SFN	Group_Fields <ASCII_NonNegative_Integer>	Spectra from SFN detector.
SETN	Group_Fields <ASCII_NonNegative_Integer>	Spectra from SETN detector.
STN	Group_Fields <ASCII_NonNegative_Integer>	Spectra from STN detector.
PART	Group_Fields <ASCII_NonNegative_Integer>	Spectra of gamma and charged particles for PART detector.
SHEN	Group_Fields <ASCII_NonNegative_Integer>	Spectra of neutrons SHEN detector.
CHSUM	ASCII_NonNegative_Integer	Source data checksum.
G1_GRS	Group_Fields <ASCII_NonNegative_Integer>	Spectra for GRS detector (part 1)
G1_CHSUM	ASCII_NonNegative_Integer	Checksum.
G2_GRS	Group_Fields <ASCII_NonNegative_Integer>	Spectra for GRS detector (part 2)

Label	Type	Description
G2_CHSUM	ASCII_NonNegative_Integer	Checksum.

Table 5-2: MGNS Raw Science Neutrons and Gamma Product (mgn_raw_sc_pid90) label definitions

Label	Type	Description
UTC_TIME	ASCII_Date_Time_YMD_UTC	UTC time of this frame, derived from SC time through SPICE.
PACKET_NUM	ASCII_NonNegative_Integer	This value is an incremental counter.
ONBOARD_TIME_SEC	ASCII_NonNegative_Integer	BepiColombo onboard time sampled at accumulation time counter expiration.
ONBOARD_TIME_SUBSEC	ASCII_NonNegative_Integer	
INT_TIME	ASCII_NonNegative_Integer	MGNS internal time.
HV_GAMMA	ASCII_NonNegative_Integer	HV values, shows commanded state for HV: 0 = OFF 3 = Low 2 = High.
HV_SC	ASCII_NonNegative_Integer	
HV_HE	ASCII_NonNegative_Integer	
DSC_SC	ASCII_NonNegative_Integer	Discriminators values. (Discriminators SC = SHEN and PART) 0 = OFF 1 = ON.
DSC_SFN	ASCII_NonNegative_Integer	
DSC_SETN	ASCII_NonNegative_Integer	
DSC_STN	ASCII_NonNegative_Integer	
ACC_TIME	ASCII_NonNegative_Integer	Current MGNS accumulation time.
STN	Group_Fields <ASCII_NonNegative_Integer>	Spectra from STN detector.
SETN	Group_Fields <ASCII_NonNegative_Integer>	Spectra from SETN detector.
SFN	Group_Fields <ASCII_NonNegative_Integer>	Spectra from SFN detector.
PART	Group_Fields <ASCII_NonNegative_Integer>	Spectra of gamma and charged particles for PART detector.
SHEN	Group_Fields <ASCII_NonNegative_Integer>	Spectra of neutrons for SHEN detector.
CHSUM	ASCII_NonNegative_Integer	Source data checksum.
G1_GRS	Group_Fields <ASCII_NonNegative_Integer>	Spectra for GRS detector. (part 1)
G1_CHSUM	ASCII_NonNegative_Integer	Checksum.
G2_GRS	Group_Fields <ASCII_NonNegative_Integer>	Spectra for GRS detector. (part 2)

Label	Type	Description
G2_CHSUM	ASCII_NonNegative_Integer	Checksum.

Table 5-3: MGNS Raw Science Neutrons and Gamma Product (mgn_raw_sc_pid91) label definitions

5.1.2 Calibrated Data Products

Calibrated products are derived from raw by:

- appending time information (it is converted from source ONBOARD_TIME_* fields, which are spacecraft time, by applying SPICE library);
- converting all engineering units to physical units (temperatures and voltages);
- removing instrument engineering effects from measured data (exclusion of post switch-on warm-up intervals).
    - STN, SETN and SFN detector: neutrons are extracted from the 16-channels spectra - single float number representing neutron counts.
    - SHEN detector: integers in 16 channels representing neutron counters.
    - GRS spectrometer: integers in 4078 channels representing gamma ray counts that are obtained after combining blocks of 2043 channels one after another. The last 8 channels are excluded because they are not physical channels.

The following ASCII tables (Table Character) describe the format of calibrated data.

Label	Type	Description
UTC_TIME	ASCII_Date_Time_YMD_UTC	UTC time of this frame, derived from SC time through SPICE.
OBT_TIME	ASCII_String	S/C clock at observation time.
HK_PERIOD	ASCII_Real	HK period as commanded per TC.
TEMP_PSU1	ASCII_Real	Temperature readings in deg C.
TEMP_PSU2	ASCII_Real	
TEMP_HV_HE	ASCII_Real	
TEMP_HV_SC	ASCII_Real	
TEMP_HV_GA	ASCII_Real	
TEMP_ACTEL	ASCII_Real	
TEMP_GRS	ASCII_Real	

Label	Type	Description
TEMP_MNT_PNT	ASCII_Real	
TEMP_PSU3	ASCII_Real	
TEMP_PSU4	ASCII_Real	
ANALOG_REFERENCE	ASCII_Real	
TEMP_ACTEL_PLATA	ASCII_Real	
VOLTAGE_U5V	ASCII_Real	Internal instrument voltages in volts.
VOLTAGE_U3_3V	ASCII_Real	
VOLTAGE_U1_5V	ASCII_Real	
VOLTAGE_U6V	ASCII_Real	
STN_MIN	ASCII_NonNegative_Integer	Spectra total counts limits for detectors.
STN_MAX	ASCII_NonNegative_Integer	
SETN_MIN	ASCII_NonNegative_Integer	
SETN_MAX	ASCII_NonNegative_Integer	
SFN_MIN	ASCII_NonNegative_Integer	
SFN_MAX	ASCII_NonNegative_Integer	
SHEN_MIN	ASCII_NonNegative_Integer	
SHEN_MAX	ASCII_NonNegative_Integer	
PART_MIN	ASCII_NonNegative_Integer	
PART_MAX	ASCII_NonNegative_Integer	
GW1_MIN	ASCII_NonNegative_Integer	
GW1_MAX	ASCII_NonNegative_Integer	
GW2_MIN	ASCII_NonNegative_Integer	
GW2_MAX	ASCII_NonNegative_Integer	
STN_TOTAL	ASCII_NonNegative_Integer	Total counts for detectors.
SETN_TOTAL	ASCII_NonNegative_Integer	
SFN_TOTAL	ASCII_NonNegative_Integer	
SHEN_TOTAL	ASCII_NonNegative_Integer	
PART_TOTAL	ASCII_NonNegative_Integer	
GW1_TOTAL	ASCII_NonNegative_Integer	
GW2_TOTAL	ASCII_NonNegative_Integer	
AC_TIME_PID90	ASCII_NonNegative_Integer	Accumulation time in s.
AC_TIME_PID91	ASCII_NonNegative_Integer	Accumulation time in s.
HV_FAIL_GAMMA	ASCII_Boolean	High Voltage failure flags: 0 = OK 1 = Failure observed
HV_FAIL_SC	ASCII_Boolean	
HV_FAIL_HE	ASCII_Boolean	
INSTRUMENT_MODE_PID90	ASCII_NonNegative_Integer	MGNS Mode (Standby/Scientific) If one of the parameters is

Label	Type	Description
INSTRUMENT_MODE_PID91	ASCII_NonNegative_Integer	'1', then the MGNS instrument is in scientific mode, if both are '0', then it is in standby mode.
HV_GAMMA	ASCII_NonNegative_Integer	High voltage state values: 0 = OFF 3 = Low 2 = High
HV_SC	ASCII_NonNegative_Integer	
HV_HE	ASCII_NonNegative_Integer	
DSC_SC	ASCII_Boolean	Discriminator levels: 0 = OFF 1 = ON
DSC_SFN	ASCII_Boolean	
DSC_SETN	ASCII_Boolean	
DSC_STN	ASCII_Boolean	
CMD1_STATUS	ASCII_NonNegative_Integer	Execution status of command: 0 = Failed 1 = OK
CMD1_PID	ASCII_NonNegative_Integer	PID of command: 0 = PID 90 1 = PID 91
CMD1_TYPE	ASCII_NonNegative_Integer	0 = Set HK Generation Interval 1 = Accept Time update 2 = Connection test request 3 = Maximum length TC test 4 = Enable Science packet generation 5 = Disable Science generation 6 = Reset output buffer 7 = MGNS Private CMD
CMD1_OPCODE	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command OpCode, byte 1 of TC Data Field otherwise.
CMD1_PARAM1	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param1, byte 2 of TC Data Field otherwise.
CMD1_PARAM2	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param2, byte 3 of TC Data Field otherwise.
CMD1_TIME	ASCII_NonNegative_Integer	Command receipt time (MGNS Internal Time first 4 bytes)

Label	Type	Description
CMD2_STATUS	ASCII_NonNegative_Integer	Execution status of command: 0 = Failed 1 = OK
CMD2_PID	ASCII_NonNegative_Integer	PID of command: 0 = PID 90 1 = PID 91
CMD2_TYPE	ASCII_NonNegative_Integer	0 = Set HK Generation Interval 1 = Accept Time update 2 = Connection test request 3 = Maximum length TC test 4 = Enable Science packet generation 5 = Disable Science generation 6 = Reset output buffer 7 = MGNS Private CMD
CMD2_OPCODE	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command OpCode, byte 1 of TC Data Field otherwise.
CMD2_PARAM1	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param1, byte 2 of TC Data Field otherwise.
CMD2_PARAM2	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param2, byte 3 of TC Data Field otherwise.
CMD2_TIME	ASCII_NonNegative_Integer	Command receipt time (MGNS Internal Time first 4 bytes)
CMD3_STATUS	ASCII_NonNegative_Integer	Execution status of command: 0 = Failed 1 = OK
CMD3_PID	ASCII_NonNegative_Integer	PID of command: 0 = PID 90 1 = PID 91
CMD3_TYPE	ASCII_NonNegative_Integer	0 = Set HK Generation Interval 1 = Accept Time update 2 = Connection test request 3 = Maximum length TC test 4 = Enable Science packet

Label	Type	Description
		generation 5 = Disable Science generation 6 = Reset output buffer 7 = MGNS Private CMD
CMD3_OPCODE	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command OpCode, byte 1 of TC Data Field otherwise.
CMD3_PARAM1	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param1, byte 2 of TC Data Field otherwise.
CMD3_PARAM2	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param2, byte 3 of TC Data Field otherwise.
CMD3_TIME	ASCII_NonNegative_Integer	Command receipt time (MGNS Internal Time first 4 bytes)
CMD4_STATUS	ASCII_NonNegative_Integer	Execution status of command: 0 = Failed 1 = OK
CMD4_PID	ASCII_NonNegative_Integer	PID of command: 0 = PID 90 1 = PID 91
CMD4_TYPE	ASCII_NonNegative_Integer	0 = Set HK Generation Interval 1 = Accept Time update 2 = Connection test request 3 = Maximum length TC test 4 = Enable Science packet generation 5 = Disable Science generation 6 = Reset output buffer 7 = MGNS Private CMD
CMD4_OPCODE	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command OpCode, byte 1 of TC Data Field otherwise.
CMD4_PARAM1	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param1, byte 2 of TC Data Field otherwise.

Label	Type	Description
CMD4_PARAM2	ASCII_NonNegative_Integer	In case of MGNS Private Command, Command Param2, byte 3 of TC Data Field otherwise.
CMD4_TIME	ASCII_NonNegative_Integer	Command receipt time (MGNS Internal Time first 4 bytes)

Table 5-4: MGNS Calibrated Housekeeping Product (mgn_cal_hk) label definitions

Label	Type	Description
UTC_TIME	ASCII_Date_Time_YMD_UTC	UTC time of this frame, derived from SC time through SPICE.
OBT_TIME	ASCII_String	S/C clock at observation time.
HV_GAMMA	ASCII_NonNegative_Integer	High voltage state values: 0 = OFF 3 = Low 2 = High.
HV_SC	ASCII_NonNegative_Integer	
HV_HE	ASCII_NonNegative_Integer	
DSC_SC	ASCII_Boolean	Discriminator levels: 0 = OFF 1 = ON
DSC_SFN	ASCII_Boolean	
DSC_SETN	ASCII_Boolean	
DSC_STN	ASCII_Boolean	
ACC_TIME	ASCII_NonNegative_Integer	Accumulation time of current frame in s.
SFN_PROFILE	ASCII_Real	Neutrons are extracted from the 16-channels spectra, exclusion of post switch-on warm-up intervals - single float number representing neutron counts.
SETN_PROFILE	ASCII_Real	Neutrons are extracted from the 16-channels spectra, exclusion of post switch-on warm-up intervals - single float number representing neutron counts.
STN_PROFILE	ASCII_Real	Neutrons are extracted from the 16-channels spectra, exclusion of post switch-on warm-up intervals - single float number representing neutron counts.
SHEN_SPECTRA	Group_Fields <ASCII_NonNegative_Integer>	Exclusion of post switch-on warm-up intervals - single

Label	Type	Description
		integer numbers representing neutron counts in 16 channels.
GRS_SPECTRA	Group_Fields <ASCII_NonNegative_Integer>	Spectra for GRS detector. Exclusion of post switch-on warm-up intervals - single integer numbers representing gamma-rays counts in 4078 channels.

Table 5-5: MGNS Calibrated Science Neutron and Gamma-ray Product (mgn_cal_sc_pid90) label definitions

Label	Type	Description
UTC_Time	ASCII_Date_Time_YMD_UTC	UTC time of this frame, derived from SC time through SPICE.
OBT_Time	ASCII_String	S/C clock at observation time.
HV_GAMMA	ASCII_NonNegative_Integer	High voltage state values: 0 = OFF 3 = Low 2 = High.
HV_SC	ASCII_NonNegative_Integer	
HV_HE	ASCII_NonNegative_Integer	
DSC_SC	ASCII_Boolean	Discriminator levels: 0 = OFF 1 = ON
DSC_SFN	ASCII_Boolean	
DSC_SETN	ASCII_Boolean	
DSC_STN	ASCII_Boolean	
ACC_TIME	ASCII_NonNegative_Integer	Accumulation time of current frame in s.
SFN_PROFILE	ASCII_Real	Neutrons are extracted from the 16-channels spectra, exclusion of post switch-on warm-up intervals - single float number representing neutron counts.
SETN_PROFILE	ASCII_Real	Neutrons are extracted from the 16-channels spectra, exclusion of post switch-on warm-up intervals - single float number representing neutron counts.
STN_PROFILE	ASCII_Real	Neutrons are extracted from the 16-channels spectra, exclusion of post switch-on warm-up intervals - single float number representing

Label	Type	Description
		neutron counts.
SHEN_SPECTRA	Group_Fields <ASCII_NonNegative_Integer>	Exclusion of post switch-on warm-up intervals a - single integer numbers representing neutron counts in 16 channels.
GRS_SPECTRA	Group_Fields <ASCII_NonNegative_Integer>	Spectra for GRS detector. Exclusion of post switch-on warm-up intervals - single integer numbers representing gamma-rays counts in 4078 channels.

Table 5-6: MGNS Calibrated Science Neutron and Gamma-ray Product (mgn_cal_sc_pid90) label definitions

Note, that Calibrated products contain only instrument-related data and no auxiliary information like spacecraft geometry. This is due to the fact that appending any non-instrument information will lead to reprocessing of the whole instrument archive in case, e.g. SPICE mission kernels are updated, which is undesirable. Preferable to generate SPICE information at time of use of calibrated product, using the latest SPICE kernels.

5.1.3 Derived Data Products

Derived products for the neutron detectors and gamma-rays spectrometer are created from calibrated data by putting time series data of counts from different detectors and summing these up in each pixel, over a period of time. The structure of derived products is defined below:

Label	Type	Description
START_TIME	ASCII_Date_Time_YMD_UTC	UTC start and end times of the current map
END_TIME	ASCII_Date_Time_YMD_UTC	
MAP	Array_2D	Array of detectors counts per second in current pixel
MAP_EXPOSURE	Array_2D	Array of exposure time in current pixel in seconds
MAP_ERR	Array_2D	Errors of counts in current pixel

Table 5-7: MGNS Derived Neutron and Gamma Science product label definition

X and Y are dimensions of map arrays that define the spatial resolution of the product, to be defined at time of product delivery and will depend on the time span of the product (i.e.

longer periods of maps will have better statistics that will allow for higher spatial resolution).
Since geometry information is used during the generation of product, the SPICE version and kernels used will be included into product delivery documentation to allow traceability.

5.2 Supplementary Products Formats

Supplementary products will generally have the same format as Derived products defined in the section above, but will contain data converted to Hydrogen, water equivalent concentrations or contents of soil elements for each pixel. Product contents to be defined at times of delivery of such supplementary product.

END OF DOCUMENT