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BEPICOLOMBO SGS

SERENA Data User Guide (DUG)

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APPROVAL

SERENA Data User Guide	
Issue 1	**Revision** 4
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CHANGE LOG

Reason for change	Issue	Revision	Date
First draft for iteration	1	0	05/06/2019
Preparation for first SERENA Archive Review	1	1	16/10/2023
Iteration after first feedback by SGS	1	2	31/10/2024
New pipeline versions	1	3	30/09/2025
SGS Archive Scientist feedback	1	4	05/12/2025

CHANGE RECORD

Issue 1, Revision 4 - 05/12/2025	
Reason for change	**Section**
Included cross-references to sections, tables, and figures	All
Added a few more acronyms	Section 1.2.3
Added ELENA Acknowledgment text	Section 1.3.3
Expanded the LID description	Section 4.3
Combined data products description and filename tables for each sensor	Section 4.4
The Datasets by Mission Phase section is now a subsection of the Datasets Overview	Section 5.1
Added a placeholder for a section describing the different major product versions	Section 5.2
Detailed description of the Datasets moved to Appendix	Appendix B

Issue 1, Revision 3 - 30/09/2025	
Reason for change	**Section**
Expanded the Citation and Licensing section	Section 1.3
Added text to the Data Availability section	Section 1.4
Addition of ELENA C-32 mode	Sections 2.2.1.2, 4.4.1

Added more details on the translation from raw to calibrated data	Section 3.2
Products updated to IM 1.22.0.0 naming conventions.	Section 4.4
Added text on how to approach the SERENA dataset	Section 6.1
Added text on working with the SERENA data sensor by sensor	Section 6.2
Added examples of scientific analysis for the sensors that have meaningful science data after the cruise phase (MIPA and PICAM)	Section 6.3

Issue 1, Revision 2 - 31/10/2024

Reason for change	Section
Changed the name of this document from EAICD to Data User Guide (DUG)	all
Added a placeholder for the section on Citation and License Information	Section 1.3
Added a placeholder for the section on Data Availability	Section 1.4
The sensors description (concept, modes, scientific measurements, and calibration) is now consolidated into single subsections for each sensor.	Section 2.2
Removed irrelevant information about flexible downlink	Section 3.1
Consolidated the Data Generation subsection by subunit	Section 3.2
Removed the placeholder for the subsection on Data Validation	Section 3.3
Removed the Data Delivery Schedule subsection	Section 3.5
The section on the data products has been consolidated by subunit and moved to the SERENA Data Products and Organisation section	Section 4.4
Added a table for the ELENA operations since launch	Section 5.1
Added a table for the STROFIO operations since launch	Section 5.2
Added a table for the PICAM operations since launch	Section 5.4
Added a placeholder for the section on Science User Guide	Section 6
Minor text improvements	all

Issue 1, Revision 1 - 16/10/2023

Reason for change	Section
Added SERENA specific acronyms	Section 1.4
Added a paragraph describing SCU	Section 2.2.5
Updated information about MIPA and PICAM modes	Sections 2.3.3, 2.3.4
Updated SERENA science operations plan	Section 2.4
Updated information about PICAM in-flight calibration	Section 2.5.8
Updated information about sensor measurements	Section 3.1
Added sections on data flow and data generation	Sections 3.2, 3.3
Updated SERENA data organization section	Section 4
New and revised data products format section	Section 5
Added a new Section 6 covering the details of the various data sets	Section 6

Created Appendix A with data products fields descriptions	Appendix A

Table of Contents

1. Introduction

1.1 Purpose and Scope

This Data User Guide (DUG) describes the format, content, and usage of the SERENA archived data. It provides details of the data products and associated metadata, including their format, content, and the processing pipeline used to generate them. The specifications described in this DUG apply to all SERENA products submitted for archiving to ESA's BepiColombo Science Ground Segment (SGS), for all phases of the BepiColombo mission, unless stated otherwise in the data caveats sections. Archive products are produced both by the SERENA instrument team and by the SGS.

In addition to these specifications, this document is intended as a guide for scientists using SERENA data. It explains how the data are organized, what information can be extracted from them, and how to approach them for different types of scientific investigations. The major sections of the DUG are organized as follows:

- **Section 2 – SERENA Instrument Description:** Provides an overview of the four SERENA sub-instruments (ELENA, STROFIO, PICAM, MIPA), their measurement principles, operating modes, and science objectives.
- **Section 3 – Data Generation and Analysis Process:** Describes the overall data flow from telemetry to the various levels of archived products, including the processing pipelines and product generation overview.
- **Section 4 – SERENA Data Products and Organisation:** Outlines the structure of the SERENA data bundle, its collections (raw, calibrated, derived, browse, document), and the organization and types of data products within each collection.
- **Section 5 – Datasets Overview:** Summarizes the datasets available from different phases of the BepiColombo mission (cruise, flybys, orbital phases), indicating which types of data are generated during each phase. Additionally, provides information on the different major versions issued.
- **Section 6 – Science User Guide:** Provides practical guidance for scientists, including strategies for approaching the datasets, working with instrument-specific metadata and caveats, and example analyses.
- **Appendix A - Detailed Fields Description of the SERENA Data Products**: Presents the full list of fields used in SERENA data products, including names, data types, units, and definitions. This appendix is intended as a technical reference for users working directly with the data tables.
- **Appendix B - Detailed Description of the SERENA Datasets**: Gives detailed information on the scientific, calibration, or testing purposes of each dataset.

Together, these sections are intended to give users both the **technical details** necessary for understanding the archived products and the **practical guidance** needed to make effective scientific use of the SERENA datasets.

1.2 Related Documentation

1.2.1 Applicable Documents

The following documents are pertinent to the extent specified here and impose requirements to the SGS or the SGS schedule. They are referenced in the form [AD.XX]:

[AD.01] – BC-SGS-PL-014, BepiColombo Science Data Generation, Validation and Archiving Plan

[AD.02] – BC-SGS-TN-026, BepiColombo Archiving Guide

[AD.03] – PDS4 Standards Reference (SR)

[AD.04] – PDS4 Data Dictionary (DDDB)

[AD.05] – PDS4 Information Model Specification (IM)

1.2.2 Reference Documents

The following documents 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] – BC-SGS-ICD-011, SERENA Data Processing Agreement

[RD.03] – PDS4 Data Providers Handbook (DPH)

[RD.04] – PDS4 Concepts

[RD.05] – BC-SGS-LI-014, SGS Glossary

[RD.06] – BC-SRN-UM-03001__SERENA_Instrument_User_Manual__16_0

[RD.07] – BC-SRN-RP-00028__SERENA_Science_Perf_Report__6_2

[RD.08] – BC-SRN-RP-34254__ELENA_PFM_CalibrationReport__1_4

[RD.09] – BC-SRN-TR-40020__MIPA_FM_Calibration_Report__1_0

Reference documents RD.06-RD.10 can be found in the SERENA Document collection (see Section 4.2.7).

1.2.3 Abbreviations and Acronyms

See BepiColombo online Glossary [RD.05].

CCEM	Ceramic Channel Electron Multipliers
CDF	Common Data Format
CSV	Comma-Separated Values
ELENA	Emitted Low Energy Neutral Atoms
ENA	Energy Neutral Atoms
ISTP	International Solar-Terrestrial Physics
MCP	Microchannel Plate
MIPA	Miniature Ion Precipitation Analyzer
PICAM	Planetary Ion CAMera
SCU	System Control Unit
SERENA	Search for Exospheric Refilling and Emitted Natural Abundances
STROFIO	STart from a ROtating FIeld mass spectrOmeter
TSV	Tab-Separated Values
XML	eXtensible Markup Language

1.3 Citation and License Information

This section describes how the SERENA data should be cited in the literature and under which license will the data be distributed. Once data are public, any related issued DOIs will be listed here.

1.3.1 Citation of the Data Bundle and the Data Collections

Each bundle and collection is assigned a persistent identifier (DOI), which should be used for citation (see Table 1-1).

Sensor	Collection/Bundle	Authors	DOI
ELENA	SERENA ELENA Raw Data		TBD

	SERENA ELENA Partially Processed Data	E. De Angelis, R. Rispoli, A. Mura, R. Sordini, A. Brin, A. Milillo, A. Aronica, A. Kazakov, V. Mangano	TBD
	SERENA ELENA Calibrated Data		TBD
	SERENA ELENA Derived Data		TBD
STROFIO	SERENA STROFIO Raw Data	S. Livi, J. Raines, B. Trantham, P. Wurz, J. Schroeder, F. Allegrini, A. Milillo, A. Aronica, A. Kazakov, V. Mangano	TBD
	SERENA STROFIO Partially Processed Data		TBD
	SERENA STROFIO Calibrated Data		TBD
	SERENA STROFIO Derived Data		TBD
MIPA	SERENA MIPA Raw Data	S. Barabash, H. Nilsson, M. Wieser, H. Williamson, A. Milillo, A. Aronica, A. Kazakov, V. Mangano	TBD
	SERENA MIPA Calibrated Data		TBD
	SERENA MIPA Derived Data		TBD
PICAM	SERENA PICAM Raw Data	A. Varsani, H. Jeszenszky, F. Giner, G. Laky, A. Milillo, A. Aronica, A. Kazakov, V. Mangano	TBD
	SERENA PICAM Calibrated Data		TBD
	SERENA PICAM Derived Data		TBD

***Table 1-1** - SERENA data bundle and collections DOIs*

1.3.2 Citation of Related Publications

In addition, users are encouraged to cite the relevant instrument papers (see Table 1-2).

Instrument/ Topic	Reference	DOI
SERENA Suite Overview	Orsini et al. Space Science Reviews, 2021	10.1007/s11214-020-00787-3
	Orsini et al., Nature Communications, 2022	10.1038/s41467-022-34988-x
Mission Context	Benkhoff et al., Space Science Review, 2021	10.1007/s11214-021-00861-4
	Milillo et al., Space Science Reviews, 2020	10.1007/s11214-020-00712-8
	Mangano et al., Space Science Review, 2021	10.1007/s11214-020-00787-3

***Table 1-2 -** SERENA key publication references and DOIs*

1.3.3 Acknowledgement Text

When publishing results that make use of these data, please include the following acknowledgement:

Short version:

"SERENA is supported by the Italian Space Agency (ASI) and by the Italian National Institute of Astrophysics (INAF): SERENA agreement no. 2024-66-HH.0 "Attività scientifiche per il Payload SERENA su Bepi-Colombo, relative alla fine della fase di crociera e fase operativa".

Full version:

"These data were provided by the SERENA instrument team and are archived in the ESA Planetary Science Archive (PSA). The SERENA instrument suite is part of ESA-JAXA's BepiColombo Mercury Planetary Orbiter mission. The experiment is led by INAF/IAPS (Italy) and has been developed by the Italian industrial consortium OHB Italia and AMDL srl. SERENA is supported by the Italian Space Agency (ASI) and by the Italian National Institute of Astrophysics (INAF): SERENA agreement no.

2024-66-HH.0 *"Attività scientifiche per il Payload SERENA su Bepi-Colombo, relative alla fine della fase di crociera e fase operative."*

For publications focusing on a specific sensor, it is recommended to also acknowledge the respective instrument team:

- ELENA: "The ELENA sensor has been developed by INAF/IAPS (Italy) with a participation of CNR/ISC and CNR/IFN (Italy) and IRAP (France), with the support from the Italian Space Agency (ASI) and from the Italian National Institute of Astrophysics (INAF): SERENA agreement no. 2024-66-HH.0 *"Attività scientifiche per il Payload SERENA su Bepi-Colombo, relative alla fine della fase di crociera e fase operative."*
- STROFIO: "The Strofio sensor was developed with support from NASA at Southwest Research Institute and the Johns Hopkins University Applied Physics Lab, as well as the University of Bern."
- MIPA: "The MIPA sensor was developed with support from the Swedish National Space Agency, the Swedish Institute of Space Physics, and the University of Bern."
- PICAM: "The PICAM sensor was developed by an international consortium led by the Space Research Institute of the Austrian Academy of Sciences with support from the Austrian Research Promotion Agency (FFG) and the Programme de Dévelopement d'Expériences scientifiques (PRODEX). The consortium included the Laboratoire de Physique des Plasmas and Laboratoire Atmosphères (LPP/LATMOS France), Max Planck Institute for Solar System Research (MPS, Germany), the Research Institute for Particle and Nuclear Physics (KFKI, Hungary), the Space Technology Ireland (STIL, Ireland) and the European Space Technology and Research Centre (ESTEC, The Netherlands).

1.3.4 Licensing

The SERENA data bundle is distributed under the ESA Planetary Science Archive open data policy, equivalent to Creative Commons Attribution 3.0 International (CC BY-NC 3.0 IGO). This permits use, distribution, and reproduction in any medium, provided the data are properly cited. Data are provided 'as is' without warranty as to accuracy or completeness.

1.3.5 Responsibility Disclaimer

Neither ESA, NASA nor the SERENA instrument team shall be held responsible for any secondary analysis, interpretation, or conclusions drawn from these data by users.

1.4 Data Availability

All SERENA data are archived and distributed through the ESA Planetary Science Archive (PSA), which serves as the authoritative and permanent repository. The PSA provides access through both a web-based interface and an API service, enabling direct search, browse, and download of SERENA data products. The repositories of the PSA can be directly accessed at https://psa.esa.int. The help page therein describes alternative methods to access or download the data.

Additional repositories (e.g., Zenodo mirrors, NASA Planetary Data System cross-archiving, or institutional archives) may be considered in the future. If available, such complementary repositories will be listed in this guide.

2. SERENA Instrument Description

2.1 Science Objectives

Search for Exospheric Refilling and Emitted Natural Abundances (SERENA) addresses some of the main scientific objectives of the BepiColombo mission: composition, origin and dynamics of Mercury's exosphere and polar deposits; and structure and dynamics of Mercury's magnetosphere. The major goals of SERENA are to understand:

- Exosphere composition and spatial distribution and dynamics
- Search for exo-ionosphere and its relationship with neutral atmosphere
- Surface release processes
- Exosphere-magnetosphere exchange and transport processes
- Escape, source-sink balance, geochemical cycles

The accomplishment of these goals is crucial for the knowledge of the environment and the evolution of Mercury.

SERENA is a single experiment composed by four sensors devoted to the detection of neutral and ionized particles in the Hermean environment. In particular, the four sensors are:

- STROFIO (STart from a ROtating Field mass spectrOmeter) measures the in-situ neutral particle composition at the lowest energy range [from ~0 up to a few eV], and the particle density in the exosphere. The analysis of the exospheric released gases allows indirect reconstruction of the surface composition, by processing successive measurements over several orbits.
- ELENA (Emitted Low Energy Neutral Atoms) covers the [10 eV – 5 keV] integrated energy spectrum of neutral population from the surface and the close-to-planet environment. It has a high angular resolution and a nadir pointing 1-D field-of-view (perpendicular to the S/C orbital plane). This configuration allows a subsequent collection of the ELENA observations along each single orbit for reconstructing the global image of the particle populations surrounding Mercury and its interaction with the surface.
- MIPA (Miniature Ion Precipitation Analyzer) will detect ions up to 15 keV with low mass resolution. It is specifically devoted to monitor the intense solar wind fluxes out and inside the Mercury's magnetosphere in the context of the planetary responses detected by ELENA.
- PICAM (Planetary Ion CAMera) is an ion spectrometer with good mass resolution. Its main goal is to detect and characterize low energy ions (up to 3 keV), so that a complete analysis of the planetary particles' composition in the Hermean environment will be obtained together with STROFIO.

These science goals are considered to have the highest priority, but SERENA will be also contributing to investigations addressed by other instruments of the BepiColombo payload related to magnetospheric plasma circulation or to surface composition and properties. The opportunity to operate sensors simultaneously greatly improves the success of SERENA scientific objectives and allows for additional objectives. The scientific objectives and requirements are considered assuming SERENA as a single experiment. Nevertheless, the four sensors can technically operate independently from each other. The detailed scientific objectives and requirements are described in the SERENA Science Performance Report [RD.07].

2.2 Sensor Descriptions

For a detailed description, see the SERENA User Manual [RD.06]

2.2.1 ELENA

2.2.1.1 ELENA concept

ELENA (Figure 2-1) is a neutral-particle imaging sensor. The purpose of the system is to image the incoming particles without introducing "disturbing" detector elements, which may affect the particle's trajectory. The external collimator defines the overall ELENA field of view (FoV) (4.5° x 76°) and instrument aperture with the main axis directed toward the nadir direction. To observe the horizon during apoherm passages, the linear array of ELENA angular pixels is shifted 8° perpendicular to the spacecraft orbital plane opposite to the spacecraft radiator (Figure 2-2).

To reduce the charged particle background, the ELENA entrance has a charged particle deflector comprising three wire grids operated at different potentials. To reduce the UV noise induced by solar photons reflected by the planet surface, a UV filter, comprising two grating membranes, is placed at the ELENA entrance. Neutral particles passing through the entrance travel inside the instrument and are detected directly by an MCP detector over imposed to an array of 32 anodes. Inside the instrument chamber, an internal deflector, constituted by two plates at different electric potentials, which introduce a transversal E-field, is able to deviate out the bulk of the charge particles of both signs not suppressed by the external deflectors or generated by the interaction of the particles with the entrance grids. In this way, imaging of the neutral emission from planet's surface is guaranteed. The ion population can be detected by switching-off the deflectors.

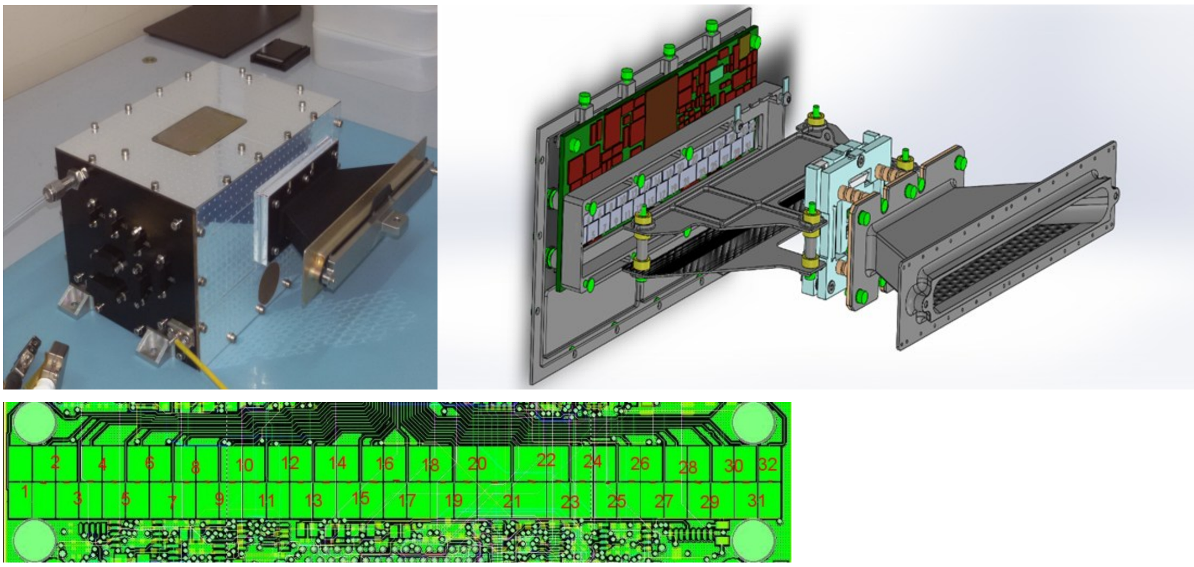


Figure 2-1 - *Above left: ELENA sensor. Above right: ELENA concept. Below: ELENA anode schematics.*

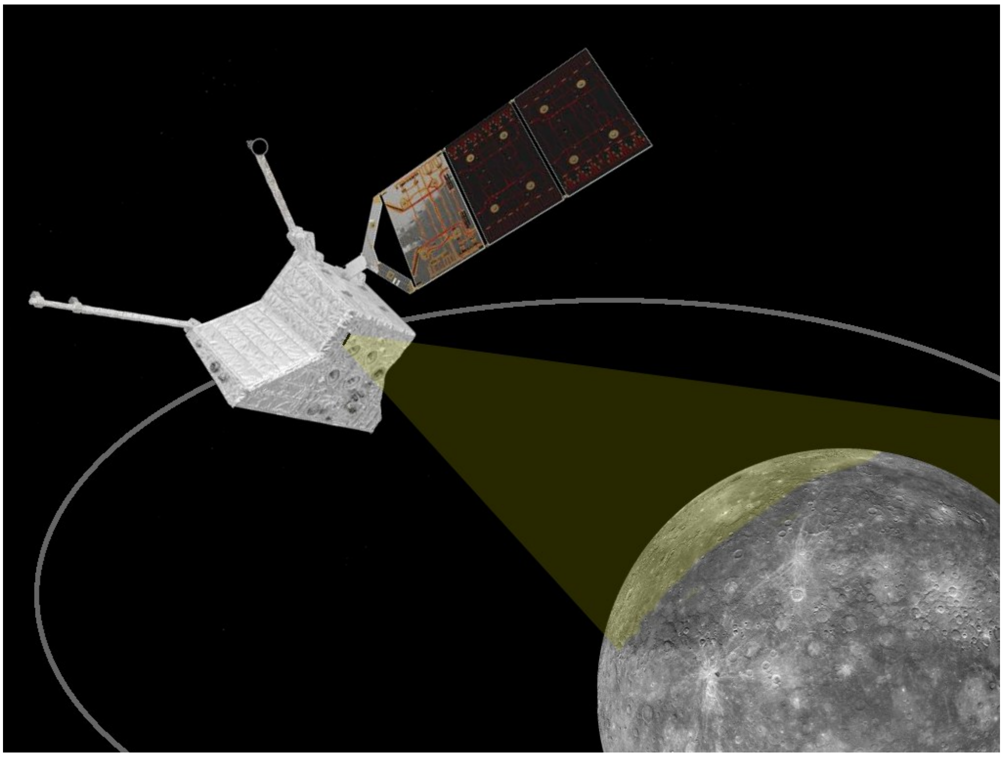


***Figure 2-2 –** Shift of ELENA's FoV to allow observations of the horizon at apoherm.*

2.2.1.2 ELENA modes and scientific measurements

ELENA has only one scientific state and the different science modes can be set by a specific telecommand (TC) (ZSE03016) and several parameters. Among the parameters, we define:

1. Integration time in seconds (s): default is 10 s for modes S, SO-32, SO-16, and C-32; 1 s for mode R (see Table 2-1)
2. Science mode: 1 = Sector histogram; 4 = Event by event.
3. Sector resolution: 1 = 32 sectors; 2 = 16 sectors.
4. Test mode: 0 = Sampled data; 1 = Simulated data.
5. Histogram type: 0 = Standard Histogram type; 1 = Extended Histogram type (multiplicity info).

From the telemetry point of view, the science resolution is identified by the SID (Structure ID) as follows:
SID: 0 = 32 Sectors resolution; 1 = 16 Sectors resolution; 4 = Event-by-Event.

NAME	INFO	MODE	HISTOGRAM TYPE	POWER at Beginning of Life (BOL) [W]	POWER at End of Life (EOL) [W]	Telemetry Rate (uncompressed) [bit/s]	TIME [s]
SO-16	Sector (Old type, 16 Sectors)	Sector histogram	Standard	10.5*	11.5*	52**	10
SO-32	Sector (Old type, 32 Sectors)	Sector histogram	Standard	10.5*	11.5*	77**	10
C-32	Sector (Calibration type, 32 Sectors)	Sector histogram	Standard	10.5*	11.5*	77**	10

S	**Sector (32 Sectors)**	**Sector histogram**	**Extended (with multiplicity info)**	**10.5***	**11.5***	77**	**10**
R	**Ev-by-ev**	**Event-by-event**	**N/A**	**10.5***	**11.5***	**8480*****	**1*******

Table 2-1 - *ELENA Science Modes, Power (W) and Telemetry (bit/s).*

These are all the combinations of ELENA science modes but only **modes S and R** (in bold) **are** considered **nominal** and will be the ones primarily **used in-flight**. While, SO-16, SO-32, and C-32 are backup modes mainly used for in-flight testing and calibration.

The ELENA ion detection can be configured by setting the ion deflectors' voltages to zero. All the above modes can be used for the ion detection as ion modes.

(*) Power BOL and EOL include only ELENA consumption, without considering the contribution of 4.2/4.6 W (BOL/EOL) for SCU and 0.91/1.00 W (BOL/EOL) added when MIPA is turned ON.

(**) Telemetry rate depends on the integration time applied to the Sector histogram modes. Nominally, ELENA integration time is set to 10 sec (default value) but can be increased up to the maximum value of 60 sec. So, the TM rate changes as following:

- with a resolution of 32 sectors: 10s integration time (default value) => 77 bit/s; 60s integration time => 12 bit/s.

- with a resolution of 16 sectors: 10s integration time (default value) => 52 bit/s; 60s integration time => 8 bit/s.

(***) Based on 0s integration time (corresponding to 100 ms) the maximum bitrate for R mode is 17000 bit/s, that is 2 KB/s and 2 TM packets per second. Similarly: 1s integration time => max bitrate 8480 bit/s, that is 1 KB/s and 1 TM packets per second (default value); 2s integration time => max bitrate 4240 bit/s, that is 0.5 KB/s and 1 TM packets every 2 seconds.

(****) Note that for R mode the bitrate depends on the integration time (1s is default value) and is independent from real events because every packet is always pre-set with 512 zero-events that are overwritten by real time events or particle events in case of detection.

In all the scientific modes of ELENA the sensor measures the number of activations on each of its actively measuring anodes and reports it for the respective integration time. The S, SO-16, SO-32, and C-32 modes report the cumulative counts for the total integration time. While mode R gives a more fragmented temporal view of the particles hitting the MCP by splitting the period to short intervals of 12.5 ms and reporting the activated anodes during this short time span one by one (event by event).

Depending on the filtering efficiencies, besides the neutral particle counts in the number of activations there may be present also noise from photons and charged particles. These are excluded in the processing step from raw to calibrated data (Section 3.2.1.3), and the raw activation counts are transformed to neutral particle counts/cm^2s. If the ion deflectors are turned off, the activations of the anodes from charged particles are also included in the flux evaluation.

All ELENA scientific modes (S, R, SO-16, SO-32, and C-32) produce science data products in the raw and calibrated levels, while the event-by-event mode (R) produces also partially processed data. See Section 3.2.1 for more information on the ELENA data generation process and Section 4.4.1 for detailed description of the data products.

2.2.1.3 ELENA on-ground calibrations

The ELENA model mounted on-board the MPO is the ELENA Proto-Flight Model (PFM). The calibrations of the ELENA PFM are reported in [RD.08] and its performances have been verified as reported in [RD.07].

Angular resolution

Different energies and species and charge states have been tested in the PFM for evaluating the angular resolution and the absolute calibration at the Mefisto facility in Bern. In Figure 2-3 an example of angular scan is shown. Note that the anodes are disposed on two rows so that there is an over-sampling of angles, which further improves the angular resolution. The verified angular resolution is < 5°, better than the science performance requirement.

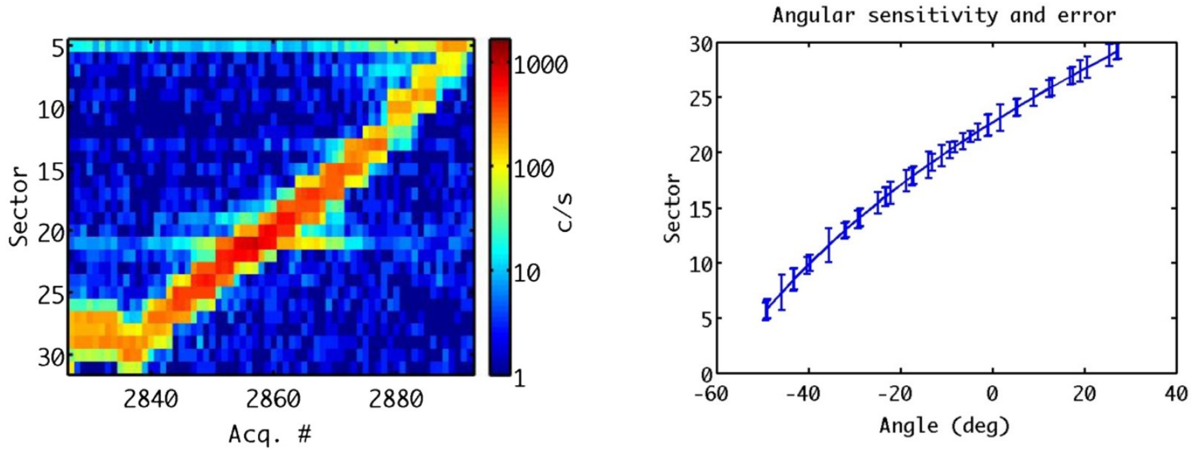


***Figure 2-3 -** 1-keV O angular scan vs acquisition number (left), T int=10 s. The sector distribution of the scanning as a function of incidence angle (right) shows the angle-sector correspondence and spread. Note that the efficiency is lower at higher angle as shown by the normalization factor (below)*

Angular responsivity

The Angular Responsivity (*AR*) depends on the input direction. The lower responsivity at higher entrance angles is due to the geometric shadow of the finite width of the membranes at the ELENA entrance. An extra reduction of responsivity at high angles could be due to MCP efficiency reduction at wide incidence angles.

Efficiency

The total input flux can be obtained by the expected counts C_{ei} on the single anode:

$$C_{ei}^{*}=F_t \cdot r \cdot T \cdot AR_i\, \varepsilon \cdot K_d \cdot K_M \cdot A$$

where:

- F_t = total input flux
- r = fraction of F_t impinging on the single sector, estimated as C_{mi}/S_s where C_{mi} are counts on the sector *i* and S_s are total counts for all sectors (sector sum)
- T = shutter membrane transparency = 10^{-2}
- AR_i = normalized angular response of each sector (see Table 2-2)
- ε(*E*) = MCP efficiency (Rispoli et al. 2013)
- K_d = reduction factor due to electronic readout loss time (1.6s/Tint -> 84%, where Tint=10s)
- K_M = reduction factor for electronic memory load (52% - 93%)

- A = area = 1 cm^2

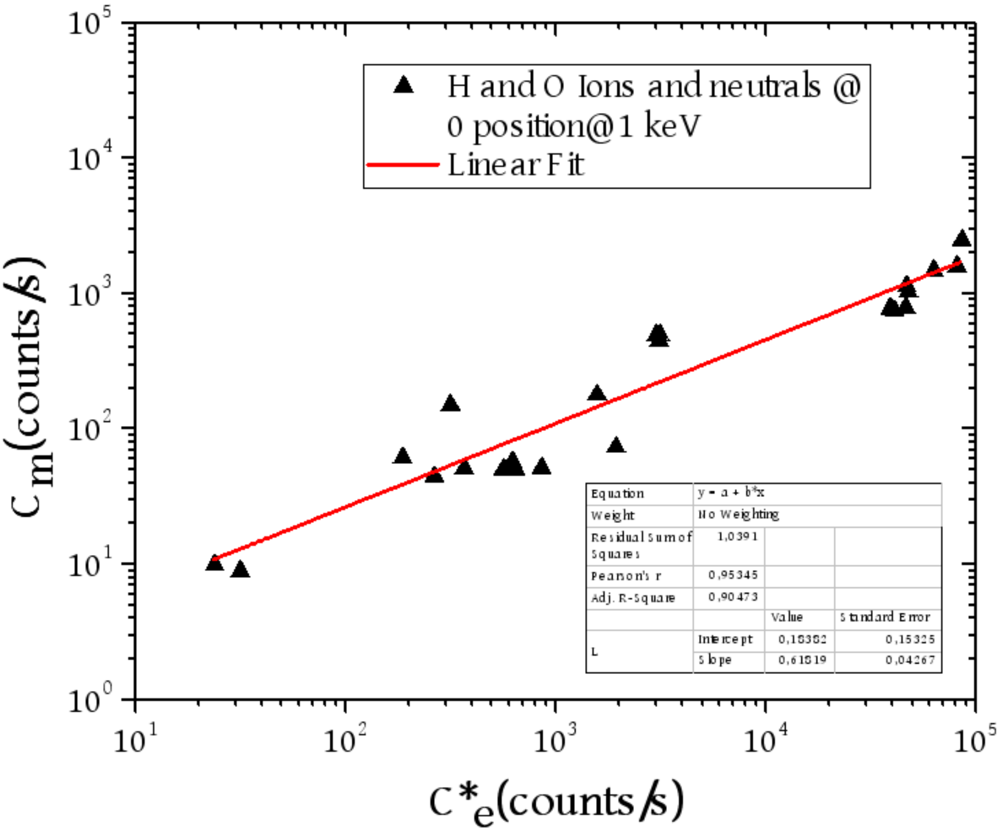


Figure 2-4 *- Measured counts vs. expected counts at 0° angle to the normal for different flux intensities, energies, species and charges.*

The data collected at 0° incidence angle for H and O neutrals, H^+ ions and UV have been compared. Figure **2-4** shows the sector integrated counts C_m as function of C_e at 0°. The best-fit curve obtained using all the tested particles is $C_e^* = 0.51\ C_m^{1.61}$. The estimated uncertainty on the C_e^* is in the range 50%–75%.

The same analysis has been performed for the other anodes and incident directions [RD.08]. . The transformation function is: $C_{ei}^* = 0.51\ C_{mi}^{1.61}$.

AR_i values are reported in Table 2-2:

Anode	Angular Response Factor
31	0.03724
30	0.25408
29	0.46559
28	0.55005
27	0.67279
26	0.77142
25	0.83367

European Space Agency
Agence spatiale européenne

24	0.7979
23	0.86344
22	0.91817
21	1
20	0.91206
19	0.78536
18	0.6056
17	0.58136
16	0.57593
15	0.56097
14	0.49015
13	0.42305
12	0.32747
11	0.30613
10	0.38881
9	0.38615
8	0.27913
7	0.14541
6	0.08946

Table 2-2 - *ELENA Angular Response (AR) for each sector.*

Ion rejection capability

Ion rejection capability has been successfully verified with the ELENA Flight Spare (FS) and PFM. Since the evaluated performance is a ratio between signal before and after deflection, the results of FS can be considered valuable as the PFM one. Table 2-3 summarizes the results for ion rejection capability (R_{ion}) for Voltages above or below the input energy. The two tested ion species (Hydrogen and Oxygen) at different energies are reported.

Species	E (keV)	R_{ion}(%) @ $V_{app}<V_{th}$	R_{ion}(%) @ $V>V_{th}$	R_{ion}(%) @ nominal
H^+	1.0	97.3-99	98.3-99.8	99.0±0.8
H^+	3.0	96	99.5	99.5
O^+	4.0	97	NA	97

Table 2-3 - *Summary of ion rejection background for different species/energy.*

In Mercury's environment, the solar wind heavy ions component is more energetic; nevertheless, heavy ions can have higher charge state, so that finally the rejection efficiency is similar to that of protons.

There is a possible warning during extreme events. In the case of extreme events, during strong CME, the energies and fluxes could be higher (H up to 3 keV and He^+ at 6 keV); hence, background could be higher. Also back-scattering signal would increase. The conclusion is that in the nominal configuration of deflector voltages the R_{ion} is > 99.5% as requested by [RD.07] for positive charged particles at E/q <3 keV/C.

UV Transparency

Average UV Transparency T_{UV} between -25° and +25° is $5.5x10^{-5}$ considering the total sector integrated counts, in good agreement with the estimated $T_{UV-ex} = 3x10^{-5}$. The estimated uncertainty of this parameter is between 50% - 75%. The UV suppression seems more efficient in the lateral sectors. In the illuminated side of Mercury, this noise is expected to be slightly lower than the estimated signal of back scattered population. Better S/N is expected at higher latitudes and especially in the shadowed regions.

2.2.1.4 ELENA in-flight calibration

The ELENA in-flight characterization of the anode response will be done regularly by analysing the dark count when the ELENA FoV is pointing where no signal is expected. For performing this measurement ELENA requires:

- Pointing the nightside **500 km out of limb from the dayside** MPO orbital path by **rotating around y_{sc},** every Mercury's year.
- Optimal mission phases are when the apoherm (not mandatory) is about the terminator (**TAA 66°-90° or 270°-300°**).
- It shall remain in limb-pointing attitude for 15-30 minutes.
- No preferred direction of rotation toward North or South.

Calibration observations of this type are flagged in the data using the *dark_counts_indicator* parameter (see Section 6.2.1.2).

2.2.2 STROFIO

2.2.2.1 STROFIO concept

STROFIO is a novel type of mass spectrometer, where the mass of the particle is determined by the time of flight through a given region. The start time is imprinted on the trajectory of the particle by a radio frequency (RF) electric field, that bends the trajectory in a given plane, and the stop time is the time when the particle reaches the detector. The main components of the STROFIO sensor (Figure 2-5) in order as they are traversed by an incoming ion are:

- Ionisation source
- Focusing optic
- RF dispersing region
- Field free region
- 2D detector.

The neutral particles enter the system through the first element, which ionises the neutral gas. The ions are released into the focusing optic that then delivers a beam of ions to the RF dispersing system. Once the particles leave the dispersing region, they move on a constant trajectory to the 2D MCP detector system where the time of flight is measured, from which the mass/charge can be calculated. To increase the UV rejection capability of the sensor and compensate for the second-order effects of energy straggling in the source, the trajectory of the particles may be bent over 180° before reaching the detector in a reflectron type configuration (Balsiger et al, 1997). STROFIO has two 20°-cone entrances directed in the ram direction (i.e. in the direction of the spacecraft velocity vector) and anti-ram directions for collecting the exospheric particles independently of the MPO orbit phase.

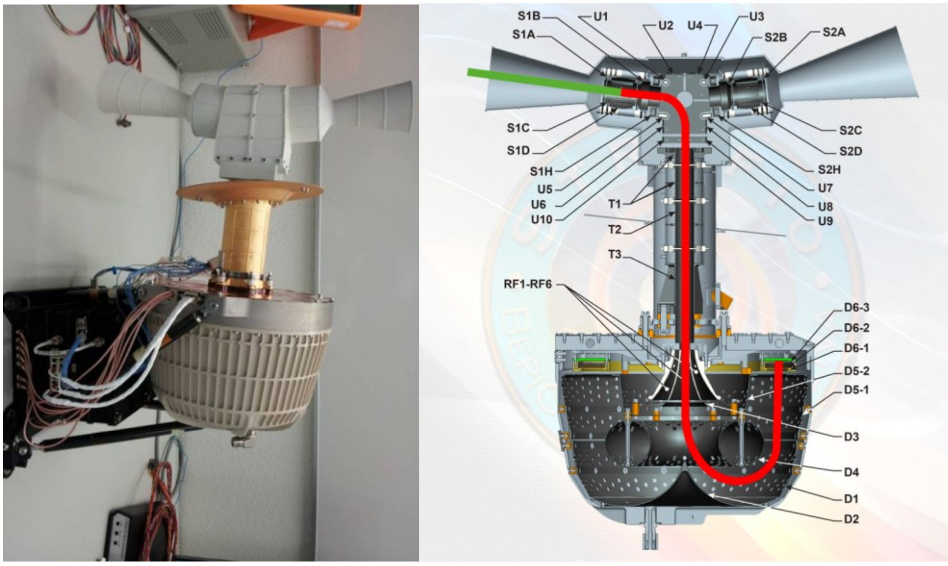


Figure 2-5 - *Left: STROFIO flight model. Right: Cross section of sensor layout and example of trajectories.*

2.2.2.2 STROFIO modes and scientific measurements

STROFIO has two scientific configurations depending on which instrument entrance is activated, Primary or Secondary. Each of these corresponds to one of the MPO orientations. The vast majority of STROFIO science data is taken with the source that is pointed in the spacecraft ram direction. Since the MPO spacecraft changes orientation twice during a single Mercury orbit (a 180 degree flip that swaps ram and anti-ram), STROFIO also changes its scientific configuration at the same time to match the active state with the new ram direction. The single science mode can be set with TC with variable parameters at constant power and data rate.

NAME	INFO	Telemetry Rate (uncom-pressed) [bit/s]	Telemetry Rate (compres-sed) [bit/s]	POWER at Beginning of Life (BOL) [W]	POWER at End of Life (EOL) [W]	TIME [s]
N	Nominal	600	200	6.58	7.5	100
I	Ion	600	200	<6.58	<7.5	100
M	Molecular	600	200	<6.58	<7.5	100
HE	High-energy	600	200	<6.58	<7.5	100

Table 2-4 - *STROFIO Modes, Telemetry (bit/s) and Power (W).*

STROFIO measures the in-situ neutral particle composition at the lowest energy range (~0 to a few eV), and the particle density in the exosphere. The neutral gas enters the ionization chamber through the entrance in the ram direction (see Figure **2-5**), after which it is ionized and accelerated into the mass analyser by a series of electrodes. Here the ions experience the effects of an electric field, constant in magnitude, but with direction rotating uniformly in space, in a plane perpendicular to the initial ion velocity, at a frequency f. The trajectory of an ion can hit the detector only if the field points to the detector, while the ion traverses the dispersing region. At other times, the ion will simply miss the detector. The time difference between the instant when the particle arrives at the detector and the time when the field was pointing in the appropriate direction is equal to the travel time through the field free region. The detector is divided into two halves, via left and right anodes, which are treated separately in on-board processing and provides added flexibility in data processing.

The detected hits are counted and reported in the telemetry packets, which are then converted to raw data counts, counts per mass channel, and density per mass channel. See Section 3.2.2 for more information on the STROFIO data generation process and Section 4.4.2 for detailed description of the data products.

2.2.2.3 STROFIO on-ground calibrations

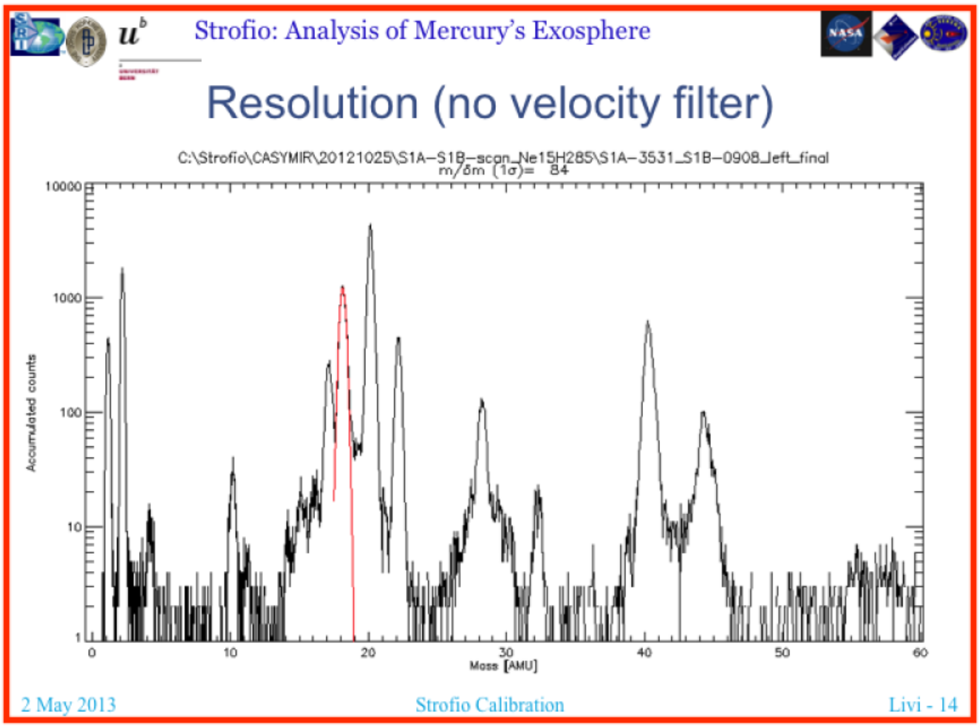
The STROFIO model mounted on-board the MPO is the STROFIO Flight Model (FM). STROFIO FM calibrated performances are reported in [RD.07].

Field of View

The angular response over a FoV of ±12° for Neon (without a velocity filter) is relatively uniform.

Mass resolution

STROFIO mass resolution is determined by spatial resolution on the anode and established by voltage optimization. The nominal mass resolution for STROFIO is M/˚ΔM~84 (Figure 2-6 below).



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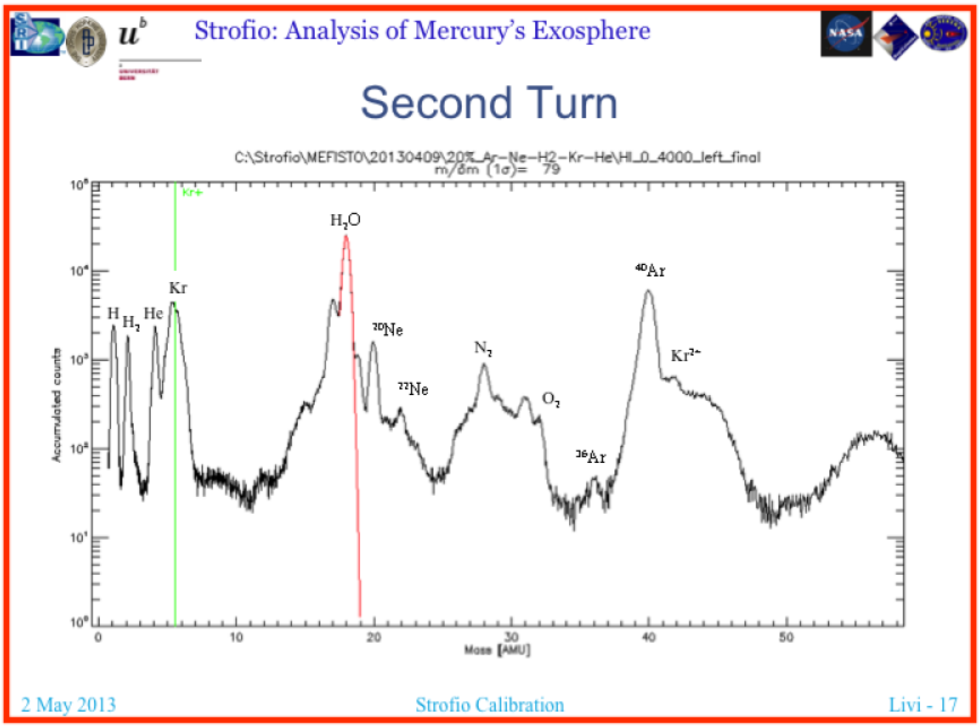


***Figure 2-6** - Above: STROFIO mass resolution without a velocity filter. Below: STROFIO mass range for two turns.*

STROFIO mass range is determined by the path length in the reflectron and has two inherent ranges corresponding to one turn and two turns of the rotating electric field. By using two turns, STROFIO will detect the heavier species (M > 60 AMU), albeit with degraded mass resolution (Figure **2-6**). The mass range can be tuned in flight.

Note: Time of flight of particles is determined by the difference in phase between phase zero of the rotating field and the phase of the field at the instant of arrival of the particle at the detector. As this phase difference has an ambiguity of 360 degrees, the time of flight may refer to the zero phase of the present cycle, or to the zero phase of the preceding cycle of the field. We call this first turn (0-360) or second turn (360-720).

Efficiency

The STROFIO count rate depends on the ionization current and the pressure. If the effect of space charging was negligible, we would expect to find Counts = k*P*I where P = pressure and I = current. Space charge reduces the number of counts as: Counts = $k*(P*I)^{\alpha}$, where $\alpha<1$ is an experimentally determined coefficient. From the calibration results the relation between the count-rate vs. Pressure (mbar) x Current (A) can be approximated by a power-law of the form: Counts = 2.59×1014×(P*I)^0.784. Finally, we expect the count rates at Mercury listed in Table **2-5**.

Count rates n (1/cm^3)	P(mbar) (600K)	I (A)	CR (1/s)
10	8.28E-16	1.00E-03	1.73E+00
100	8.28E-15	1.00E-03	1.05E+01
1000	8.28E-14	1.00E-03	6.38E+01
10000	8.28E-13	1.00E-03	3.88E+02

100000	8.28E-12	1.00E-03	2.36E+03

***Table 2-5** - Expected count rates at Mercury under different pressures and constant current.*

Velocity filter

Outgassing from the BepiColombo spacecraft will limit the capabilities of the STROFIO mass spectrometer to measure small amounts of exospheric gases. To enhance the Signal-to-Noise (S/N) ratio, a velocity filter was implemented in STROFIO. This filter discriminates between the gas evaporating from the spacecraft and the exospheric gas evaporation from Mercury by using the velocity of the spacecraft: the exospheric component will have an average apparent velocity in the sensor of 2–3 km/s due to spacecraft motion, while the spacecraft-generated gas will be at rest. The free parameter in STROFIO is the difference between two voltages on electrodes in the ionizing source, S1A & S1B, where S1A is the grid at the entrance and S1B the grid at the exit of the ionizing region. On the secondary source, these two electrodes are named S2A and S2B.

Table 2-6 provides an estimate of the expected densities of various species around Mercury compared with background gases around BepiColombo, extrapolated from the Rosetta in-flight data. Blue are species already measured around Mercury; black species estimated to be present, but not measured yet; red highlight species that STROFIO will not be able to measure; orange: species with small S/N ratio; green: species with good S/N ratio. Two cases are presented: without and with background rejection via velocity filter.

Element/Molecule	Expected or measured density at 400km (1/cm³)	Background estimated from Rosetta S/C. No background rejection (1/cm³)	Background rejected by a factor of 40 by the velocity filter (1/cm³)
H	10	240.000	6.000
H_2	10.000	20.000	500
He	1.000	1.000	25
C	60	7.000	175
N	10	1.000	25
O	400	1.000	25
OH	30	5.000	125
H_2O	90.000	15.000	375
Ne	300	2.000	50
Na	260	5	0.1
Mg	20	4	0.1
Al	1	4.000	100
N_2	25.000	4.500	100
Si	50	4.500	100
O_2	15.000	100	2
S	600	50	1
K	300	150	4
Ar	200	100	2
Ca	1	100	2
CO_2	1.500	1.000	25
Fe	2	15	0.4

***Table 2-6** - Forecast of Signal around Mercury.*

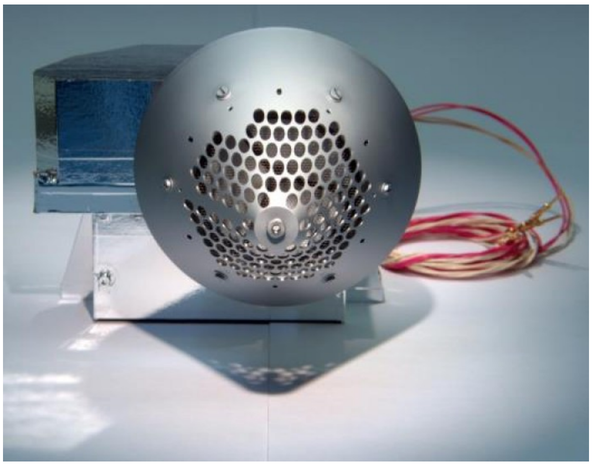
2.2.2.4 STROFIO in-flight calibration

STROFIO in-flight calibration operations are currently under definition.

2.2.3 MIPA

2.2.3.1 MIPA concept

MIPA is a simple ion analyser optimised to provide monitoring of the intense ion fluxes (Figure 2-7). The ion flux arrival angle is analysed by a three-90°-plate electrostatic deflector and the energy by a following 128° double focusing cylinder electrostatic analyser. The voltage is applied to different combination of the plates. Changing the combination allows measurements of ions from different azimuthal directions. Changing the value of the applied voltage results in the polar angle change. The ions exiting the energy analyser are post-accelerated up to 1 keV energy by a voltage applied to the time-of-flight (TOF) cell consisting of START and STOP surfaces and two ceramic channel electron multipliers (CCEM). The ions hit a START surface made of monocrystal tungsten. On hitting the START surface the ions produce secondary electrons and are reflected towards a STOP surface. The electrons are collected by a START CCEM and produce a START pulse. Secondary electrons from the STOP surface are collected by the STOP CCEM and provide the STOP pulse. The timing of the event gives the ion velocity and, in combination with the known energy, the mass. The energy analyser is equipped with a UV trap to increase the UV absorption of the system. Stepping high voltage on the deflector and applying it to different deflector plates provides 360° x ~80° angular coverage. Stepping analyser voltage provides energy coverage from 10 eV to 15 keV. The MIPA FoV central axis is directed in the MPO motion direction, so that both populations of ions directed toward the planet and those reflected back can be detected.



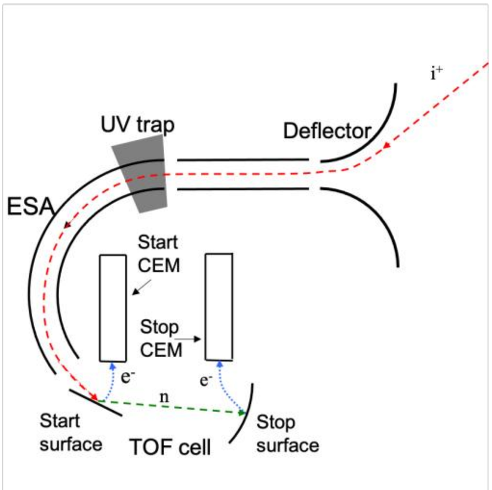


Figure 2-7 - *Left: MIPA flight model. Right: MIPA general schematics.*

2.2.3.2 MIPA configurations for scientific measurements

MIPA uses a lookup table approach, where an energy table is loaded into the SCU based on lookup table ID. There have been 4 different lookup table versions, where each version contains 4 table IDs. Further table updates are not anticipated. Lookup table versions 2-4, with four table IDs for each version, can be found in the SERENA calibration collection (see Sections 4.2.5 and 4.4.3.2) as a calibration product for MIPA. The table version and number for each data product can be found in the product metadata. Dates of validity for each version are shown below (versions 0 and 1 were not used for data collection):

VERSION	START DATE	END DATE
2	2016-05-19T01:01:01	2020-09-05T00:01:00
3	2020-09-05T00:01:01	2022-01-01T13:35:00
4	2022-01-01T13:35:01	N/A

Table 2-7 – *Dates of use for the MIPA lookup table versions*

MIPA registers different types of counts as it scans over energy, elevation, and azimuth as described in Section 2.2.3.1. The count matrices have dimensions of number of energy bins x number of angular directions. In the raw data products, the first count matrix contains START counts, registered when an incoming ion impacts on the START surface, producing a secondary electron which is detected by the START CEM. After the ion traverses the TOF cell, it impacts the STOP surface, where a secondary electron is detected by the STOP CEM, which is registered in the STOP matrix. If the time between a START and STOP counts is determined to be unphysical, it is registered in either the OVER or UNDER matrix. Finally, coincidence counts (i.e., those with a reasonable time between START and STOP detections) are collected in the N_TOF_COUNTER. The MIPA raw product additionally contains the ENERGY_MASS_MATRIX, with dimensions number of angular directions x number of energy bins x number of mass bins. This matrix separates the TOF counts in their measured mass bin, which is determined by the time between the START and STOP signal, giving particle mass/charge. For all counter matrices, the energy and direction bin are determined by the ion-optical deflector settings at the time of arrival. The number of angular, energy, and mass bins are given in both the raw product metadata and the data product itself in columns nD, nE, and nM. MIPA can additionally run with a different number of measurement cycles, where one measurement cycle takes 20s, if lower time resolution data for e.g. monitoring is needed. The number of measurement cycles is additionally included in both the metadata and the data product itself as the column CYCLE.

Power consumption is constant for all MIPA scientific configurations, 2.6W at beginning of life and 3.5W at end of life. The TM data rates depend on the configuration parameters. The science packets can be compressed using a lossless RICE compression method. MIPA data compresses very efficiently, with compression factors > 10 for most configurations. While in theory MIPA can use many combinations of bin numbers, in practice a limited number of configurations have been used in flight. The table below shows the energy, direction, and mass bins, plus number of integration cycles and table number, of the configurations used or planned in the future, along with their telemetry rates and power usage. Only the parameters for table version 4 are shown; previous table versions had half as many directions and twice as many energy bins.

ENE (nE)	**ANG (nD)**	**MASS (nM)**	**TIME (s)**	**TABLE #**	**TM Rate (uncomp.)**	**TM Rate (comp.)**	**Purpose**
48	48	32	20	0	37888	2440	Full resolution
48	48	32	120	0	6315	504	Full resolution slow
16	48	2	80	0	1792	116	Monitoring
16	48	2	20	0	2389	227	Low mass resolution plasma dynamics
16	48	2	80	0	1792	116	Low time, mass resolution plasma dynamics
16	48	8	20	0	3328	440	Low energy resolution plasma dynamics
48	48	8	20	0	3328	493	Standard plasma dynamics
32*	24	2	6.67*	1	7168	717	High time resolution
16	12	128	80	0	2387	256	Mass resolution
48	12	128	80	0	2387	405	Mass resolution with higher nE
48	12	64	20	0	5674	810	Faster mass resolution

Table 2-8 - *MIPA bin number combinations, integration time (s), table number, telemetry (bits/s), and purpose.*

For the high time resolution configuration, marked with *, the time resolution is achieved by having an energy table of 96 steps that contains 3 sweeps from low to high energy. Thus, the data products currently will show 96 energy bins and 20s time resolution. Future pipeline updates will properly reshape the data and interpolate to the actual time resolution.

Each MIPA configuration parameter combination maps to a raw data product and to a provisional calibrated data product. See Section 3.2.3 for more information on the MIPA data generation process and Section 4.4.3 for detailed description of the data products.

2.2.3.3 MIPA on-ground calibrations

The MIPA model mounted on-board the MPO is the MIPA Flight Model (FM). The MIPA FM has been calibrated as described in [RD.10].

Energy resolution

The energy resolution ΔE/E derived by the calibrations, including start and stop events, is about 7%. However, the effective energy resolution of the data depends on the number of energy bins, as some data have had multiple energy channels binned together onboard, typically 3 for data with either 32 (table version 2-3) or 16 (table version 4) energy bins.

Mass/ToF Resolution

The MIPA mass/ToF resolution is coarse; nevertheless, it is possible to distinguish light and heavy species. Technically MIPA is able to resolve 32 bins with different masses per charge; however, proton (H+), alphas (He++), and oxygen (O+) ions will be well recognized and reconstructed among other species. The mass resolution is $\frac{M}{\Delta M} \sim 2$.

Angular resolution

MIPA has three deflector plates, which can have voltages configured in various ways to scan over different pixels. See [RD.10] for details on deflector voltage configurations. The default pixel configuration for after October 2022, with 48 pixels, is shown in Figure **2-8**. The number of pixels, however, is configurable in flight and depends on the mode, as seen in column 2 of Table **2-8**. For example, if a mode with 24 pixels is chosen, the instrument will measure pixels D0-D23 as numbered in Figure **2-8**. The varying pixel shapes and sizes, in addition to the gaps in between pixels, can be seen in the figure. In the 48-pixel configuration, the delta elevation ranges from 4° – 36° and the delta azimuth from 10° – 61°. The smallest pixel has an angular resolution of 8°x10° and the largest has a resolution of 26°x61°.

The boresights and corners of each polygonal pixel in MIPA coordinates can be retrieved from the SERENA SPICE instrument kernel. Potential geometry products or metadata containing pixel geometry within data products is currently under consideration.

MIPA angular resolution was calibrated using H^+ and N^+ beams at 500 eV, 2000 eV, and 9000 eV. The geometric factor of each pixel varies widely, with the pixels at highest elevations having the lowest geometric factor and largest size due to geometric reasons. Pixels along the magnetometer boom, seen in the figure as the grey obstruction at 180°, have low geometric factor because the antenna will reflect a non-negligible number of particles and thus holes were not drilled in this direction on the entrance cone.

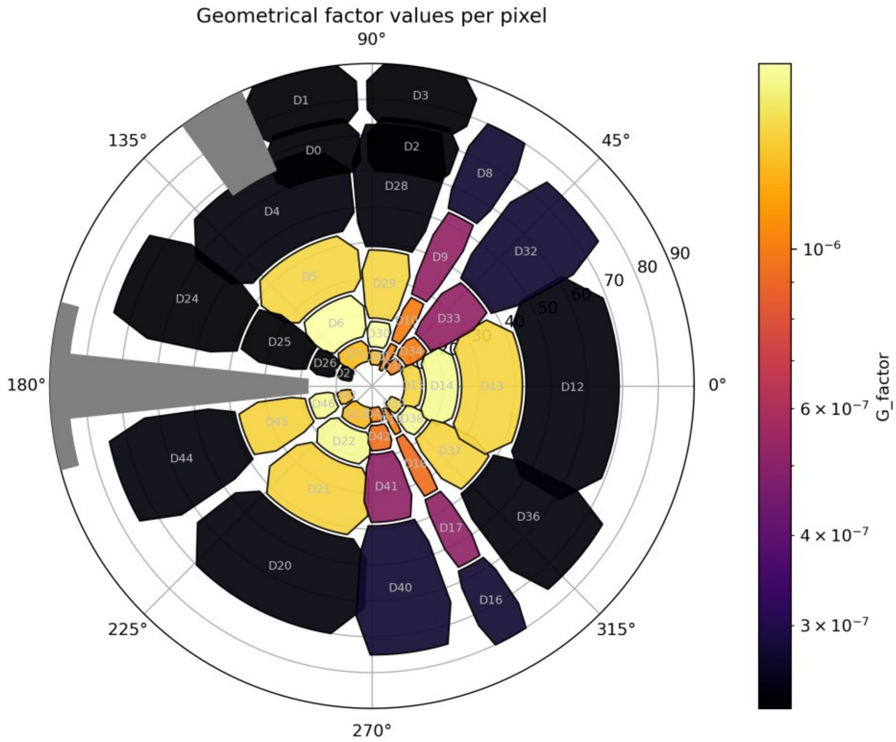


***Figure 2-8** - MIPA 48-pixel configuration, where colour is the geometric factor without efficiency. The magnetometer boom and radiator obstructions are indicated in grey. The nominal Sun direction is (90°, 90°). Instrument boresight is directed out of the centre of the plot.*

Instrument efficiency

The MIPA geometrical factor including the time-of-flight cell efficiency (e.g., the ratio of coincidence counts to the start and stop counts) has been calibrated with N^+ for each pixel and for different energies. The resulting geometrical factor (GF in cm^2 sr eV/eV) without efficiency, with START efficiency ($G \cdot \eta_{STA}$) , STOP efficiency ($G \cdot \eta_{STO}$) and coincidence efficiency ($G \cdot \eta_{STA} \cdot \eta_{STO}$) is shown in Table **2-9**, of which the second column corresponds to the pixel colour in Figure **2-8**. This table will be included as a calibration product in SERENA calibration collection in the future (see Section 4.4.3.2).

Pixel number	GF w/o eff	GF start	GF stop	GF coinc
0	2.30E-07	4.10E-08	2.40E-08	4.40E-09
1	2.30E-07	4.10E-08	2.40E-08	4.40E-09
2	2.30E-07	4.10E-08	2.40E-08	4.40E-09
3	2.30E-07	4.10E-08	2.40E-08	4.40E-09
4	2.40E-07	4.30E-08	2.56E-08	4.58E-09
5	1.47E-06	2.63E-07	1.57E-07	2.81E-08
6	1.81E-06	3.23E-07	1.93E-07	3.45E-08
7	1.33E-06	2.37E-07	1.41E-07	2.53E-08
8	2.77E-07	4.96E-08	2.96E-08	5.29E-09
9	5.31E-07	9.51E-08	5.66E-08	1.01E-08
10	1.01E-06	1.81E-07	1.08E-07	1.93E-08
11	1.04E-06	1.87E-07	1.11E-07	1.99E-08
12	2.40E-07	4.30E-08	2.56E-08	4.58E-09
13	1.46E-06	2.61E-07	1.55E-07	2.78E-08
14	1.75E-06	3.14E-07	1.87E-07	3.35E-08
15	1.47E-06	2.63E-07	1.57E-07	2.81E-08
16	2.77E-07	4.96E-08	2.96E-08	5.29E-09

17	5.18E-07	9.28E-08	5.53E-08	9.90E-09
18	9.40E-07	1.68E-07	1.00E-07	1.80E-08
19	1.05E-06	1.88E-07	1.12E-07	2.01E-08
20	2.40E-07	4.30E-08	2.56E-08	4.58E-09
21	1.45E-06	2.60E-07	1.55E-07	2.77E-08
22	1.75E-06	3.14E-07	1.87E-07	3.35E-08
23	1.33E-06	2.38E-07	1.42E-07	2.54E-08
24	2.30E-07	4.10E-08	2.40E-08	4.40E-09
25	2.30E-07	4.10E-08	2.40E-08	4.40E-09
26	2.30E-07	4.10E-08	2.40E-08	4.40E-09
27	2.30E-07	4.10E-08	2.40E-08	4.40E-09
28	2.40E-07	4.30E-08	2.56E-08	4.58E-09
29	1.47E-06	2.63E-07	1.57E-07	2.81E-08
30	1.81E-06	3.23E-07	1.93E-07	3.45E-08
31	1.33E-06	2.37E-07	1.41E-07	2.53E-08
32	2.77E-07	4.96E-08	2.96E-08	5.29E-09
33	5.31E-07	9.51E-08	5.66E-08	1.01E-08
34	1.01E-06	1.81E-07	1.08E-07	1.93E-08
35	1.04E-06	1.87E-07	1.11E-07	1.99E-08
36	2.40E-07	4.30E-08	2.56E-08	4.58E-09
37	1.46E-06	2.61E-07	1.55E-07	2.78E-08
38	1.75E-06	3.14E-07	1.87E-07	3.35E-08
39	1.47E-06	2.63E-07	1.57E-07	2.81E-08
40	2.77E-07	4.96E-08	2.96E-08	5.29E-09
41	5.18E-07	9.28E-08	5.53E-08	9.90E-09
42	9.40E-07	1.68E-07	1.00E-07	1.80E-08
43	1.05E-06	1.88E-07	1.12E-07	2.01E-08
44	2.40E-07	4.30E-08	2.56E-08	4.58E-09
45	1.45E-06	2.60E-07	1.55E-07	2.77E-08
46	1.75E-06	3.14E-07	1.87E-07	3.35E-08
47	1.33E-06	2.38E-07	1.42E-07	2.54E-08

Table 2-9 – *Geometric factors per pixel assuming a 2000 eV N+ beam. The second column is the geometric factor without efficiencies, the third is the START geometric factor, the fourth is the STOP geometric factor, and the fifth is the COINCIDENCE geometric factor.*

2.2.3.4 MIPA in-flight calibration

For MIPA inflight calibration refer to the SERENA User Manual [RD. 06].

2.2.4 PICAM

2.2.4.1 PICAM concept

The PICAM ion mass spectrometer works as an all-sky camera for charged particles (Vaisberg, 2001) allowing the determination of the 3D velocity distribution and mass over a 1.5π FoV, from thermal up to ~ 3 keV energies and in a mass range extending up to ~ 132 amu (Xenon). The concept of the instantaneous 1.5π electro-optics is shown in Figure 2-9. A key element of the scheme is an ellipsoidal electrostatic mirror (M1) that focuses charged particles entering through a narrow circular window at the entrance to a toroidal electrostatic analyser. The particles exit the analyser through another narrow slit and are reflected by a mirror (M2) to the MCP. This layout provides energy selection by the pass-band of the electrostatic analyser. The electro-optics provides an inverted image of the hemisphere on the imaging detector. There is a one-to one correspondence of the particle direction at the entrance and its location on the detector. The mass analysis is activated by a deflection gate located between the elliptic mirror and the toroidal analyser. Mass analysis is performed by measuring the time of flight of the ions between a set of gate electrodes located between the primary and secondary mirror, and the time of impact on the MCP. The mass analysis section consists of a plane mirror whose geometry and potentials are set to optimize the resolution of the time of flight (ToF) measurements, a classical retarding potential analyser (RPA), and the detector in the form of a circular micro-channel plate (MCP). The MCP detector provides both the "stop" time for ToF measurements when an ion impacts the front face and is also used as an imaging detector that determines the position of the ion impact on the MCP. The energy pass-band is determined by the electrostatic analyser and is about 11% of the central energy.

The classical gating sequence (single pulse) significantly reduces the effective operating time of the instrument to a few percent of the total time. This mode of operation can be used when ion fluxes are high enough. However, to improve the effectiveness of the sensor, especially when ion fluxes are low, a more sophisticated gating sequence based on the Hadamard time mask technique is used. The PICAM FoV central axis is directed in the MPO direction of motion, the same as the MIPA sensor.

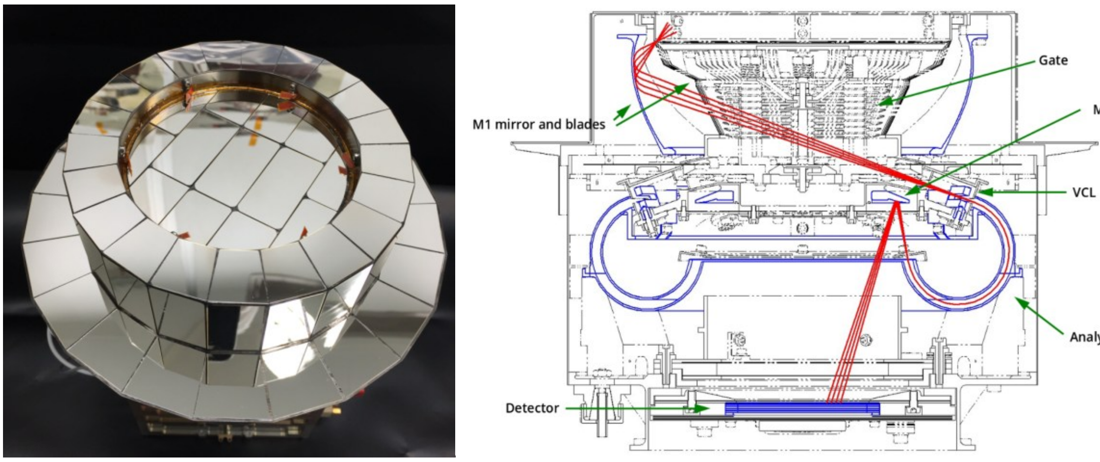


Figure 2-9 - *Left: PICAM. Right: PICAM general schematics.*

2.2.4.2 PICAM modes and scientific measurements

PICAM utilises 16 different measurement modes that can be classified into three categories:

- Imaging modes (no ToF measurement): modes 1-6.
- ToF modes (single pixel; no spatial resolution): modes 7-10. These 4 modes can either be run in a Single Pulse or a Hadamard setting.
- Combined modes: modes 11-15 and mode 0.

In ToF modes and combined modes the power consumption depends on the gate pulsing (S = Single pulse, H = Hadamard pulse). Data rates depend on settable parameters. Data compression is typically done by the SCU. In Table 2-10, a conservative compression factor of 4 is assumed:

Mode No.	Mode Name	Description	TLM_UNC			TLM_COMP			POWER_BOL [W]	POWER_EOL [W}
			Min	Nominal	Max	Min	Nominal	Max		
1	IM_HT_HR31	High Time and Spatial Resolution Image	522	4176	8352	138	1104	2208	4.8	5.3
2	IM_HT_NR13	High Time and Normal Spatial Resolution Image	458	1832	3664	122	488	976	4.8	5.3
3	IM_HT_LR7	High Time and Low Spatial Resolution Image	266	1064	2128	74	296	592	4.8	5.3
4	IM_HR_31	High Resolution Image	522	1044	8352	138	276	2208	4.8	5.3
5	IM_NR_13	Normal Resolution Image	458	458	3664	122	122	976	4.8	5.3
6	IM_LR7	Low Resolution Image	266	266	2128	74	74	592	4.8	5.3

7	MC_HR511_HE	High Resolution TOF, High Energy Resolution	522	16704	133632	138	4416	35328	* S/H : 6.0/8.5	S/H : 6.7/9.4
8	MC_HR511_LE	High Resolution TOF, Low Energy Resolution	522	8352	133632	138	2208	35328	S/H : 6.0/8.5	S/H : 6.7/9.4
9	MC_NR128_HE	Normal Resolution TOF, High Energy Resolution	522	4176	33408	138	1104	8832	S/H : 6.0/8.5	S/H : 6.7/9.4
10	MC_LR64_LE	Low Resolution TOF, Low Energy Resolution	522	1044	16704	138	276	4416	S/H : 6.0/8.5	S/H : 6.7/9.4
11	MD_NR511_HE	High Resolution TOF	2088	66816	133632	552	17664	35328	S/H : 6.0/8.5	S/H : 6.7/9.4
12	MP_NR128_HE	Full Polar Angle, High Energy Resolution	2088	66816	133632	552	17664	35328	S/H : 6.0/8.5	S/H : 6.7/9.4
13	MD_NR128_HE	High Energy Resolution	1832	58624	117248	488	15616	31232	S/H : 6.0/8.5	S/H : 6.7/9.4
14	MD_NR128_LE	Low Energy Resolution	1832	29312	117248	488	7808	31232	S/H : 6.0/8.5	S/H : 6.7/9.4
15	MD_LR64_LE	Low Mass and Energy Resolution	522	8352	133632	138	2208	35328	S/H : 6.0/8.5	S/H : 6.7/9.4
0	TEST_COMM	High Resolution TOF, High Energy Resolution	16704	66816	133632	4416	17664	35328	S/H : 6.0/8.5	S/H : 6.7/9.4

***Table 2-10 -** PICAM Modes, Telemetry (bit/s) and Power (W). (* S: Single pulse, H: Hadamard pulse).*

The instrument records ion spectra from various directions in azimuth and elevation, and TOF spectra (depending on the measurement mode). This is done by registering count rates as counts over a certain period on an MCP. The time periods depend on the measurement mode. The MCP is subdivided into areas, so called pixels. A count on a pixel can be traced to the azimuth and elevation of the incoming ion in the imaging modes. For the time-of-flight measurements, a gate provides start times. Together with the known path length between the gate and the MCP and the information about the energy sweep the mass, and hence the species of an incoming ion, can be determined. Single pulse mode and Hadamard mode do not affect what is measured, they only define how the gate is operated. When run in Hadamard mode, the gate is left open significantly longer than when being run in single pulse mode. Such it should be more suitable for lower incoming fluxes.

Each PICAM mode maps to a raw science data product (level 2) and to a provisional calibrated data product (level 3). See Section 3.2.4 for more information on the PICAM data generation process and Section 4.4.4 for detailed description of the data products. See also the tables with the "PICAM Data Products Fields Description" in the Appendix .

2.2.4.3 PICAM on-ground calibration

The PICAM model mounted on-board the MPO is the PICAM Flight Spare (FS). The acronym FS for the actual flight model indicates that this model was planned originally to become the flight spare. As it flies to Mercury it is called FM02 in the following. The former flight model has the ID FM01 it used for lab testing on ground. The most current on-ground calibration and performance assessment is given in Orsini et al., 2021 (see Section 1.3.2 for DOI).

Energy resolution

To determine the energy resolution of the PICAM FM02, the count rates for different M1 voltage settings have been measured and for different energies and masses. The energy resolution is better at higher energies and lower M/Q ranging between 10% and 20%. 32 energy channels are the PICAM baseline.

Mass and ToF resolution

ToF measurements of three different species have been carried out for FM02: He, N and N_2^+, in single pulse as well as in Hadamard mode. Mass resolution of the FM02 is evaluated to be equal or better than M/ΔM = 50 as required and expected.

Angular resolution

For calibrating the PICAM angular resolution a beam of 0.2, 0.5 and 1 keV He+ ions was directed toward the centre of each azimuthal sector at different elevation angles between 25° and 90° (Figure 2-10). FS shows reasonable count rates in the angular range 30° – 80° elevation, only sector 1 shows low count rates below 45° and sectors 2 and 3 exhibit lower count rates at elevation > 78° (Figure 2-11). The PICAM FM02 angular resolution in elevation is about 30°. In the azimuthal angles there are "blind zones" between the sectors, clearly seen as is a distinct drop in count rates at 60°, 120°, 180°, 240°, 300°. The azimuthal angular resolution is 60°, but at high elevation angles (>75°), due to geometric reasons, the azimuth resolution becomes worse than 60°.

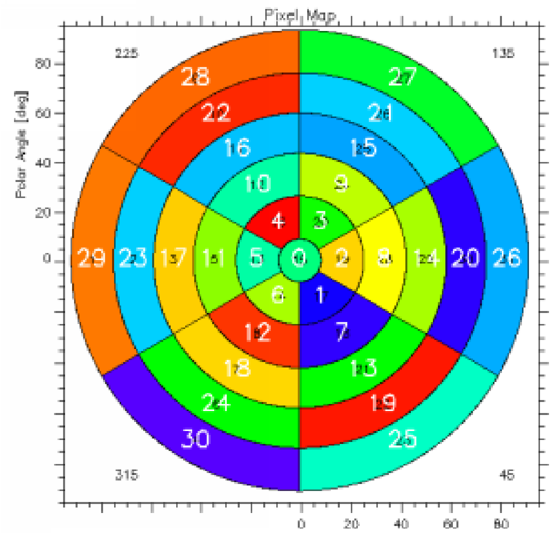


Figure 2-10 - *PICAM sectors and pixel map.*

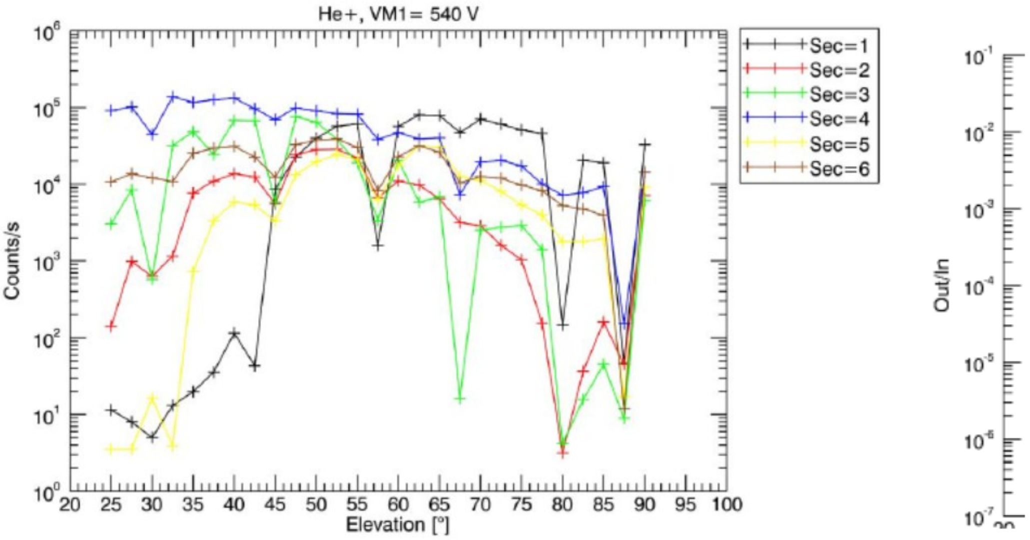


Figure 2-11 - *Count rates and Out/In ratio of PICAM FM02 for different elevation and azimuth angles of the incoming ion beam (He^+ at 500 eV).*

Instrument efficiency

PICAM FM02 transparency (out/in) varies with elevation angles and sectors, but it is about uniform and greater than 10^{-3} over an elevation angles interval of 30° – 80° for almost all sectors (Figure 2-10). The geometrical factor is estimated about 10^{-3}-10^{-5} cm^2 sr and 10^{-4} – 10^{-6} cm^2 sr eV/eV by including the energy-dependent efficiency.

2.2.4.4 PICAM in-flight calibration

For PICAM inflight calibration refer to the SERENA User Manual [RD. 06].

2.2.5 SCU – the System Control Unit

The System Control Unit (SCU) of SERENA provides instrument functionality control, memory, and computational capability to the whole four sub-unit suite. SCU implements a central hub for communication between the four sensors and itself, and to the spacecraft. It provides 2 Mb/s bitrate to ELENA and MIPA, 38.4 Kb/s to STROFIO, and 10 MB/s to PICAM and MPO. The communication interfaces support uplink of telecommands, data, look-up tables and parameters to the sensors, and downlink of science and housekeeping data from the sensors. SCU is itself a producer of data concerning the operation of all four sub-units and the complete system, i.e. housekeeping data.

The foreseen housekeeping rate of SERENA instrument is 88 bit/s subdivided as shown in the following table:

SubSystem	HK size [Bytes]	Generation frequency [s]	HK rate [bit/s]
SCU	68	20	27
ELENA	86	20	34.5
MIPA	50	60	6.7
PICAM	146 (extended HK) +70 (standard HK)	20 (extended HK) 60 (standard HK)	58.4 9.3
STROFIO	316	600	4.2
SERENA TOTAL			140.1

Table 2-11 - *SERENA HK telemetry (bit/s).*

2.3 SERENA science operations plan

SERENA operates as a single experiment. Only PICAM and MIPA can provide science return during cruise, Venus and Mercury Flybys. The science modes of each sensor during cruise and along the Mercury's orbit are defined to optimize the science return given the allocated resources.

2.3.1 Cruise Phase

MIPA and PICAM are turned on at particular observational periods during the cruise phase to participate in the investigation of the solar wind and the interplanetary magnetic field's structure and in radio-science experiments.

During the cruise phase, MIPA has been operated in the bin number combinations shown in Table 2-8.

For the solar wind observations (cruise science and radio-science experiments), PICAM has mainly used IMG1, IMG4 and ToF7 modes.

The data sets relevant to the cruise phase are described in more detail in Chapter 5.1.3.

2.3.2 Flybys

2.3.2.1 Venus Flyby #1

During Venus Flyby #1 MIPA and PICAM were operated in the following modes:

MIPA was operated in monitoring mode (nE 32, nD 24, nM 2, time resolution 80s) for energy spectrograms and collected data with energies from 20 – 15000 eV. The objective was to observe charged particles around Venus, but no significant science observations were made.

PICAM was operated in science modes IMG1, IMG4 and ToF7, with nominal energy range (planetary table) to detect the magnetosheath and potential planetary ions.

2.3.2.2 Venus Flyby #2

During Venus Flyby #2 MIPA and PICAM were operated in the following modes:

MIPA was operated in monitoring mode (nE 32, nD 24, nM 2, time resolution 80s) at the beginning of the flyby and low mass resolution plasma dynamics (nE 32, nD 24, nM 2, time resolution 20s) near closest approach. Energies ranged from 20 – 15000 eV and data include energy spectrograms. This flyby crossed through the subsolar “stagnation region” of the Venusian magnetosheath, which MIPA measurements were used to confirm.

PICAM was operated in science modes IMG4 and ToF7, with plasma-dependant energy ranges (planetary, solar wind and 8ch scanner tables) to detect the solar wind, magnetosheath and dayside planetary ions.

2.3.2.3 Mercury Flyby #1

During Mercury Flyby #1 MIPA and PICAM were operated in the following modes:

MIPA was operated in monitoring mode before and after the flyby and in low energy resolution plasma dynamics mode (nE 32, nD 24, nM 8, 20s) near closest approach. The energy range was 20 – 14000 eV. The objective was to observe the various boundary crossings in the Mercury magnetosphere; MIPA charged particle data showed the presence of a low latitude boundary layer, in addition to a magnetopause and bow shock.

PICAM was operated in science modes IMG4 and ToF11, with plasma-dependant energy ranges (planetary and solar wind tables) to detect the solar wind, Mercury’s magnetosphere and planetary ions.

2.3.2.4 Mercury Flyby #2

During Mercury Flyby #2 MIPA and PICAM were operated in the following modes:

MIPA was operated in low energy resolution plasma dynamics mode (nE 16, nD 48, nM 8, 20s). The energy range was 20 – 14000 eV. For this flyby, the number of pixels was increased from 24 to 48. As with Mercury flyby #1, the objective was to observe charged particles in the various regions of the magnetosphere. MIPA data show boundary crossings, as well as high energy ions close to the planet.

PICAM was operated in science modes IMG1 and IMG4, with plasma-dependant energy ranges (planetary and solar wind tables) to detect the solar wind, Mercury’s magnetosphere in high-time resolution.

2.3.2.5 Mercury Flyby #3

During Mercury Flyby #3 MIPA and PICAM were operated in the following modes:

MIPA was operated in low energy resolution plasma dynamics mode (nE 16, nD 48 (1), nM 8, 20s). The energy range was 20 – 14000 eV. For this flyby, the deflector plate voltages were fixed to only observe a single pixel, creating a high time resolution mode. The objective of the fixed deflection was to observe dynamic structures that would not be visible in lower time resolution data. The fixed pixel was selected based on the observations of high energy ions in Mercury flyby #2, which were again successfully observed.

PICAM was operated in science modes IMG1 and IMG4, with plasma-dependant energy ranges (planetary and solar wind tables) to detect the Solar Wind, Mercury’s magnetosphere in high-time resolution.

2.3.2.6 Mercury Flyby #4

During Mercury flyby #4 MIPA was operated in a new standard plasma dynamics mode (nE 48, nD 48, nM 8, 20s). In this mode, the number of bins were the same as for the existing plasma dynamics mode, but the full energy resolution of 48 energy bins was returned, rather than the SCU summing down to 16 energy bins when processing the data packet as with previous flybys. Thus, MIPA had a full 48 energy and direction bins, resulting in higher energy and angular resolution than previous flybys. The energy range was from 20 – 14000 eV and the 48 observed pixels covered approximately a hemisphere. As with previous flybys, the objective was to observe boundary crossings and ion dynamics in Mercury's magnetosphere. MIPA additionally observed ions with mass/charge consistent with alpha particles and oxygen group ions.

2.3.3 Mercury Orbit Phase

The SERENA operation scenario for the first Mercury year has been considered as simple as possible in order to use the first year as a learning phase. In the following years the modes used by each sensor could change and could be optimized for specific observations and according to the specific season, but for the telemetry rate and power the presented planning is representative of the whole nominal mission. The number of used modes and of needed telecommands could be different.

	mode	cycle orbit#	Notes and other modes
STROFIO	St-by/diagn/pre-sci	1	Cycle of 115 orbit, tuneable to fit the observation period. Ion mode should be synchronized with ion sensors' inner magnetosphere detection. Note that we want to close the cycle in st-by since probably MPO will be close to perihelion limitation period, so there is probably a gap from cycle end and beginning of a new one.
	Sci Survey	24	
	Background	1	
	Sci Survey	14	
	Ion	2	
	Sci Survey	14	
	molecular	3	
	Sci Survey	14	
	High energy	2	
	Sci Survey	14	
	Background	1	
	Sci Survey	24	
	St-by/diagn/pre-sci	1	
ELENA	S		Other modes: SO32, Ion mode ELENA R not run when PICAM mode TOF compressed
	R	5 min every 1.5 h	
PICAM	ToF Had 11 comp	1	Cycle of 24 orbits All the modes are operated in *adaptive bitrate** modes and compression are chosen to avoid conflict with MIPA 6 and ELENA R
	ToF Had 13 comp	1	
	ToF Had 7 uncomp	2	
	ToF Had 8 uncomp	2	
	Image 1 uncomp	18	
MIPA	48 nE, 48 nD, 8 nM	11	Cycle of 12 Orbits 16 nE if there are TM restrictions Other possibility: high time resolution (6.67s), 32 nE, 24 nD, 2 nM
	48 nE, 12 nD, 64 nM	1	

* *adaptive bitrate*: when a mode's accumulation time is decreased or increased in comparison with its nominal duration, in order to meet the science and or telemetry requirements.

***Table 2-12** – Long Term Planning of SERENA in the first Mercury year.*

3. Data Generation and Analysis Process

The SERENA science products are generated by the SERENA Instrument Team in cooperation with the SGS. The data generation and analysis process are described in this section, and follows the general concept for data generation, validation and archiving described in the Archiving Plan [RD.01]. The assignment of the tasks (roles and responsibilities) has been agreed upon by all parties and documented in a Data Processing Agreement [RD.02]. Science data received by the SGS from the SERENA team are made available to end users through the BepiColombo archive following the policies described in the Archiving Plan [RD.01].

3.1 Data Flow Overview

This section provides a top-level description of the SERENA data processing workflow.

BepiColombo has adopted the following terms for broadly classifying science data products in the archive according to the level of processing as in Table 3-1. This classification is based on the PDS policy on Data Processing Levels.

Data Processing Level	Definition
Telemetry	Original binary stream from an instrument encoded in telemetry packets.
Raw	Original data from an instrument. If compression, reformatting, packetization, or other translation has been applied to facilitate data transmission or storage, those processes will be reversed so that the archived data are in a PDS approved archive format.
Partially Processed	Data that have been processed beyond the raw stage but which have not yet reached calibrated status.
Calibrated	Data converted to physical units where all of the calibration based on the instrument has been done.
Derived	Results that have been distilled from one or more calibrated data products (for example, maps, gravity or magnetic fields, or ring particle size distributions). Supplementary data, such as calibration tables or tables of viewing geometry, used to interpret observational data should also be classified as 'derived' data if not easily matched to one of the other three categories. Navigation products (including SPICE kernels) will be classified as Derived data.

***Table 3-1** – Definition of data processing levels for BepiColombo*

The SERENA data processing pipeline is composed of a set of processing chains – TM2Raw, Raw2Cal, Cal2Der (Figure 3-1). Each processing chain can be executed as a stand-alone routine.

The TM2Raw processor takes as input the binary telemetry packets and outputs raw data values directly corresponding to the detector's hardware readouts (e.g. counts, digital units), formatted as PDS4-compliant products.

The Raw2Cal continues the processing taking the raw data as input and outputs the data parameters translated to real physical units by using calibration curves and/or tables defined in the calibration products.

In the case of the ELENA data processing, the Raw2Cal module also generates partially processed data for the R-mode. The partially processed data is routed back to the Raw2Cal processor to produce the calibrated products. Currently, the generation of partially processed products for STROFIO which may be directly routed to the Cal2Der processor is under validation (Section 3.2.2.2).

Auxiliary browse products are also generated for science data, but not for housekeeping data, in each processing step.

Note: The Cal2Der processor is currently still in development.

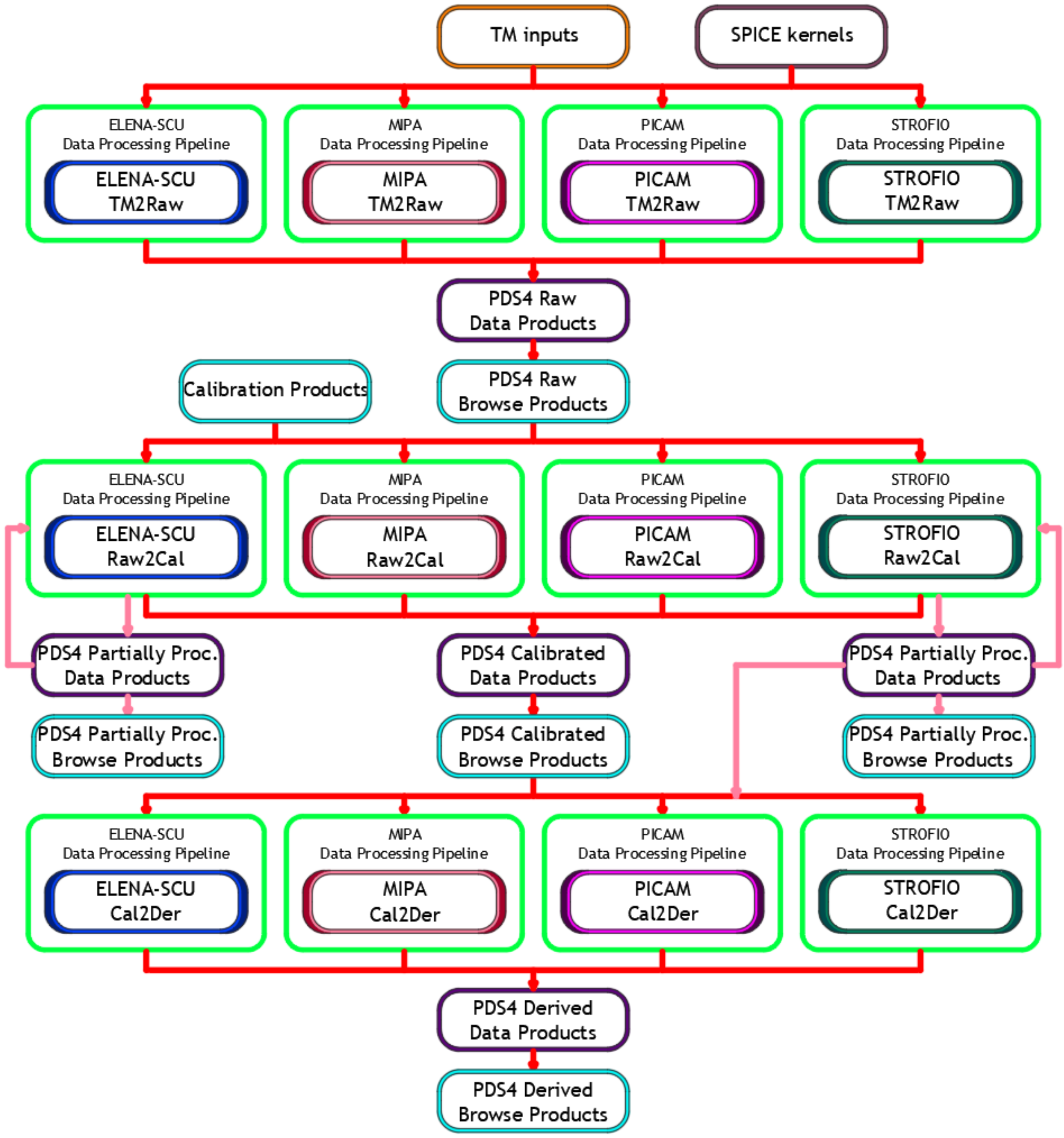


***Figure 3-1** – Block diagram with the SERENA data processing steps.*

3.2 Data Generation

The following sections describe the process by which data products of different data processing levels are generated for each of the SERENA sub-units.

3.2.1 ELENA Data Generation

3.2.1.1 ELENA Raw Data Generation

ELENA produces housekeeping and science raw data by converting binary telemetry DDS files into ASCII CSV files with the ELENA-SCU TM2Raw data processing pipeline. The telemetry translation is performed by splitting the continuous binary sequence in the DDS file to individual telemetry packets and mapping the binary number to a decimal number for each parameter in each packet. Each CSV product file is accompanied by its respective metadata in the PDS4 label format (XML).

3.2.1.2 ELENA Partially Processed Data Generation

Partially processed data is generated only for ELENA R mode science data. The event-by-event raw data is integrated in time for each anode sector to produce a histogram of detection counts similar to the one in the S mode raw science data.

3.2.1.3 ELENA Calibrated Data Generation

ELENA produces both housekeeping and science calibrated data. The housekeeping calibrated data comprises of the raw data values translated into physical or engineering units. Science calibrated data takes the counts from the raw data of the S, SO-16, SO-32, and C-32 modes and the partially processed data of the R mode and applies the calibration curves acquired during the performance evaluation of the instrument to produce histograms of particles fluxes (counts/s).

The translation from raw to calibrated values follows the below procedure:

1. Read and parse of the calibration product for the respective mode (the calibration product contains calibration curves in the form of polynomials);
2. Check in which number range is the raw value of the parameter;
3. Based on parameter type and range, apply a polynomial mapping to the engineering or counts value.

We plan to arrive at the calibrated level of science data after a thorough calibration campaign at Mercury [RD. 06]. The generation of calibrated science data will start from raw data using calibration tables/curves as a PDS4 calibration product.

3.2.1.4 ELENA Derived Data Generation

ELENA derived products are under consideration. One such product is the surface map imaging via ENA, which would represent the reconstructed ENA flux emitted from the surface for every single orbit around Mercury (see Figure 3-2). It would basically be a deconvolution of the ELENA acquisition along the orbit. The pixel dimensions at the surface will be given by:

1. the projection of the instrument sector along the array length – in the direction perpendicular to spacecraft motion.
2. $v_{s/c}$ * T_{int} * the projection of the instrument sector perpendicular to the array length – in the direction parallel to the spacecraft motion.

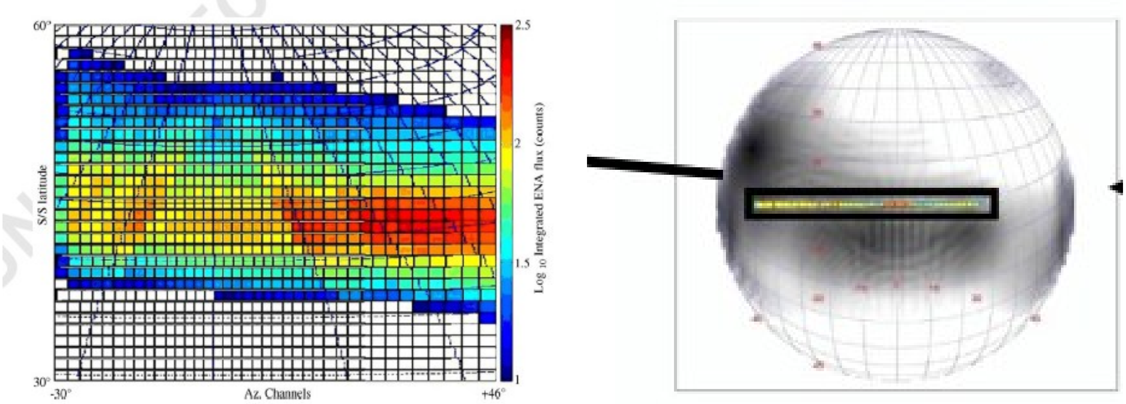


Figure 3-2 - *Depiction of ELENA derived surface map imaging.*

3.2.2 STROFIO Data Generation

3.2.2.1 STROFIO Raw Data Generation

STROFIO's tm2raw software reads EDDS binary telemetry files and converts them to CDF output files. A separate CDF file is created for each packet type found in the input telemetry. This process also produces PDS4 XML labels and browse images. The same procedure is followed for all observation modes, though processing parameters differ.

3.2.2.2 STROFIO Partially Processed Data Generation

STROFIO partially processed products will be generated in the future and will represent vectors of counts versus mass channel for each time step at the native time stepping. This is essentially calibration applied to one dimension of the raw data, i.e. calibration of time of flight to mass. This conversion can be determined from ground calibration and modelling.

3.2.2.3 STROFIO Calibrated Data Generation

STROFIO housekeeping values are converted from raw to engineering units using polynomial conversions based on ground calibration observations.

The STROFIO raw2cal software converts the raw science TOF products into calibrated science TOF products by performing the following operations:

1. Counts are divided by the integration time to get counts/s
2. Calibration tables are used to convert each bin to a mass range
3. Bins are integrated based on mass range
4. We read the current in SC1/SC2 at the time of the measurement from the engineering housekeeping data
5. We calculate pressure from the count rate and current
6. Pressure is then converted to density
7. Calibration tables are used to calculate the corrected density for each mass

This results in density per mass/charge assuming a single compound with no fractionation.

We plan to arrive at the calibrated level of science data after a thorough calibration campaign at Mercury [RD. 06]. The generation of calibrated science data will start from raw data using calibration tables/curves as a PDS4 calibration product.

3.2.2.4 STROFIO Derived Data Generation

STROFIO will generate the following types of derived products in the future:

- Matrices of relative densities versus mass channel and altitude for each true anomaly angle bin and time step. This product will require multiple Mercury years of data to achieve the altitude. True Anomaly Angle (TAA) represents Mercury's position in its orbit around the Sun, effectively the season, and has a strong influence on the neutral exosphere. Time stepping for this product will be in Mercury years.

- Matrices of absolute densities versus mass channel and altitude for each true anomaly angle bin and time step. This product will require multiple Mercury years of data to achieve the altitude. True Anomaly Angle (TAA) represents Mercury's position in its orbit around the Sun, effectively the season, and has a strong influence on the neutral exosphere. Time stepping for this product will be in Mercury years. This product requires the extra calibration to absolute density derived by analysis of long accumulations of data and modelling of the velocity distributions of observed species.

3.2.3 MIPA Data Generation

3.2.3.1 MIPA Raw Data Generation

MIPA transfers its measured signal data into SERENA SCU. The SCU software processes the received data from MIPA sensor and prepares the data to be transferred to the ground receivers. The SCU software generates MIPA telemetry data. The data files are in compressed binary format (DDS) and contain both the housekeeping and science data from MIPA. As the very first step, we need to use a SW product developed by MIPA team (named "mipa-ccsds") to convert the DDS files into CSV files, and make them ready to be processed by MIPA's tm2raw SW. The raw data contains two different categories of data: housekeeping and science data. Both of these are stored in ASCII format (.TSV), later converted into calibrated data products. The general MIPA data processing is explained in detail in document BC-SGS-MN-477. Browse images consisting of an energy-time spectrogram are produced from the START counts in each raw data product.

3.2.3.2 MIPA Partially Processed Data Generation

MIPA will not produce partially processed data products.

3.2.3.3 MIPA Calibrated Data Generation

Calibrated housekeeping and science data are currently generated from the raw data by the MIPA raw2cal SW. The calibrated housekeeping data converts instrument parameters such as voltage to physical units and is stored in ASCII format (.TSV). Calibrated science data converts counts to differential flux by first converting counts to counts/sec then dividing the count rate by the pixel geometrical factor and energy bin value, for units of $\#/cm^2$ s sr eV. The differential flux maintains the same dimensions as the raw counts, giving an energy and angular distribution for each mass bin.

The translation from raw to calibrated housekeeping data follows the below procedure:

1. The system mode, critical error, and rejection cause bits are converted from an integer to a descriptive string
2. The status bits are split into the fields 'TOF_IRQ_STATUS', 'SAMPLING', 'MEMORY BANK', 'HVPS', 'TDC_STATUS', 'TDC_PROTECTION', AND 'TDC_POWER'.
3. The voltage settings, current, and temperature are converted from onboard values to physical units.

The equations for conversion of housekeeping values to physical units are found in the MIPA hk calibration product.

The translation from raw to calibrated science data has the following procedure, in addition to conversion of voltage, current, and temperature:

1. The count matrices ('START', 'STOP', 'N_TOF', and 'ENERGY_MASS_MATRIX') are separated from the data and reshaped into multidimensional arrays according to the instrument energy and direction settings.

2. The integration time for an energy-direction-time bin is calculated from the size of the count matrix and the lookup table version, as the integration time is dependent on the number of energy and direction bins, as well as measurement cycles.
3. The values of the measure energy bins in eV are retrieved from the energy lookup table.
4. The raw counts are then converted to differential flux with the equation $j(E,\Omega) = \frac{C(E,\Omega)}{\tau\, E\, g(\Omega)}$ where tau is the integration time, E is the energy bin, and g is the geometrical factor for the current angular pixel.

The calibrated science data will be produced for all raw data of scientific interest (e.g., excluding instrument checkouts).

3.2.3.4 MIPA Derived Data Generation

MIPA derived products will include particle velocity and pitch angle distributions (see Section 3.2.4.4 for the definition of the same type of products for PICAM). Pitch angle distributions could be given in either differential flux or phase space density in units of s^3/m^6.

3.2.4 PICAM Data Generation

3.2.4.1 PICAM Raw Data Generation

PICAM archiving S/W produces housekeeping and science raw data by reading the XML-formatted ASCII input packages provided by the EDDS system and generates tab-delimited human readable ASCII files. Science data tables also contain relevant geometry information derived from the SPICE kernels.

Additionally, to the science raw data images showing the measured counts as omnidirectional plots are produced and packed into browse products.

3.2.4.2 PICAM Partially Processed Data Generation

For the time being, there are no dedicated processes or analysis available for the generation partially processed data. Though, PICAM does not exclude the possible generation of partially processed products, for the data collected during cruise in the future.

3.2.4.3 PICAM Calibrated Data Generation

The calibrated housekeeping data are generated from the raw input packages. Housekeeping data contain different status parameters of the instrument; It also includes temperatures, voltages, which are then converted from the instrument parameters to the physical units. The conversions are done based on the calibration curves, generated on ground from PICAM flight model lab tests. These data products already exist in the PSA.

The structure of the science data in the files are kept the same, with the difference that the ion counts are converted to differential flux, and differential energy flux. To do that, the ion counts are converted to counts per second, taking the mode of PICAM operation into account. Afterwards, by using the geometrical factor for each other 31 pixels, and the corresponding energy value, the fluxes are produced as #/(cm^2 s sr eV), and the energy fluxes as eV/(cm^2 s sr eV). The calibration tables are generated using both the ground lab test, and the in-flight measurements.

Calibrated science data will be generated in the future. We plan to arrive at the calibrated level of science data after a thorough calibration campaign at Mercury [RD. 06].

3.2.4.4 PICAM Derived Data Generation

PICAM does not exclude the possible generation of Derived Data Product for the mission phase. In particular, common data products with other sensors could be interesting. Though, for the time being, there are no dedicated processes or analysis available.

Still, there are derived products under consideration:

- Pitch Angle Distribution (PAD):
  - Timeseries of ion flux as 2D-matrix (Energies vs Pitch Angle (ϑ), where ϑ = angle between B and V, see Figure 3-3).
- Velocity Distribution Function (VDF):
  - Catalogue of 2D-cut plots for ion flux ($V_{\perp1} - V_{//}$, $V_{\perp2} - V_{//}$, $V_{\perp1} - V_{\perp2}$)
  - $V_{//}$ is the velocity of ions parallel to the Magnetic field orientation
  - $V_{\perp1}$ is the velocity of ions perpendicular to the Magnetic field orientation (commonly along ExB direction)
  - $V_{\perp2}$ is the velocity of ions perpendicular to both the Magnetic field orientation and $V_{\perp1}$.

For producing derived products, the PICAM science data should be of publication quality, and must include directional information (e.g. IMG mode, or mixed ToF mode). Furthermore, reliable Magnetic Field from MPO-MAG is essential for generating such products, and a clear interface to such data must be available.

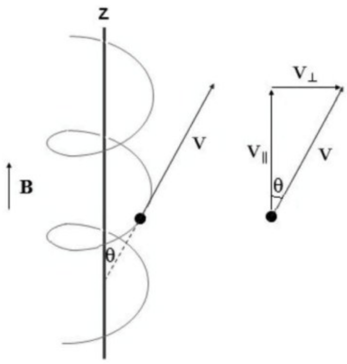


Figure 3-3 – *Spiralling ion particle along a magnetic field line*

3.2.5 SCU Data Generation

3.2.5.1 SCU Raw Data Generation

SCU produces only housekeeping raw data by converting binary telemetry DDS files into ASCII CSV files with the ELENA-SCU TM2Raw data processing pipeline by the same process described in Section 3.2.1.1.

3.2.5.2 SCU Partially Processed Data Generation

No partially processed data will be produced for SCU.

3.2.5.3 SCU Calibrated Data Generation

The SCU calibrated data is generated by the ELENA-SCU Raw2Cal data processing pipeline by translating the housekeeping raw data parameters, such as temperatures, voltages and currents, from units related to the hardware of SCU to real physical units. The input is the SCU HK raw data product in tabular CSV format, with each row reporting a single data packet. The output is the SCU HK calibrated product again in tabular CSV format and accompanied by its respective metadata in the PDS4 XML label format.

The translation from raw to calibrated values follows the below procedure:

1. Read and parse of the calibration product for the respective mode (the calibration product contains calibration curves in the form of polynomials);
2. Check in which number range is the raw value of the parameter;
3. Based on parameter type and range, apply a polynomial mapping to the engineering or counts value.

3.2.5.4 SCU Derived Data Generation

No derived data will be produced for SCU.

4. SERENA Data Products and Organisation

SERENA data products are formatted in accordance with the PDS4 specifications (see [AD.03], [AD.04], [AD.05], and [RD.04]) following the rules in the BepiColombo Archiving Guide [AD.02]. This section describes the basic organization of a SERENA bundle, and the naming conventions used for the products, collections and bundle and provides details on the formats used for each of the products included in the SERENA science and housekeeping data.

4.1 Bundle Content and Structure

All data from the SERENA experiment for the entire mission are stored in a top-level structure (root directory) called **bundle**. This bundle resides in the PSA as a single entity. 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, calibration products, documentation, etc. The structure of the bundle is depicted in Figure 4-1. The high-level description of the SERENA data bundle and subdirectories (collections) is provided in Table 4-1.

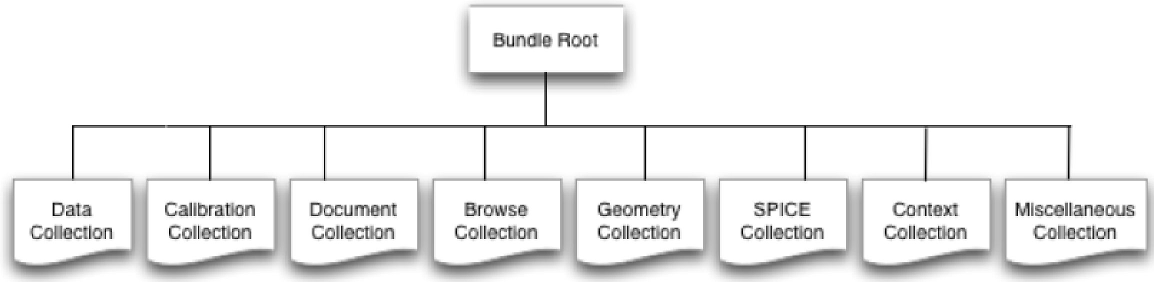


***Figure 4-1 –** High-level structure of SERENA's PDS4 bundle and collections*

Bundle Title	*Bundle Logical Identifier (LID)*	*Description*
SERENA bundle	urn:esa:psa:bc_mpo_serena	This bundle contains the data collected by the SERENA experiment on-board the BepiColombo Mercury Planetary Orbiter (MPO) spacecraft, along with the documents and other information necessary for the interpretation of the data.

***Table 4-1 -** SERENA instrument bundle.*

The following files are contained in the root directory of the bundle:

- bundle_bc_mpo_serena.xml (*an inventory file for the bundle)*
- readme_bc_mpo_serena.txt *(a README file for the bundle; it contains a table of contents)*

4.2 Data Collections

For the instrument science and housekeeping data, there are separate collections for each processing level, and this is standardised by PDS4 to four levels: raw, partially processed, calibrated, and derived. Each level includes data from the four SERENA sensors and from the SCU. The SERENA data collections are summarized in Table 4-2.

Directory Name	***Collection Logical Identifier (LID)***	***Description***

European Space Agency
Agence spatiale européenne

data_raw	urn:esa:psa:bc_mpo_serena: data_raw	See section 4.2.1.
data_partially_processed	urn:esa:psa:bc_mpo_serena: data_partially_processed	See section 4.2.2.
data_calibrated	urn:esa:psa:bc_mpo_serena: data_calibrated	See section 4.2.3.
data_derived	urn:esa:psa:bc_mpo_serena: data_derived	See section 4.2.4.
calibration_files	urn:esa:psa:bc_mpo_serena: calibration_files	See section 4.2.5.
browse_raw	urn:esa:psa:bc_mpo_serena: browse_raw	See section 4.2.6.
browse_partially_processed	urn:esa:psa:bc_mpo_serena: browse_partially_processed	See section 4.2.6.
browse_calibrated	urn:esa:psa:bc_mpo_serena: browse_calibrated	See section 4.2.6.
document	urn:esa:psa:bc_mpo_serena: document	See section 4.2.7.
context (S)	urn:esa:psa:bc:context	Text files describing the agency, mission, spacecraft, instrument, and targets. These files refer to the full descriptions in the document collection.
spice_kernels (S)	urn:esa:psa:bc:spice_kernels	SPICE kernels.
xml_schema (S)	urn:esa:psa:bc:xml_schema	XML Schemas used in the bundle.

***Table 4-2** - SERENA data collections.*

4.2.1 Raw Data Collection

The Raw Data Collection includes SCU (housekeeping only), ELENA, STROFIO, MIPA, and PICAM scientific and housekeeping products at the instrument-native level. Units reflect the detector hardware (e.g., counts, ADC channels, instrument subunit identifiers), and no calibration or data conversion has been applied. Products are delivered as ASCII (tab- or comma-separated) and CDF files, each accompanied by the corresponding XML label.

Directory structure:

data_raw/

- collection_mpo_srn_data_raw.lblx
- collection_mpo_srn_data_raw.csv
- <mission_phase>/
    - elena/
        - sc/
        - hk/
    - mipa/
        - sc/
        - hk/
    - picam/
        - sc/
        - hk/
    - strofio/
        - sc/

        - hk/
    - scu/
        - hk/

where **<mission_phase>** is one of:

- prelaunch/testing: On-ground testing and calibration campaign
- near_earth_commissioning: Near Earth Commissioning Phase (NECP)
- cruise: Interplanetary Cruise Phase (ICP)
- flybys/earth_flyby: Earth flyby
- flybys/venus_flyby_#: Venus flyby, with #=1-2
- flybys/mercury_flyby_#: Mercury flyby, with #=1-6
- mercury_commissioning: Mercury Commissioning Phase (MCP)
- mercury_science_orbit: Mercury Science Nominal and Extended Phase (MSP)

  The **sc**, **hk** directories are further sub-divided by calendar month (yyyymm).

4.2.2 Partially Processed Data Directory

The Partially Processed Data Collection contains ELENA scientific data where event-by-event R-mode observations have been time-integrated. Products are provided as ASCII (comma-separated) files with corresponding XML labels.

Directory structure:

partially_processed/

- collection_mpo_srn_partially_processed.lblx
- collection_mpo_srn_partially_processed.csv
- <mission_phase>/
    - elena/
        - sc/

where **<mission_phase>** is defined as in section 4.2.1.

4.2.3 Calibrated Data Directory

The Calibrated Data Collection includes SCU (housekeeping only), ELENA, STROFIO, MIPA, and PICAM scientific and housekeeping products in engineering or physical units. Products are delivered as ASCII (tab- or comma-separated) and CDF files with XML labels.

Directory structure:

data_calibrated/

- collection_mpo_srn_data_calibrated.lblx
- collection_mpo_srn_data_calibrated.csv
- <mission_phase>/
    - elena/
        - sc/
        - hk/
    - mipa/
        - sc/
        - hk/
    - picam/
        - sc/

      - hk/
  - strofio/
      - sc/
      - hk/
  - scu/
      - hk/

where **<mission_phase>** is defined as in section 4.2.1, and the **sc**, **hk** directories are further sub-divided as described in section 4.2.1.

4.2.4 Derived Data Directory

To be defined.

This section will describe any higher-level scientific analysis products generated from the calibrated datasets (e.g., maps, spectra, distributions), once confirmed.

4.2.5 Calibration Files Directories

This collection contains calibration data for SCU (housekeeping only), ELENA, STROFIO, MIPA, and PICAM, used to convert raw detector units into engineering or physical units. Products are distributed as ASCII (tab- or comma-separated) and CDF files with XML labels.

Directory structure:

calibration_files/

- collection_mpo_srn_calibration.lblx
- collection_mpo_srn_calibration.csv
- elena/
- mipa/
- picam/
- strofio/
- scu/

4.2.6 Browse Plots Directories

The browse collections contain science overview and quick-look analysis plots for raw, partially processed, and calibrated data. Files are organized by processing level and mission phase.

Directory structure:

browse_raw/ (or browse_calibrated/ ; or browse_partially_processed/)

- collection_mpo_srn_browse_<level>.lblx
- collection_mpo_srn_browse_<level>.csv
- <mission_phase>/
  - elena/
      - sc/
  - mipa/
      - sc/
  - picam/
      - sc/
  - strofio/
      - sc/

where **<level>** is one of *raw*, *calibrated* or *partially_processed*, **<mission_phase>** is defined as in section 4.2.1, and the **sc** directories are further sub-divided as described in section 4.2.1.

4.2.7 Document Directory

This collection includes supporting documents required for the interpretation and correct use of the data (e.g., the Data User Guide, calibration reports, mission and instrument descriptions).

Directory structure:

document/

- collection_mpo_srn_document.lblx
- collection_mpo_srn_document.csv
- < Documents; see Table 4-3 >

Document LID	*Document Number*	*Description*
srn_doc_data_user_guide	BC-SRN-ICD-94001	SERENA Data User Guide (this document)
srn_doc_user_manual	BC-SRN-UM-03001	SERENA User Manual
srn_doc_science_performance_report	BC-SRN-RP-00028	SERENA Science Performance Report
srn_doc_elena_pfm_calibration_report	BC-SRN-RP-34254	ELENA PFM Calibration Report
srn_doc_mipa_fm_calibration_report	BC-SRN-TR-40020	MIPA FM Calibration Report

Table 4-3 – *List of SERENA documents inside the document collection.*

4.3 Logical Identifier (LID) Formation

Each product in the SERENA bundle is uniquely identified by a **Logical Identifier (LID)**. The LID acts as the permanent and referenceable name of the product within the archive, independent of file format or storage location. All SERENA bundle- and collection-level LIDs are listed in Table 4-1 and Table 4-2.

For individual data products, the LID is constructed according to:

urn:esa:psa:bc_mpo_serena:<collection_identifier>:<product_identifier>::<version_id>

where:

- <collection_identifier> is the short name of the collection containing the product (e.g., data_raw, data_calibrated, data_partially_processed, calibration_files, browse_raw, etc.).
- <product_identifier> is the structured identifier describing the content and origin of the product (defined below).
- <version_id> is the PDS4 version identifier (e.g., 1.0, 1.1, etc.).

Relationship Between LID and Filenames:

The base filename of the product is the <product_identifier>, followed by a double underscore version suffix derived from <version_id>, and then the file extension:

<product_identifier>__<m>_<nn>.<ext>

where <version_id> = m.nn in the LID maps to __<m>_<nn> in the filename.

This ensures:

- The **LID and filename are always traceable to each other**.
- The **product version is explicit in both the LID and the file name**.

- Filenames remain unique even when multiple versions of the same product exist.

Product Identifier Structure:
The <product_identifier> is based on the following convention:

srn_[<processing_level>]_[<type>]_[<subunit>]_<descriptor>

where:
- [] are optional fields
- <processing_level>: Allowed values: raw|par|cal|der
- <type>:
    - For primary products: hk|sc
    - For supplementary products: calib|browse|thumb|qla|geo|doc|misc
- <subunit>: Allowed values: elena|strofio|mipa|picam|scu
- <descriptor>: Provides additional information, e.g.:
    - Science mode
    - Measurement type
    - Start/stop date

4.4 SERENA Data Products

The following sections describe the SERENA data products by subunit: their location in the various data collections, filename convention, content, and metadata.

4.4.1 ELENA Products

4.4.1.1 ELENA Data Products

All ELENA data product types are summarized in the following Table 4-4 and Table 4-5.

Product Level	***Product Type***	***Mode Description***	***Data Format***
Raw Data	Science Mode SO-16	16 sectors, standard type => ENA counts for each sector with lower sector resolution. Used primarily for in-flight testing and calibration.	Table_Delimited/ CSV
	Science Mode SO-32	32 sectors, standard type => ENA counts for each sector. Used primarily for in-flight testing and calibration.	Table_Delimited/ CSV
	Science Mode C-32	32 sectors, standard type => ENA counts for each sector. Used primarily for in-flight testing and calibration.	Table_Delimited/ CSV
	Science Mode S	**32 sectors, extended type => ENA counts of instantaneous maximum signal for each sector (with multiplicity information in the first 4 sectors). Nominal science mode.**	**Table_Delimited / CSV**
	Science Mode R	**Event by event data => reference time and sectors of each single event. Nominal science mode.**	**Table_Delimited / CSV**
	HK	**Housekeeping, Decimal numbers of hardware reported units**	**Table_Delimited / CSV**

Partially Processed Data	**Science Mode R**	**32 sectors => ENA counts of instantaneous maximum signal for each sector (with multiplicity information, integrated from event-by-event detections)**	**Table_Delimited / CSV**
Calibrated Data	Science Mode SO-16	16 sectors => neutral particle fluxes (counts/cm2s), Used primarily for in-flight testing and calibration.	Table_Delimited/ CSV
	Science Mode SO-32	32 sectors => neutral particle fluxes (counts/cm2s), Used primarily for in-flight testing and calibration.	Table_Delimited/ CSV
	Science Mode C-32	32 sectors => neutral particle fluxes (counts/cm2s), Used primarily for in-flight testing and calibration.	Table_Delimited/ CSV
	Science Mode S	**32 sectors => neutral particle fluxes (counts/cm2s), Nominal science mode**	**Table_Delimited / CSV**
	Science Mode R	**32 sectors => neutral particle fluxes (counts/cm2s), Nominal science mode**	**Table_Delimited / CSV**
	HK	**Housekeeping, Physical units**	**Table_Delimited / CSV**
Derived Data	TBD	TBD	TBD

Table 4-4 – *ELENA data products description.*

Product Level	***Product Type***	***File Naming Convention***
Raw Data	**Science Mode S**	srn_raw_sc _elena_s_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	Science Mode R	srn_raw_sc _elena_r_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	Science Mode SO-16	srn_raw_sc_elena_s16_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	Science Mode SO-32	srn_raw_sc _elena_s32_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	Science Mode C-32	srn_raw_sc _elena_c32_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	HK	srn_raw_hk_elena_<yyyymmdd>__<m_nn>.lblx/.csv
Partially Processed Data	**Science Mode R**	srn_par_sc _elena_r_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
Calibrated Data	**Science Mode S**	srn_cal_sc _elena_s_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	Science Mode R	srn_cal_sc _elena_r_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	Science Mode SO-16	srn_cal_sc_elena_s16_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	Science Mode SO-32	srn_cal_sc _elena_s32_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	Science Mode C-32	srn_cal_sc _elena_c32_<yyyymmddtHHMM>__<m_nn>.lblx/.csv
	HK	srn_cal_hk_elena_<yyyymmdd>__<m_nn>.lblx/.csv
Derived Data	TBD	TBD

Table 4-5 - *ELENA data product types and filename convention.*

The parameters in the table above are:
<yyyymmddtHHMM> : UTC datetime of the first measurements in the product
<m_nn>: major (m) and minor (nn) version numbers of the product

Raw Data Products

ELENA can generate five different science raw data products based on the science mode used and one additional housekeeping raw data product.

Since SO-16, SO-32, and C-32 are backup and test modes, data from these modes will be generated only occasionally. **S and R are the nominal in-flight science modes**, and most of ELENA data will consist of data from these modes. Data are provided with the integration time, the timestamp at which the acquisition starts and some auxiliary information such as the multiplicity of the event (for mode S). The raw data counts do not account for anode sector efficiency.

ELENA HK raw data are ASCII files containing the positive integers (digital counts) of the instrument parameters, such as voltages, currents, and temperatures.

Partially Processed Data Products

ELENA partially processed data are histogram of ENA counts for each sector, with the integration time and the timestamp at which acquisition starts. In particular, the R-mode (event-by-event) raw data are processed to obtain the histogram.

ELENA partially processed data are ASCII files similar to the raw S mode data files. The data format is Table_Delimited/CSV.

Calibrated Data Products

ELENA calibrated data products are ASCII files in Table_Delimited/CSV format. The housekeeping calibrated data products are providing the same tabular information as the corresponding raw data products but translated from hardware units to physical units. The science data products include translation of the anode detections from simple counts to neutral particle fluxes (counts/cm^2s).

Derived Data Products

TBD

4.4.1.2 ELENA Calibration Products

The lower-level sub-directories of the calibration collection contain the following types of ELENA calibration products shown in Table 4-6.

Product Level	***File Naming Convention***	***Product Type***
Calibration	srn_calib_sc_elena_s_<yyyymmdd>>__<m_nn>.lblx/.csv	**Science Mode S**
	srn_calib_sc_elena_r_<yyyymmdd>>__<m_nn>.lblx/.csv	**Science Mode R**
	srn_calib_sc_elena_s16_<yyyymmdd>>__<m_nn>.lblx/.csv	Science Mode SO-16
	srn_calib_sc_elena_s32_<yyyymmdd>>__<m_nn>.lblx/.csv	Science Mode SO-32
	srn_calib_sc_elena_c32_<yyyymmdd>>__<m_nn>.lblx/.csv	Science Mode C-32
	srn_calib_hk_elena_<yyyymmdd>>__<m_nn>.lblx/.csv	**HK**

Table 4-6 - *ELENA calibration products by type and filename convention.*

Where:

<yyyymmdd> : UTC date of the generation of the calibration product

<m_nn>: major (m) and minor (nn) version numbers of the product

4.4.1.3 ELENA Browse Products

The ELENA browse products are generated as a quick visual representation of all the ELENA science data products in the raw, partially processed, and calibrated processing levels, except for the raw R mode products. All ELENA browse products are simple graph histogram plots with UTC time on the x-axis and channel number on the y-axis, where the z-axis – represented as colour intensity – shows anode detections (counts in the case of raw and partially processed products) or fluxes (particles/cm^{2}s, calibrated products). See Figure 4-2 for example ELENA browse product plots.

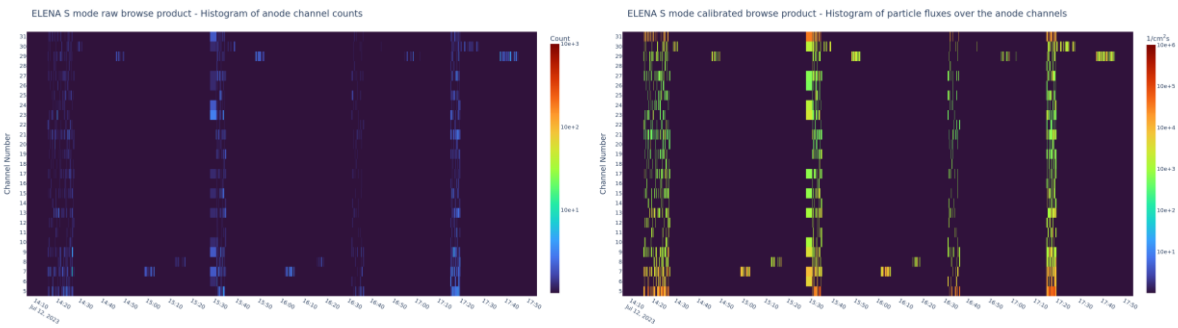


***Figure 4-2 -** ELENA browse product plots for raw (left) and calibrated (right) S mode.*

The lower-level sub-directories of the browse products collections contain the following types of ELENA supplementary products shown in Table 4-7.

Directory Name	***File Naming Convention***	***Product Type***
browse_raw/ elena/sc/yyyymm	srn_raw_sc _elena_browse_s_<yyyymmddtHHMM>__<m_nn>.png/.lblx	Browse products for raw data.
	srn_raw_sc _elena_browse_r_<yyyymmddtHHMM>__<m_nn>.png/.lblx	
	srn_raw_sc_elena_browse_s16_<yyyymmddtHHMM>__<m_nn>.png/.lblx	
	srn_raw_sc _elena_browse_s32_<yyyymmddtHHMM>__<m_nn>.png/.lblx	
	srn_raw_sc _elena_browse_c32_<yyyymmddtHHMM>__<m_nn>.png/.lblx	
browse_partially _processed/ elena/sc/yyyymm	srn_par_sc _elena_browse_r_<yyyymmddtHHMM>__<m_nn>.png/.lblx	Browse product for partially processed data.
browse_calibrated/ elena/sc/yyyymm	srn_cal_sc _elena_browse_s_<yyyymmddtHHMM>__<m_nn>.png/.lblx	Browse products for calibrated data.
	srn_cal_sc _elena_browse_r_<yyyymmddtHHMM>__<m_nn>.png/.lblx	
	srn_cal_sc_elena_browse_s16_<yyyymmddtHHMM>__<m_nn>.png/.lblx	
	srn_cal_sc _elena_browse_s32_<yyyymmddtHHMM>__<m_nn>.png/.lblx	
	srn_cal_sc _elena_browse_c32_<yyyymmddtHHMM>__<m_nn>.png/.lblx	

***Table 4-7 -** ELENA browse products directories and filenames.*

The parameters in the above are:
<yyyymmddtHHMM> : UTC datetime of the first measurement in the product
<m_nn>: major (m) and minor (nn) version numbers of the product

4.4.2 STROFIO Products

4.4.2.1 STROFIO Data Products

All STROFIO data product types are summarized in the following Table 4-8 and Table 4-9. Strofio has built in capability of selecting section of the MCP areas that may present lower performances. This is done with specific entries in the lookup table. Low quality (were it present) would be transmitted to the ground with lower priority. Presently this feature is not implemented, and low quality and high quality will be transmitted with the same priority.

Product Level	***Product Type***	***Mode Description***	***Data Format***
Raw Data	Science HQ TOF	High-quality time of flight spectra (array of 2048 bins per measurement)	CDF
	Science LQ TOF	Low-quality time of flight spectra (array of 2048 bins per measurement)	CDF
	Science RHQ TOF	Re-binned high-quality time of flight spectra (array of 64 bins per measurement)	CDF
	Science RLQ TOF	Re-binned low-quality time of flight spectra (array of 64 bins per measurement)	CDF
	Science Basic Rates	Basic event counter	CDF
	HK	Housekeeping	CDF
Partially Processed Data	TBD	TBD	TBD
Calibrated Data	Science HQ TOF	Density per mass per charge assuming a single compound with no fractionation from HQ TOF data	CDF
	Science LQ TOF	Density per mass per charge assuming a single compound with no fractionation from LQ TOF data	CDF
	Science RHQ TOF	Density per mass per charge assuming a single compound with no fractionation from Rebinned HQ TOF data	CDF
	Science RLQ TOF	Density per mass per charge assuming a single compound with no fractionation from Rebinned LQ TOF data	CDF
	HK	Housekeeping data converted to engineering units when applicable	CDF
Derived Data	TBD	TBD	TBD

Table 4-8 – *STROFIO data products description.*

Product Level	***Product Type***	***File Naming Convention***
Raw Data	Science HQ TOF	srn_raw_sc _strofio_hq_<yyyymmddThhmm >__<m_nn>.lblx/.cdf
	Science LQ TOF	srn_raw_sc _strofio_lq_<yyyymmddThhmm >__<m_nn>.lblx/.cdf
	Science RHQ TOF	srn_raw_sc _strofio_re-hq_<yyyymmddThhmm>__<m_nn>.lblx/.cdf
	Science RLQ TOF	srn_raw_sc _strofio_re-lq_<yyyymmddThhmm >__<m_nn>.lblx/.cdf
	Science Basic Rates	srn_raw_sc _strofio_basic-rates_<yyyymmddThhmm>__<m_nn>.lblx/.cdf
	HK	srn_raw_hk_strofio_hk-status_<yyyymmddThhmm>__<m_nn>.lblx/.cdf
Partially Processed Data	TBD	TBD
Calibrated Data	Science HQ TOF	srn_cal_sc _strofio_hq_<yyyymmddThhmm>__<m_nn>.lblx/.cdf
	Science LQ TOF	srn_cal_sc _strofio_lq_<yyyymmddThhmm>__<m_nn>.lblx/. cdf
	Science RHQ TOF	srn_cal_sc _strofio_re-hq_<yyyymmddThhmm>__<m_nn>.lblx/.cdf
	Science RLQ TOF	srn_cal_sc _strofio_re-lq_<yyyymmddThhmm>__<m_nn>.lblx/.cdf
	Science Basic Rates	srn_cal_sc _strofio_basic-rates_<yyyymmddThhmm>__<m_nn>.lblx/.cdf

	HK	srn_cal_hk_strofio_hk-status_<yyyymmddThhmm>__<m_nn>.lblx/.cdf
Derived Data	TBD	TBD

Table 4-9 - *STROFIO data product types and filename convention.*

The parameters in the table above are:
<yyyymmddThhmm> : UTC date of the first and last measurement in the product
<m_nn>: major (m) and minor (n) version numbers of the product

Raw Data Products

STROFIO produces four different time-of-flight spectra along with a basic rate products containing basic event counters. The spectra of the four TOF products are delivered in ISTP-compliant CDF files where each spectrum is given along with the integration time and the time at which acquisition started. The accompanying PDS4 labels replicate the data description and meta-data from the CDF variables.

Description of the most important parameters in the basic rates science products is given in the following table. Anode on the MCP has been divided in two sections: left and right. Counters show the total events collected in the relative half.

Name	***Description***
Left Start	Counts start pulses from left anode
Left Stop	Counts stop pulses from left anode
Left Position Only	Counts position measurements without corresponding time measurement from left anode
Left Time Only	Counts time measurements without corresponding position measurement from left anode
Left Paired Event	Counts coincident position and time measurements, i.e. paired events, from left anode
Right Start	Counts start pulses from right anode
Right Stop	Counts start pulses from right anode
Right Position Only	Counts position measurements without corresponding time measurement from right anode
Right Time Only	Counts time measurements without corresponding position measurement from right anode
Right Paired Event	Counts coincident position and time measurements, i.e. paired events, from right anode
Rotation Sync.	Counts rotation synchronization pulses

Table 4-10 – *STROFIO basic rates parameters.*

The instrument parameters product contains the reported values of the instrument's on-board parameters data structure. The parameters are delivered in CDF files along with the time that the data structure was recorded.

STROFIO generates a housekeeping status packet periodically. Each status packet consists of a header and status data; the status includes analogue, digital and software data. The status packets are delivered in CDF files along with the time at which each status packet was generated.

Partially Processed Data Products

To be defined when partially processed data products become available.

Calibrated Data Products

The TOF spectra will be calibrated by assigning a range of masses to each bin in the spectra. The range will be defined by providing a start and end mass for each bin. The calibrated spectra are delivered in CDF files along with the integration time and the time at which acquisition started. See section 3.2.2.3 for a description of how calibrated products are created.

Derived Data Products

To be defined when derived products become available.

4.4.2.2 STROFIO Calibration Products

The lower-level sub-directories of the calibration collection contain the following types of STROFIO supplementary products shown in Table 4-11.

Product Level	File Naming Convention	Product Type
Calibration	srn_calib_strofio_efficiency__<m_nn>.csv/.lblx	Detection efficiency table used to convert density to mass
	srn_calib_strofio_hq-tof__<m_nn>.csv/.lblx	Science HQ TOF
	srn_calib_strofio_lq-tof__<m_nn>.csv/.lblx	Science LQ TOF
	srn_calib_strofio_re-hq-tof__<m_nn>.csv/.lblx	Science RHQ TOF
	srn_calib_strofio_re-lq-tof__<m_nn>.csv/.lblx	Science RLQ TOF

Table 4-11 - *STROFIO calibration products directories and filenames.*

Where:

<m_nn>: major (m) and minor (nn) version numbers of the product

4.4.2.3 STROFIO Browse Products

The STROFIO browse products show basic rates values and TOF counts/s over time. One plot is generated for each raw product CDF file. Currently browse products are only generated for raw science products.

The lower-level sub-directories of the browse products collections contain the following types of STROFIO supplementary products shown in Table 4-12.

Directory Name	File Naming Convention	Description
browse_raw/ strofio/sc/yyyymm	srn_raw_sc _strofio_browse_basic-rates_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx	Browse products for raw data.
	srn_raw_sc _strofio_browse_hq_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx	
	srn_raw_sc _strofio_browse_lq_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx	
	srn_raw_sc _strofio_browse_rhq_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx	

	srn_raw_sc _strofio_browse_rlq_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx	
browse_calibrated/ strofio/sc/yyyymm	srn_cal_sc _strofio_browse_basic-rates_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx srn_cal_sc _strofio_browse_hq_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx	Browse products for calibrated data.
	srn_cal_sc _strofio_browse_lq_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx	
	srn_cal_sc _strofio_browse_rhq_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx	
	srn_cal_sc _strofio_browse_rlq_<yyyymmdd>_<yyyymmdd>__<m_nn>.png/.lblx	

Table 4-12 - *STROFIO browse products directories and filenames.*

The parameters in the table above are:

<yyyymmdd> : UTC date of first and last the measurement in the product

<m_nn>: major (m) and minor (nn) version numbers of the product

4.4.3 MIPA Products

4.4.3.1 MIPA Data Products

All MIPA data product types are summarized in the following Table 4-13 and Table 4-14.

Product Level	***Product Type***	***Mode Description***	***Data Format***
Raw Data	Science	MIPA energy, pixel, ToF and counts data for different bin number combinations.	Table_Delimited/ TSV
	HK	Housekeeping, Decimal numbers of hardware reported units	Table_Delimited/ TSV
Calibrated Data	Science	MIPA differential flux per energy, pixel, and mass bin	Table_Delimited/ TSV
	HK	Housekeeping, Physical units	Table_Delimited/ TSV
Derived Data	Science PAD	MIPA pitch angle distribution data as a function of energy, mass, and time for various bin number combinations.	Table_Delimited/ TSV
	Science VD	MIPA velocities as a function of mass and time for various bin number combinations.	Table_Delimited/ TSV

Table 4-13 – *MIPA data products description.*

Product Level	***Product Type***	***File Naming Convention***
Raw Data	Science	srn_raw_sc _mipa_<mass-energy-direction-time>_<yyyymmddtHHMM>__<m_nn>.lblx/.tsv
	HK	srn_raw_hk _mipa_<yyyymmdd>.xml/.tsv
Calibrated Data	Science	srn_cal_sc _mipa_<mass-energy-direction-time>_<yyyymmddtHHMM>__<m_nn>.lblx /.tsv
	HK	srn_cal_hk _mipa_<yyyymmdd>.lblx/.tsv
Derived Data	Science PAD	srn_der_sc _mipa_<mass-energy-direction-time> _pitchangle_<yyyymmddtHHMM>__<m_nn>.lblx/.tsv
	Science VD	s rn_der_sc _mipa_<mass-energy-direction-time> _vel_<yyyymmddtHHMM>__<m_nn>.lblx/.tsv

Table 4-14 - *MIPA data product types and filename convention.*

The parameters in the table above are:
<yyyymmddtHHMM> : UTC datetime of the first measurement in the product
<mass-energy-direction-time>: Number of mass bins, energy bins, direction bins, and measurement cycles for the data product.
<m_nn>: Major (m) and minor (nn) version numbers of the product

Raw Data Products

MIPA raw data products contain two distinct categories of data: housekeeping (HK) and Science (Sci) data products.

The raw housekeeping data contains a matrix of size NxM, where N is the number of observations, and M=42 column of data (Appendix A.3.1).

The science data consists of two matrices containing different type of information. The main matrix is called the energy-mass matrix. It contains of a block of size n(E) x n(M), where n(E) is the energy level and n(M) is the mass level. One energy-mass matrix is created for each direction and time instance, leading to a total matrix size of n(D) x n(E) x n(M) for each time where n(D) is the number of directions. The second matrix is called the coincidence matrix, which contains five counter sub-matrices: the start, stop, over, under, and coincidence (N_TOF) counts, creating a block of size n(D)x n(E) x 5. Every observation, depending on the selected number of MIPA bins (explained in Table 2-8), generates different sized matrices. The two science matrices contain all the science observations integrated over the integration time defined by the MIPA science mode.

Partially Processed Data Products

MIPA does not produce partially processed data products.

Calibrated Data Products

The calibrated data products have similar format to those of raw data. However, the values are converted from system level to physical values with more physically meaningful units. For example, in the raw HK data, the sensor current and voltages are in some system level units. In the calibrated data products, the currents are converted into units of Ampere and voltages to units of Volts. For the science data, raw counts are converted to differential flux, excluding the UNDER and OVER counters in the raw data, as these represent counts that could not be assigned a physically meaningful time-of-flight.

Derived Data Products

While the exact form of the MIPA derived data products has not yet been determined, the calibrated science products will likely be split into multiple derived products for the time period and mode of each lower-level product. Consistent with other products, each will be in .tsv format with a .lblx label. One example of the lower-level subdirectories containing the derived data products is shown in Table 4-13, although it is not finalized.

4.4.3.2 MIPA Calibration Products

The MIPA calibration products currently include a .csv of the energy lookup table for all table versions and numbers. The geometric factor of each pixel may be a calibration product in the future. The lower-level sub-directories of the calibration collection contain the following type of MIPA supplementary products shown in Table 4-15.

Product Level	***File Naming Convention***	***Description***

Calibration	srn_calib_mipa_lut.lblx/.csv	Energy lookup table
	srn_calib_mipa_gfactor.lblx/.csv	Angular geometrical factor
	srn_calib_mipa_hk.lblx/.csv	Conversion of housekeeping values to physical units

Table 4-15 - *MIPA calibration products directories and filenames.*

4.4.3.3 MIPA Browse Products

MIPA browse products for the RAW data are energy-time spectrograms of the START counts. Energy in eV is on the y axis and UTC time on the x axis. Colour represents the number of counts detected for a given energy bin. Calibrated browse products are similar spectrograms with colour representing differential flux. An example raw browse product is shown below.

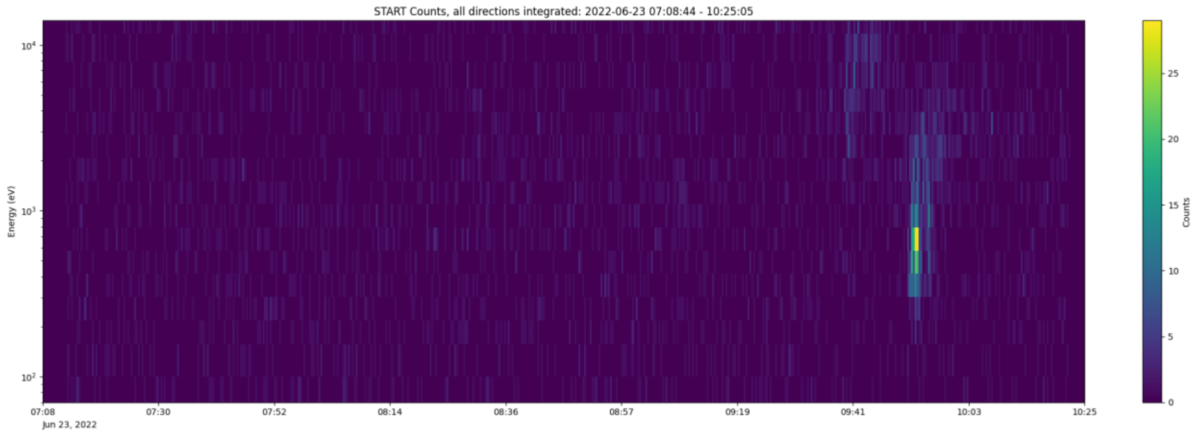


Figure 4-3 - *MIPA browse product plot for raw science data, example data from Mercury flyby 2.*

The lower-level sub-directories of the browse products collections contain the following types of MIPA supplementary products shown in Table 4-16.

Directory Name	***File Naming Convention***	***Description***
browse_raw/mipa/sc/yyyymm	srn_raw_sc _mipa_browse_ <mass-energy-direction-time>_<yyyymmddtHHMM>__<m_nn>.lblx/.png	MIPA browse product for raw data.
browse_calibrated/ mipa/sc/yyyymm	srn_cal_sc _mipa_browse_<mass-energy-direction-time>_<yyyymmddtHHMM>__<m_nn>.lblx/.png	MIPA browse product for cal data.

Table 4-16 - *MIPA browse products directories and filenames.*

The parameters in the above are:
<yyyymmddtHHMM> : UTC datetime of the first measurement in the product
<mass-energy-direction-time>: The number of mass bins, energy bins, direction bins, and measurement cycles for the data product.
<m_nn>: major (m) and minor (nn) version numbers of the product

4.4.4 PICAM Products

4.4.4.1 PICAM Data Products

All PICAM data product types are summarized in the following Table 4-17 and Table 4-18.

Product Level	***Product Type***	***Mode Description***	***Data Format***
Raw Data	Science	PICAM energy, sector, ToF and count rates data for each different science mode.	Table_Delimited/ Tab

	HK1	Housekeeping, Decimal numbers of hardware reported units	Table_Delimited/ Tab
	HK2	Housekeeping, Decimal numbers of hardware reported units	Table_Delimited/ Tab
Calibrated Data	Science	PICAM calibated energy values, differential flux and energy flux for each different science mode.	Table_Delimited/ Tab
	HK1	Housekeeping, Physical units	Table_Delimited/ Tab
	HK2	Housekeeping, Physical units	Table_Delimited/ Tab
Derived Data	TBD	TBD	TBD

***Table 4-17 –** PICAM data products description.*

Product Level	***Product Type***	***File Naming Convention***
Raw Data	Science	srn_raw_sc_picam_mode<XXY>_ <yyyymmddtHHMM>__<m_nn>.lblx/.tab
	HK1	srn_raw_hk_picam_hk1_<yyyymmdd>__<m_nn>.lblx/.tab
	HK2	srn_raw_hk_picam_hk2_<yyyymmdd> __<m_nn>.lblx/.tab
Calibrated Data	Science	srn_cal_sc_picam_mode<XXY>_ <yyyymmddtHHMM>__<m_nn>.lblx/.tab
	HK1	srn_cal_hk_picam_hk1_<yyyymmdd>__<m_nn>.lblx/.tab
	HK2	srn_cal_hk_picam_hk1_<yyyymmdd>__<m_nn>.lblx/.tab
Derived Data	TBD	TBD

***Table 4-18 -** PICAM data product types and filename convention.*

The parameters in the table above are:

<XXY>: XX is the 2-digit mode number, Y is either "i" for image modes, "s" for TOF single pulse modes, "h" for TOF hadamard modes.

<yyyymmddtHHMM> : UTC datetime of the first measurement in the product

<m_nn>: major (m) and minor (nn) version numbers of the product

Raw Data Products

PICAM HK1 raw data is a Table_Delimited (tab delimiter) ASCII file containing the binary raw data as decimal numbers of basic instrument data like voltages, temperatures, and software status.

PICAM HK2 raw data is a Table_Delimited (tab delimiter) ASCII file containing the binary raw data as decimal of MCP status, sensor voltages and configuration status of the science data generation software modules.

The instrument records ion spectra from various directions in azimuth and elevation, and TOF spectra (depending on the measurement mode). Science raw data products are tab delimited tables appearing in two file formats, one for the image modes and one for the TOF modes. Besides some common parameters, the image mode table section contains 32 columns representing the counts for each anode group for each energy channel, while TOF mode sections contain the counts in 512 time bins for each energy channel and each anode group. In case of less than 32 anode groups or less than 512 time bins, the remaining cells are filled with the value -1. For image modes one row represents one energy level, so that one sweep contains up to 32 rows (depending on the mode). The following Table 4-19 illustrates the configuration of the different TOF modes:

- Mode MC_HR511_HE: 1 anode, 32 energy levels, 511 bins: 32 rows per sweep.
- Mode MC_HR511_LE: 1 anode, 16 energy levels, 511 bins: 16 rows per sweep.

- Mode MD_NR511_HE: 4 anodes, 32 energy levels, 511 bins: 128 rows per sweep.
- Mode MC_NR128_HE: 1 anode, 32 energy levels, 128 bins: 32 rows per sweep.
- Mode MP_NR128_HE: 16 anodes, 32 energy levels, 128 bins: 512 rows per sweep.
- Mode MC_LR64_LE: 1 anode, 16 energy levels, 64 bins: 16 rows per sweep.
- Mode MD_LR64_LE: 8 anodes, 16 energy levels, 64 bins: 128 rows per sweep.
- Mode TEST_COMM: 32 anodes, 32 energy Levels, 512 bins, 1024 rows per sweep.

Example for mode MD_LR64_LE (column 0: energy index; column 1: anode index, B0 - B511: TOF bins, in this case bins 64 to 511 would contain the value 0, the number of used bins for a mode is found in the column NSD_NUMTOFS):

E_x	A_x	B_0	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	...	B_{511}
0	0	0	0	0	0	0	0	0	0	0	...	0
0	1	0	0	0	0	0	0	0	0	0	...	0
0	2	0	0	0	0	0	0	0	0	0	...	0
0	3	0	0	0	0	0	0	0	0	0	...	0
0	4	0	0	0	0	0	0	0	0	0	...	0
0	5	0	0	0	0	0	0	0	0	0	...	0
0	6	0	0	0	0	0	0	0	0	0	...	0
0	7	0	0	0	0	0	0	0	0	0	...	0
1	0	0	0	0	0	0	0	0	0	0	...	0
1	1	0	0	0	0	0	0	0	0	0	...	0
1	2	0	0	0	0	0	0	0	0	0	...	0
1	3	0	0	0	0	0	0	0	0	0	...	0
1	4	0	0	0	0	0	0	0	0	0	...	0
1	5	0	0	0	0	0	0	0	0	0	...	0
1	6	0	0	0	0	0	0	0	0	0	...	0
1	7	0	0	0	0	0	0	0	0	0	...	0
...	...	...									...	0

***Table 4-19 –** Configuration of different PICAM TOF modes*

Table A-29 (see Appendix A.4) shows the columns of the TOF science raw product without the 512 bin columns. In PDS4 this is a Table_Delimited ASCII file. Table A-30 shows the columns of the IMG science raw product without the 32 count columns. In PDS4 this is a Table_Delimited ASCII file.

Partially Processed Data Products

PICAM does not produce partially processed data products.

Calibrated Data Products

PICAM calibrated HK1 and HK2 data are Table_Delimited (tab delimiter) ASCII files containing the calibrated values as described in the respective Raw Data section.

The format of the PICAM calibrated science data is similar to the format of the raw science data but instead of counts reports fluxes. Additional information for science interpretation purpose (like amu vs. ToF, pixel FoV) is also added.

Derived Data Products

TBD. See 3.2.2.4.

4.4.4.2 PICAM Calibration Products

The following Table 4-20 shows the calibration items used to convert HK1 and HK2 raw data into physical values.

Number #	Name	Description
1	NAME	A unique calibration item name by which the item is referenced in the parameter configuration file.
2	UNIT	Unit of resulting physical value.
3	FACTOR	The calibration factor column provides the constant value by which the raw value needs to be multiplied.
4	OFFSET	The offset column provides the offset which has to be added to the (physical) value.
5	EXPRESSION	An expression/function that will be evaluated during packet processing. Functions are coded in the software.
6	CALIBRATION	A list of at least two values defining a calibration curve. If empty, FACTOR and OFFSET or EXPRESSION is used.
7	DESCRIPTION	Item description

Table 4-20 – *Calibration items for converting PICAM housekeeping raw data into physical units*

The lower-level sub-directories of the calibration collection contain the following types of PICAM supplementary products shown in Table 4-21.

Product Level	*File Naming Convention*	*Description*
Calibration	srn_calib_picam_hk_calibration_<yyyymmdd>.lblx/.tab	PICAM calibration products to calibrate HK data.
	srn_calib_picam_calibration_anodeareas.lblx/.tab	File with PICAM anode areas for different modes.

Table 4-21 - *PICAM calibration products directories and filenames.*

4.4.4.3 PICAM Browse Products

Science raw data images showing the measured counts as omnidirectional plots are produced and packed into the browse products, see an example in Figure 4-4.

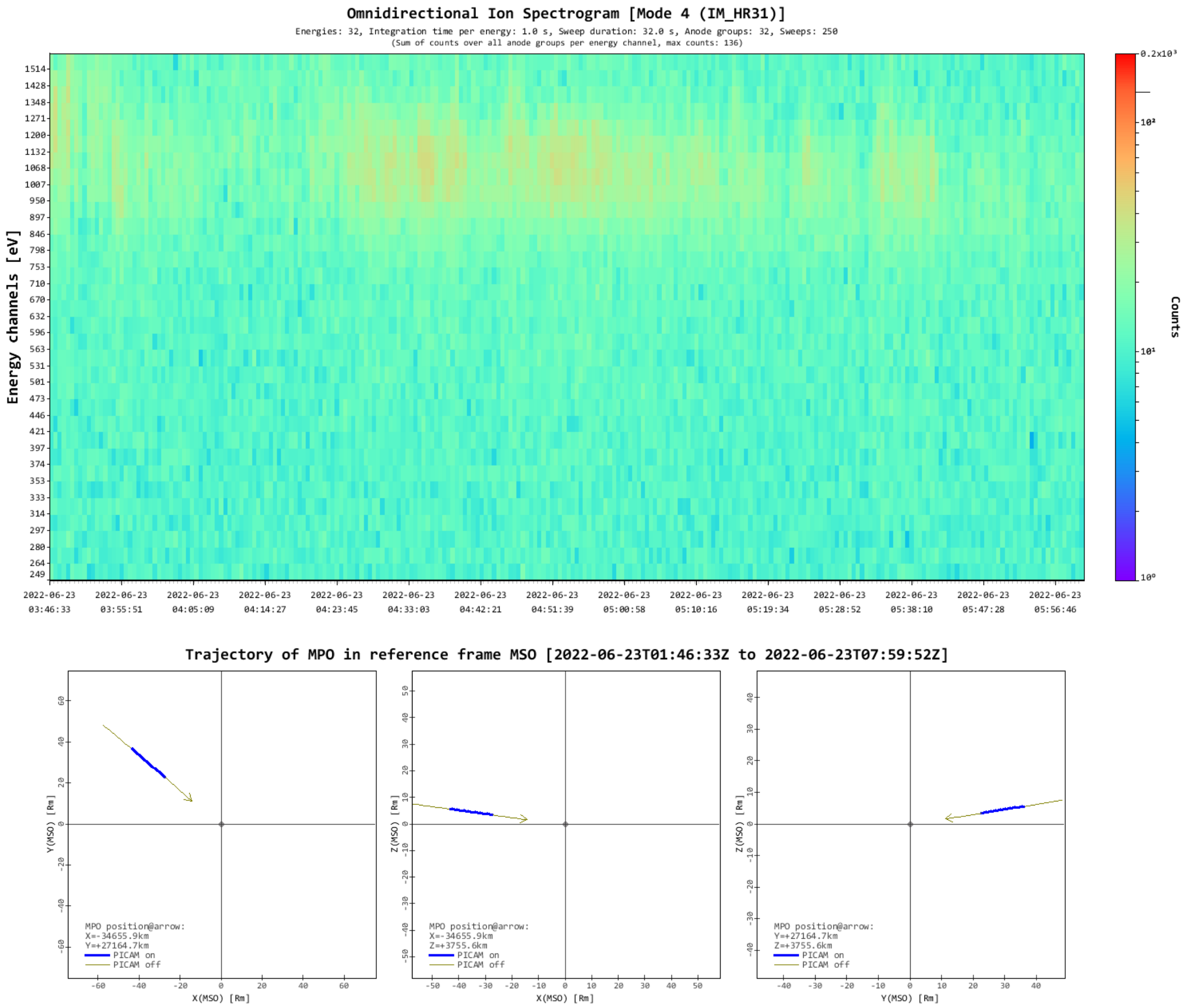


***Figure 4-4 –** Example of PICAM browse product from the second Mercury flyby.*

The lower-level sub-directories of the browse products collections contain the following types of PICAM supplementary products shown in Table 4-22.

Directory Name	*File Naming Convention*	*Description*
browse_raw/ picam/sc/yyyymm	srn_raw_sc _picam_browse_<mode>_<yyyymmddtHHMM>__<m_nn>.png/.lblx	PICAM browse product for raw data.
browse_calibrated/ picam/sc/yyyymm	srn_cal_sc _picam_browse_<mode>_<yyyymmddtHHMM>__<m_nn>.png/.lblx	PICAM browse product for cal data.

***Table 4-22 -** PICAM browse products directories and filenames.*

The parameters in the above are:
<yyyymmddtHHMM> : UTC datetime of the first measurement in the product
<mode> : Scientific mode name. It can be as follows:

- For PICAM it includes the tof (time-of-flight) or img (image) flag plus the mode number, e.g. img04 (image mode 4) or tof11 (time-of-flight mode 11).

<m_nn>: major (m) and minor (nn) version numbers of the product

4.4.5 SCU Products

4.4.5.1 SCU Raw Data Products

SCU HK raw data products are ASCII files containing basic information provided by the system parameters, such as voltages, currents, temperatures, subunits enabled/disabled flags, information about execution of telecommands, checksums, etc. The data format of the raw housekeeping products is Table_Delimited/CSV. Each row of the CSV table represents a telemetry packet capturing the system parameters at the respective timestamp. The columns of the table are described in detail in Table A-36 (see Appendix A.5).

The lower-level sub-directories of the raw data collection contain the following types of SCU data products shown in Table 4-23.

Directory Name	*File Naming Convention*	*Description*
scu/hk/yyyymm	srn_raw_hk_scu_<yyyymmdd>__<m_nn>.lblx/.csv	Raw, HK

Table 4-23 - *SCU Raw data products description.*

The parameters in the above table are:

<yyyymmdd> : UTC date of the first measurement in the product.

<m_nn>: major (m) and minor (nn) version numbers of the product

4.4.5.2 SCU Partially Processed Data Products

SCU does not produce partially processed data products.

4.4.5.3 SCU Calibrated Data Products

SCU HK calibrated data products are ASCII files providing the same tabular information as the corresponding raw data product but translated from hardware units to physical units. The data format of the calibrated housekeeping products is Table_Delimited/CSV.

The lower level sub-directories of the calibrated data collection contain the following types of SCU data products shown in Table 4-24.

Directory Name	*File Naming Convention*	*Description*
scu/hk/yyyymm	srn_cal_hk_scu_<yyyymmdd>__<m_nn>.lblx/.csv	Calibrated, HK

Table 4-24 - *SCU calibrated data products directories and filenames.*

The parameters in the above are:

<yyyymmdd : UTC date of the first measurement in the product.

<m_nn>: major (m) and minor (nn) version numbers of the product.

4.4.5.4 SCU Derived Data Products

SCU does not produce derived data products.

4.4.5.5 SCU Calibration Products

The lower-level sub-directories of the calibration collection contain the following types of SCU supplementary products shown in Table 4-25.

Directory Name	*File Naming Convention*	*Description*
scu/	srn_calib_hk_scu_<yyyymmdd>.lblx/.csv	Calibration, HK

Table 4-25 - *SCU calibration products directories and filenames.*

4.4.5.6 SCU Browse Products

The SERENA team currently does not foresee to generate SCU browse products.

5. Datasets Overview

5.1 Datasets by Mission Phase

As of the current release, the SERENA sensors have acquired data during the following mission phases:

- On-ground testing and calibration campaign
- Near-Earth Commissioning Phase (NECP)
- Interplanetary Cruise Phase (ICP)
- Planetary Flybys
    - Earth Flyby
    - Venus Flybys #1 and #2
    - Mercury Flybys #1, #2, #3, #4, and #6 (but not #5)

The following sections provide an overview of the datasets obtained in each of these phases, highlighting the specific characteristics and operational details of the active sensors. Unless otherwise specified, SCU raw and calibrated housekeeping data are implicitly included as part of each dataset description.

Detailed information about the observations of the SERENA sensors are given in Appendix B.

5.1.1 Datasets from the On-ground Testing and Calibration Campaign

TBD

5.1.2 Datasets from the NECP

During the Near-Earth Commissioning Phase, the SERENA sensors were activated in flight for the first time. The main objective of this phase was to verify the functionality and operability of each instrument through a series of engineering and performance checks. Consequently, the resulting datasets primarily serve technical validation purposes and may not include higher-level (calibrated or derived) data products.

The NECP dataset includes measurements acquired by ELENA, MIPA, PICAM, STROFIO, and SCU between **2018-12-12** and **2018-12-14**. It should be noted that commissioning activities continued into the initial day of the Interplanetary Cruise Phase (**2018-12-15**), and additional "delta commissioning" operations were conducted between **2019-07-22** and **2019-07-26**.

5.1.3 Datasets from the Interplanetary Cruise Phase (2018-2025)

During the long Interplanetary Cruise Phase, the SERENA sensors were operated intermittently for several purposes, including **science observations**, **instrument health checks**, and **operability tests**. These activities served both to monitor the status of the instruments and to collect background measurements of the interplanetary plasma.

ELENA

Due to its mounting position at the interface between the MPO and the MTM, ELENA could not perform meaningful scientific measurements during the cruise. It was operated only during dedicated checkouts and functional tests. The resulting datasets include raw housekeeping and science data, along with calibrated housekeeping data. No calibrated or derived science data products are available for this phase.

Detailed information about the ELENA datasets from the cruise phase can be found in Table B-1.

STROFIO

Similarly to ELENA, STROFIO was not operated for scientific observations during the cruise phase. It was occasionally powered on for health checks and verification activities. While, during the whole ICP, an extensive recharacterization campaign was performed to obtain the optimal functional configuration and parameters of the sensor's deflection voltages. The datasets comprise raw and calibrated housekeeping data from these tests, and raw science data products without scientifically relevant measurements.

Detailed information about the STROFIO datasets from the cruise phase can be found in Table B-2.

MIPA

MIPA was activated multiple times throughout the cruise phase to verify its performance and to acquire background measurements under various instrument configurations. The datasets include raw science and housekeeping data, as well as calibrated housekeeping products. Detailed information about the MIPA observation periods can be found in Table B-3.

PICAM

PICAM conducted a series of instrument checkouts, software update tests, and background measurements during the cruise phase. Both raw and calibrated housekeeping data are available in the standard formats. These operations also have produced science data that are only available at the raw level. They include **imaging (IMG)** and **time-of-flight (TOF)** modes, typically run in the solar wind conditions.

Since 2021, PICAM has been switched ON in various occasions inside the interplanetary medium, to monitor the Solar Wind for BepiColombo, for its Radio Science Campaign (RSE), and other Heliospheric multi-spacecraft science coordination. PICAM also participated in the campaign investigating the outgassing of BepiColombo. The raw and calibrated housekeeping and science products of such observations are available. For detailed products availability see Table B-4.

5.1.4 Datasets from the Planetary Flybys

During the planetary flybys, the SERENA instruments were operated selectively, depending on the specific spacecraft constraints. The following subsections summarize the datasets produced by each sensor.

ELENA

ELENA was not operated during any of the planetary flybys and therefore did not produce data products for these periods.

STROFIO

STROFIO was operated during the Earth flyby for purely operational and verification purposes. No scientifically significant measurements were acquired. The instrument was not operated during any of the Venus or Mercury flybys and therefore did not produce data for those events.

MIPA

MIPA was operated during all planetary flybys (except for Mercury flyby #5), acquiring raw science and housekeeping data, as well as calibrated housekeeping products.

Science observations were conducted under high-voltage conditions in various operating combinations, depending on the phase and configuration of each flyby.

The datasets corresponding to each event are summarized below:

- **Earth Flyby (2020-04-09 – 2020-04-10)**
  - 96 energy bins, 24 directions, 32 mass bins, 1 measurement cycle for overall plasma measurements
  - 96 energy bins, 24 directions, 32 mass bins, 6 measurement cycles for overall plasma measurement with lower time resolution
- **Venus Flyby #1 (2020-10-15 – 2020-10-18)**
  - 32 energy bins, 24 directions, 2 mass bins, 4 measurement cycles for monitoring farther from closest approach
  - 32 energy bins, 24 directions, 2 mass bins, 1 measurement cycle for plasma measurements near closest approach
- **Venus Flyby #2 (2021-08-09 – 2021-08-10)**
  - 32 energy bins, 24 directions, 2 mass bins, 4 measurement cycles for monitoring farther from closest approach
  - 32 energy bins, 24 directions, 2 mass bins, 1 measurement cycle for plasma measurements near closest approach
- **Mercury Flyby #1 (2021-10-01 – 2021-10-02)**
  - 32 energy bins, 24 directions, 2 mass bins, 4 measurement cycles for monitoring farther from closest approach
  - 32 energy bins, 24 directions, 8 mass bins, 1 measurement cycle for plasma measurements in the Mercury magnetosphere
- **Mercury Flyby #2 (2022-06-22 – 2022-06-25)**
  - 16 energy bins, 48 directions, 8 mass bins, 1 measurement cycle after table change to have higher angular resolution and coverage for plasma measurements in the Mercury magnetosphere. The table change also decreased the energy resolution.
- **Mercury Flyby #3 (2023-06-17 – 2023-06-21)**
  - 16 energy bins, 1 direction, 8 mass bins. Direction was fixed so that MIPA was only scanning over energy, leading to one energy spectrum every 375ms. However, the dataset contains 48 direction bins, so the data matrix must be reshaped prior to analysis (see caveats in section 6.2.3.3).
- **Mercury Flyby #4 (2024-04-08 – 2024-04-10)**
  - 48 energy bins, 48 directions, 8 mass bins, and 1 measurement cycle (the new standard MIPA configuration) for higher resolution measurements of the Mercury magnetosphere.
- **Mercury Flyby #5**
  - MIPA was not operated due to mission constraints.
- **Mercury Flyby #6 (2025-01-07 – 2025-01-09)**
  - MIPA was operated in the same configuration as Mercury Flyby #4.

Further details on the observation timings, operating modes, and instrument configurations are provided in Table B-3.

PICAM

PICAM was operated during all the planetary flybys except for Mercury flyby #5, acquiring raw and calibrated housekeeping and science products. The generation of calibrated science data for these periods is under assessment.

Instrument operations included combinations of imaging (IMG) and time-of-flight (TOF) modes, typically under nominal high-voltage conditions.

PICAM has generated datasets from the following planetary flybys:

- **Earth Flyby (2020-04-09 – 2020-04-10)**
- **Venus Flyby #1 (2020-10-15 – 2020-10-16)**
- **Venus Flyby #2 (2021-08-09 – 2021-08-10)**
- **Mercury Flyby #1 (2021-10-01 – 2021-10-02)**
  Mercury Flyby #2 (2022-06-22 – 2022-06-25)
- **Mercury Flyby #3 (2023-06-17 – 2023-06-21)**
- **Mercury Flyby #4 (2024-04-08 – 2024-04-10)**
- **Mercury Flyby #6 (2025-01-07 – 2025-01-09)**

PICAM used various mode settings based on the environment, Mercury or Solar Wind. A detailed overview of the observation timelines and available data products is provided in Table B-4.

5.2 Datasets by Version

TBD. When this section is completed it will describe the changes in the SERENA dataset introduced with each new major version of the officially published products.

6. Science User Guide

The purpose of this section is to assist scientists and data users in making effective use of the SERENA datasets. While the preceding sections describe the instruments, operating modes, and data products, here we focus on practical aspects of scientific use. Guidance is provided on how to approach the datasets, how to work with the data and metadata of each SERENA sub-instrument, what known issues and caveats to be aware of, and examples of typical analyses. Together, these notes are intended to help new users navigate the archive efficiently and ensure that the data are applied correctly in scientific investigations.

6.1 How to Approach the Datasets

The SERENA bundle contains multiple levels of data (raw, calibrated, derived, and browse) from the four sub-instruments (ELENA, STROFIO, PICAM, and MIPA) and the SCU. Because of this diversity, users may find it helpful to begin by clarifying their science objective and then selecting the appropriate product types.

This section addresses common questions new users may have:

How do I use all the different data types?

- *Raw data* provide the original instrument measurements and are mainly of interest to instrument specialists.
- *Calibrated data* are recommended for most science investigations, since instrument effects have been removed or corrected.
- *Derived data* contain higher-level products, such as spectra, maps, or distribution functions, often suitable for direct analysis.
- *Browse data* are for quick inspection and overview purposes.

Which are the most important products for different science cases?

- For studies of Mercury's exosphere, *ELENA calibrated fluxes* and *STROFIO calibrated mass spectra* are central.
- For plasma interaction studies, *PICAM and MIPA calibrated ion fluxes* are essential.
- For multi-sensor investigations (e.g., charge exchange processes, ion sputtering, etc.), a combination of calibrated data from all four sensors can be used.

How should I find data for a given type of analysis?

- Data can be located in the PSA by *mission phase* (e.g., cruise, Mercury orbit insertion, orbit phases).
- Searches may be narrowed by *time intervals* (UTC or spacecraft event time) or by orbital/geometry conditions using SPICE.
- For thematic analyses (e.g., dawn-dusk asymmetry, magnetospheric crossings), users should start from the calibrated collections and filter by *spacecraft local time or position*.

What do the different major versions mean?

- Major version numbers in the bundle and collections indicate a new calibrated data pipeline or a significant reprocessing of earlier data.
- Minor version updates (e.g., v1.1 → v1.2) typically add new data from later mission phases without altering existing products.
- Users are advised to consult Section 5.2 of this document to understand the changes between versions.

Relevant data from other instruments?

- Some science cases may benefit from combining SERENA data with those from other MPO instruments (e.g., MPO-MAG for magnetic field, SIXS for solar X-ray and energetic particles, PHEBUS for exosphere observations, and various instruments from the Mio spacecraft).

- Geometry and pointing information is available in the BepiColombo SPICE kernel dataset, which is archived separately.
- Cross-instrument use should be guided by mission-level references (see Section 1.3.2 on Related Publications).

For more detailed guidance, the following subsections provide subunit-specific notes. These include the key science use cases for each SERENA instrument (ELENA, STROFIO, PICAM, and MIPA), the most relevant metadata fields for filtering and selecting data, and known issues or caveats that should be considered in scientific analyses.

6.2 Working with the Data

6.2.1 Working with the ELENA Data

This section offers guidance for selecting the appropriate ELENA data for different science use cases, explains how to apply relevant metadata filters, and outlines known issues and caveats to consider when analysing the data.

6.2.1.1 Selecting ELENA Data Types and Levels for Science Use Cases

The ELENA collections contain several levels of data products:

- **Raw data**: contain the unprocessed detector counts. These are mainly intended for instrument specialists or re-calibration work. (Note: the partially processed product for the R-mode is equivalent to the integrated raw data products for the other ELENA science modes.)
- **Calibrated data**: detector counts are corrected for instrument response, geometry factors, and known background. This level is recommended for most scientific analyses.
- **Derived products**: higher-level data such as fluxes mapped into physical coordinates. These are most suitable for direct comparison with models.
- **Browse products**: quick-look visualizations, intended for data discovery and initial inspection, not for quantitative science.

Use-case guidance:

- *Surface neutral particle emission studies*: use **calibrated data**, filtering by instrument mode and geometry (local time, true anomaly angle).
- *Planetary limb remote sensing*: select **off-nadir pointing geometry** cases where spacecraft orientation permits limb observations.
- *Calibration or background studies*: use data flagged with the **dark_counts_indicator**, and raw data for detector characterization.
- *Special ion detection cases*: use data where **neg_deflector_voltage = 0** and/or **pos_deflector_voltage = 0**, which allow ions to reach the MCP.

6.2.1.2 Metadata Filters for ELENA

There are two ways of filtering ELENA data: by metadata parameters that apply to the whole product, or by data fields within the data product. The following metadata parameters are provided to allow selection of the most appropriate data products:

- **mode**: operational mode of ELENA (SCIENCE, STANDBY).
- **integration_time**: accumulation time per measurement. Useful for balancing time resolution vs. sensitivity.
- **dark_counts_indicator**: identifies calibration periods where only dark counts are recorded.
- **off_nadir_pointing**: flag indicating when the instrument field of view is away from nadir, important for limb observations.

- **neg_deflector_voltage / pos_deflector_voltage**: high-voltage deflectors; when set to 0, allow ions to reach the detector.
- **mcp_voltage**: operating voltage of the MCP, which influences sensitivity.

Additional geometric filters (from geometry kernel-based calculations) that apply to the whole data product include:

- geom:stop_spacecraft_heliocentric_distance
- *geom:start_spacecraft_heliocentric_distance*
- *geom:start_spacecraft_target_subspacecraft_distance*
- *geom:stop_spacecraft_target_subspacecraft_distance*
- *geom:minimum_subspacecraft_longitude*
- *geom:maximum_subspacecraft_longitude*
- *local_true_solar_time*
- *start_mercury_true_anomaly_angle*
- *stop_mercury_true_anomaly_angle*

These filters are critical for selecting subsets of data corresponding to specific orbital locations, mission phases, or planetary conditions.

Similar instrument-related and geometry parameters are provided for each data packet as fields within the ELENA data products structure. For detailed information see Appendix A.1.

6.2.1.3 Known Issues and Caveats with the ELENA Data

Users should be aware of the following caveats:

- During the **cruise phase**, ELENA's field of view was obstructed, and only limited calibration or engineering data are meaningful. Scientific analysis should primarily use data acquired after **Mercury Orbit Insertion (MOI)**.
- The **VALIDITY flag** should be checked for each packet within the data products:

  VALIDITY = 0 : valid packet

  VALIDITY = 1 : packet length disparity

  VALIDITY = 2 : wrong end word

  VALIDITY = 3 : unsynchronized time

  Only packets with VALIDITY = 0 are recommended for standard analysis.
- Instrument configuration changes (e.g., MCP voltage, deflector voltages) can strongly affect data interpretation and should always be accounted for via metadata filters.

6.2.2 Working with the STROFIO Data

This section offers guidance for selecting the appropriate STROFIO data for different science use cases, explains how to apply relevant metadata filters, and outlines known issues and caveats to consider when analysing the data.

6.2.2.1 Selecting STROFIO Data Types and Levels for Science Use Cases

STROFIO data contains several levels of data products:

- **Raw data**: contain the unprocessed detector counts. These are mainly intended for instrument specialists or re-calibration work.
- **Calibrated data**: accumulator values are corrected for instrument response, geometry factors, and known background. This level is recommended for most scientific analyses.
- **Derived products**: higher-level data such as densities mapped into physical coordinates. These are most suitable for direct comparison with models.
- **Browse products**: quick-look visualizations, intended for data discovery and initial inspection, not for quantitative science

6.2.2.2 Metadata Filters for STROFIO

There are two ways of filtering STROFIO data: by metadata parameters that apply to the whole product, or by data fields within the data product. The following metadata parameters are provided to allow selection of the most appropriate data products:

- **mode**: operational mode of STROFIO (PRIMARY_NORMAL, SECONDARY_NORMAL, HIGH_ENERGY, ION, BACKGROUND, MOLECULAR, STANDBY, or ENGINEERING).
- **num_mass_bins:** The number of mass bins measured by STROFIO, ranges from 40-80
- **calibration_type:** Type of calibration applied to the data product (none, ground, or inflight)
- **integration_time**: accumulation time per measurement. Useful for balancing time resolution vs. sensitivity.
- **off_nadir_pointing**: flag indicating when the instrument field of view is away from nadir.

Additional geometric filters (from geometry kernel-based calculations) that apply to the whole data product include:

- geom:stop_spacecraft_heliocentric_distance
- *geom:start_spacecraft_heliocentric_distance*
- *geom:start_spacecraft_target_subspacecraft_distance*
- *geom:stop_spacecraft_target_subspacecraft_distance*
- *geom:minimum_subspacecraft_longitude*
- *geom:maximum_subspacecraft_longitude*
- *local_true_solar_time*
- *start_mercury_true_anomaly_angle*
- *stop_mercury_true_anomaly_angle*

These filters are critical for selecting subsets of data corresponding to specific orbital locations, mission phases, or planetary conditions.

Similar instrument-related and geometry parameters are provided for each data packet as fields within the STROFIO data products structure. For detailed information see Appendix A.2.

6.2.2.3 Known Issues and Caveats with the STROFIO Data

TBD until sufficient flight data is accumulated.

6.2.3 Working with the MIPA Data

This section offers guidance for selecting the appropriate MIPA data for different science use cases, explains how to apply relevant metadata filters, and outlines known issues and caveats to consider when analysing the data.

6.2.3.1 Selecting MIPA Data Types and Levels for Science Use Cases

The MIPA data contain multiple levels of data products:

- **Raw data**: The raw data products contain the unprocessed counts from the instrument. They are intended for use by instrument specialists or checking of calibration. They also serve as input to the statistically smoothed and processed derived data product.
- **Calibrated data:** The calibrated data have been converted to physical units, both for instrument parameters such as temperature and for counts, which have been converted to differential flux using the instrument integration time and angular geometrical factor. The calibrated data is suitable for basic analysis, but has not been processed to account for the effects of low count rates or background noise.
- **Derived data:** The derived data should be used for most scientific analyses, depending on the use case. The statistically processed differential fluxes are the most suitable for in-

depth analysis of ion populations. Pitch angle distributions and velocities should be used for analysis of ion flow directions.
- **Browse data:** The browse data show energy-time spectrograms for the raw (counts) and calibrated (differential flux) data. They are intended to be used as quick-look visualizations for data discovery and initial inspection, not quantitative science.

6.2.3.2 Metadata Filters for MIPA

There are two ways of filtering MIPA data: by metadata parameters that apply to the whole product, or by data fields within the data product. The following metadata parameters are provided to allow selection of the most appropriate data products:

- **operation_mode:** Current system mode, always SCIENCE for scientific data
- **num_mass_bins:** The number of mass bins measured by MIPA, ranges from 2-128
- **num_energy_bins:** The number of energy bins measured, ranges from 16-48
- **num_direction_bins:** The number of direction bins (angular pixels) measured, ranges from 2-48
- **measurement_cycles:** The number of 20s measurement cycles per count matrix, ranges from 1-6
- **table_number:** The energy table used during the measurement, as numbered in calibration product urn:esa:psa:bc_mpo_serena:calibration_files:srn_calib_mipa_lut. Ranges from 0-3.
- **table_version:** The MIPA energy tables were updated three times; the table version metadata gives the version number used in the measurement according to srn_calib_mipa_lut.

Additional geometric filters (from geometry kernel-based calculations) that apply to the whole data product include:

- *start_mercury_true_anomaly_angle*
- *stop_mercury_true_anomaly_angle*
- *start_hee_x_axis_mpo_angle*
- *stop_hee_x_axis_mpo_angle*
- *minimum_mpo_mmo_distance*
- *maximum_mpo_mmo_distance*
- *local_true_solar_time*
- *geom:stop_spacecraft_heliocentric_distance*
- *geom:start_spacecraft_heliocentric_distance*
- *geom:start_spacecraft_target_subspacecraft_distance*
- *geom:stop_spacecraft_target_subspacecraft_distance*

These filters are critical for selecting subsets of data corresponding to specific orbital locations, mission phases, or planetary conditions.

Similar instrument-related and geometry parameters are provided for each data packet as fields within the MIPA data products structure. For detailed information see Appendix A.3.

6.2.3.3 Known Issues and Caveats with the MIPA Data

Users should be aware of the following caveats:

- Derived science products are currently unavailable.
- MIPA had frequent byte losses in telemetry packets early in the mission that affected the N_TOF count matrices. MIPA also has generally low count rates, particularly for N_TOF. For these reasons, we recommend using the START count/differential flux matrices for analysis.

- MIPA switched from measuring 96 energy bins x 24 direction bins to 48 energy bins x 48 direction bins in October 2022. After this table change, the angular bins in the count matrices represent pixels [0, 24, 1, 25, 2, 26 ...], which must be accounted for when applying the angular geometric factor to calculate differential flux or when calculating ion directions.
- Because of MIPA's low count rates, converting to differential flux can create unrealistic jumps in value (e.g. a jump from 0 to 1 count could be a change of $10^6/cm^2$ s sr eV in differential flux). The future derived products will be smoothed to create a more statistically valid dataset, which should be used for analysis over the calibrated data when it is available. In the meantime, we caution users not to over-interpret these features in the raw and calibrated data.
- MIPA ran in a special mode for Mercury flyby #3 where only one pixel was measured, allowing for very high time resolution. As a result, the above statement regarding low count rates is particularly applicable. *Do not use the raw or calibrated MIPA data from Mercury flyby #3 without consulting the MIPA team*, as only the smoothed data is scientifically valid.
- For data with table number 2, the count/flux matrices need to be re-shaped and the time steps interpolated, as the data matrices and metadata will show 96 energy bins but the instrument was actually measuring 32 energy bins 3 consecutive times. An example of how to do this will be provided as part of the MIPA data tutorial scripts. Future derived data will already be reshaped properly and have the correct number of energy steps in the metadata.

6.2.4 Working with the PICAM Data

During the cruise period (since the launch in 2018, and until 2025), PICAM operated for both the scientific observations, as well as performance monitoring and improvements (checkouts and software updates). All the data that were collected during the PICAM operations will be available on PSA, and expected to be categorised for the public to be able to work with. The data is expected to be categorised into various targets: calibration, tests, and science. For the science, the data will be the flagged based on their quality (science quality), for public to use them.

6.2.4.1 Selecting PICAM Data Types and Levels for Science Use Cases

PICAM science data on PSA will be listed as:

Raw data: The unprocessed ion counts, and ToF bin number (depending on the operation mode). This data is intended for specific use, by specialists and not the public users.

Calibrated data: The calibrated ion flux, and ToF/Mass_per_charge info. This data is suitable for scientific analysis by the public.

Derived data: The derived data includes additional information regarding the ion's distribution, such as their pitch angle. The data is intended to offer in-depth analysis to the scientific community.

Browse data: The browse data provide quick-look style of the data, which demonstrate energy spectrograms for Raw and Calibrated data.

6.2.4.2 Metadata Filters for PICAM

There are two ways of filtering PICAM data: by metadata parameters that apply to the whole product, or by data fields within the data product. The following metadata parameters are provided to allow selection of the most appropriate data products:

- **operation_mode:** Current system mode, always SCIENCE for scientific data
- **num_tofs:** The number of mass bins measured by PICAMs ToF modes, ranges from 1-512 (for the image modes it is always 1).

- **mode_options:** Hadamard modes flag in any combination of the R, A, H, and I letters with a plus or minus sign. Relevant are only H and I, where:
    - H- Hadamard off (single pulse)
    - H+ Hadamard on
    - I- Inverse Hadmard off (done on ground)
    - I+ Inverse Hadamard on (done by PICAM)
- **sc_structure_id:** Science data type:
    - NSD – normal science data
    - LTIMG – long term image
    - LTTOF – long term ToF
- **ug_voltage_range:** Gate voltage range – LOW or HIGH.
- **u1_voltage_range:** U1 voltage range – LOW or HIGH.

Additional geometric filters (from geometry kernel-based calculations) that apply to the whole data product include:

- *start_mercury_true_anomaly_angle*
- *stop_mercury_true_anomaly_angle*
- *start_hee_x_axis_mpo_angle*
- *stop_hee_x_axis_mpo_angle*
- *minimum_mpo_mmo_distance*
- *maximum_mpo_mmo_distance*
- *local_true_solar_time*
- *geom:stop_spacecraft_heliocentric_distance*
- *geom:start_spacecraft_heliocentric_distance*
- *geom:start_spacecraft_target_subspacecraft_distance*
- *geom:stop_spacecraft_target_subspacecraft_distance*

These filters are critical for selecting subsets of data corresponding to specific orbital locations, mission phases, or planetary conditions.

Similar instrument-related and geometry parameters are provided for each data packet as fields within the PICAM data products structure. For detailed information see Appendix A.4.

6.2.4.3 Known Issues and Caveats with the PICAM Data

The list of the known issues within PICAM's performance (engineering or data acquisition) is planned to be documents as a technical note, and for the general SERENA user manual. The corresponding data will then be flagged on PSA accordingly.

An example of such is during BepiColombo's Earth flyby, where PICAM ToF data is corrupted, due to an issue with energy channels.

In general, the public users are encouraged to only use the calibrated science data, which has the correct quality flag (not flagged as 'test', 'contaminated' etc). This way, they will not encounter the data collected by PICAM, with known issues.

6.3 Example Analysis

This section provides worked examples to help new users begin scientific analysis with the SERENA datasets. The aim is to demonstrate common workflows and highlight best practices for handling the data.

Examples may include:

- **Basic scientific investigations**, such as generating flux maps, producing spectra, or constructing ion distribution functions.

- **Calibration cookbook demonstrations**, showing how to reapply calibration curves on the raw data products to arrive at calibrated data.
- **Reproducing selected analyses from published papers**, providing users with a step-by-step guide to replicate existing results.

Where possible, free and open-source tools will be used (e.g., Python with standard libraries). The PSA team and SERENA instrument teams will endeavour to provide scripts and example plots as *SERENA Data Tutorials*, accessible via external repositories or through the ESA Datalabs platform. Users are encouraged to consult the ESA Datalabs service for interactive examples and ready-to-run analysis notebooks based on PSA archive data.

6.3.1 Example Analysis of ELENA Data

6.3.1.1 Derivation of Neutral Particle Flux Maps from the surface with ELENA Data

TBD. To include the following:

- Detailed procedure: Deriving neutral particle flux maps as a function of local time.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.1.2 Reproduction of ELENA Science Calibrated Data

TBD. To include the following:

- Detailed procedure: Using raw and calibration products to reach the calibrated data level.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.1.3 Reproduction of a Published Study using ELENA Data

TBD. To include the following:

- Detailed procedure: Step-by-step reproduction of the derived ELENA data used in the particular study.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.2 Example Analysis of STROFIO Data

6.3.2.1 Derivation of Neutral Mass Spectra with STROFIO Data

TBD. To include the following:

- Detailed procedure: Producing a neutral mass spectrum averaged over a spacecraft orbit segment.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.2.2 Reproduction of STROFIO Science Calibrated Data

TBD. To include the following:

- Detailed procedure: Using raw and calibration products to reach the calibrated data level.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.2.3 Reproduction of a Published Study using STROFIO Data

TBD. To include the following:

- Detailed procedure: Step-by-step reproduction of the derived STROFIO data used in the particular study.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.3 Example Analysis of MIPA Data

6.3.3.1 Derivation of Ion Distribution Functions with MIPA Data

TBD. To include the following:

- Detailed procedure: Constructing ion distribution functions from calibrated count rates.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.3.2 Reproduction of MIPA Science Calibrated Data

TBD. To include the following:

- Detailed procedure: Using raw and calibration products to reach the calibrated data level, derive differential fluxes, etc.
- Detailed procedure: How to use LUTs to find info about energies, sectors, etc.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.3.3 Reproduction of a Published Study using MIPA Data

TBD. To include the following:

- Detailed procedure: Step-by-step reproduction of the derived (could be any level, e.g. raw data from MSB2) MIPA data used in the particular study.
- Link to Data Tutorial (possibly at ESA Datalabs)

6.3.4 Example Analysis of PICAM Data

6.3.4.1 Derivation of Ion Distribution Functions with PICAM Data

TBD. To include the following:

- Detailed procedure: Constructing ion distribution functions from calibrated count rates.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.4.2 Reproduction of PICAM Science Calibrated Data

TBD. To include the following:

- Detailed procedure: Using raw and calibration products to reach the calibrated data level, derive differential fluxes, etc.
- Detailed procedure: How to use LUTs to find info about energies, sectors, etc.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.4.3 Reproduction of a Published Study using PICAM Data

TBD. To include the following:

- Detailed procedure: Step-by-step reproduction of the derived (could be any level, e.g. raw data from MSB3) PICAM data used in the particular study.
- Link to Data Tutorial (possibly at ESA Datalabs)

6.3.5 Example Analysis of Multi-Sensor Data

In some science cases, combining data from multiple SERENA instruments provides additional insight. While multi-sensor workflows may be more advanced, they illustrate the potential of SERENA as a suite and provide guidance for integrated studies. Or is it too advanced for this user guide? But, actually, it could showcase the power of the SERENA suite.

6.3.5.1 Correlation of ELENA Neutral Atom Fluxes with MIPA Ion Measurements

TBD. To include the following:

- Detailed procedure: Correlating ELENA neutral atom fluxes with MIPA ion measurements to investigate sputtering and backscattering processes at Mercury's surface.
- Link to Data Tutorial (possibly at ESA Datalabs).

6.3.5.2 Comparison of STROFIO Neutral Mass Spectra with PICAM Ion Distributions

TBD. To include the following:

- Detailed procedure: Comparing STROFIO neutral mass spectra with PICAM ion distributions to study charge exchange dynamics in Mercury's exosphere.
- Link to Data Tutorial (possibly at ESA Datalabs).

A. Detailed Fields Description of the SERENA Data Products

A.1 ELENA Data Products Fields Description

A.1.1 ELENA Raw Data Products Fields Description

Column #	Title	Data Type	description
1	PACKET_NUM	ASCII_NonNegative_Integer	Packet number as in the telemetry sequence (Not internal instrument sequence count)
2	VALIDITY	ASCII_NonNegative_Integer	Packet validity flag (0=perfect (valid), 1=packet length disparity, 2=wrong end word, 3=unsynchronized time)
3	SCET	ASCII_NonNegative_Integer	Spacecraft elapsed time in seconds
4	FRAC_SEC	ASCII_NonNegative_Integer	Spacecraft time - fractional ticks (in 1/65536 sec)
5	TIME_UTC	ASCII_Date_Time_YMD_UTC	UTC TIME: YYYY-MM-DDTHH:MM:SS.SSSZ
6	SEQ_COUNT	ASCII_NonNegative_Integer	Sequence counter for this APID.
7	SID	ASCII_NonNegative_Integer	Structure ID. 0 = Reduced SW, 1 = Application SW
8	ACQ_TIME	ASCII_NonNegative_Integer	HK acquisition period res. 1 s range 1..100 sec
9	CUR_MODE	ASCII_NonNegative_Integer	Current Mode: 0 = Stand-by; 1 = Science.
10	PREV_MODE	ASCII_NonNegative_Integer	Previous Mode: 0 = Stand-by; 1 = Science.
11	COMPR	ASCII_NonNegative_Integer	Science data compression: 1 = Enabled; 0 = Disabled; Note. The Boot SW (mode 0) does not support this functionality.
12	SHUT_EN	ASCII_NonNegative_Integer	Shutter: 1 = Enabled; 0 = Disabled; Note. The Boot SW does not support this functionality.
13	MCP_EN	ASCII_NonNegative_Integer	MCP HV circuit: 1 = Enabled; 0 = Disabled; Note. The Boot SW does not support this functionality.
14	ANL_EN	ASCII_NonNegative_Integer	Analyzer circuits: 1 = Enabled; 0 = Disabled; Note. The Boot SW does not support this functionality.
15	TC_REJ	ASCII_NonNegative_Integer	Last TC rejection cause. Last Error. Standard Failure ID: 0 = Illegal APID /None 1 = Incomplete or invalid length Packet (failed to receive whole packet within time out period) 2 = Incorrect checksum. 3 = Illegal packet type 4 = Illegal packet subtype 7 = Command cannot be executed at this time (incorrect status of application to allow command execution).
16	ERR_CRT	ASCII_NonNegative_Integer	Err Last Crit. Last Critical Error in short coding format. 0 = None, 2 = Anomaly; 3 = Anomaly-ground; 4 = Anomaly-Onboard Action.
17	TC_CRT	ASCII_NonNegative_Integer	TC critical flag: 1 = Armed; 0 = None. Note. The Boot SW does not support this functionality.
18	EE_WR	ASCII_NonNegative_Integer	EEPROM Write Flag: 1 = Enabled; 0 = Disabled; Note. The Boot SW does not support this functionality.

19	ERR_CNT	ASCII_NonNegative_Integer	Error counter
20	TC_CNT	ASCII_NonNegative_Integer	Total received TC counter
21	LST_TC_TYP_ACC	ASCII_NonNegative_Integer	Last accepted TC type
22	LST_TC_STYP_ACC	ASCII_NonNegative_Integer	Last accepted TC sub-type
23	LST_TC_TYP_EXE	ASCII_NonNegative_Integer	Last executed TC type
24	LST_TC_STYP_EXE	ASCII_NonNegative_Integer	Last executed TC sub-type
25	LST_TC_TYP_REJ	ASCII_NonNegative_Integer	Last rejected TC type
26	LST_TC_STYP_REJ	ASCII_NonNegative_Integer	Last rejected TC sub-type
27	LST_TC_TYP_FEX	ASCII_NonNegative_Integer	Last execution failed TC type
28	LST_TC_STYP_FEX	ASCII_NonNegative_Integer	Last execution failed TC sub-type
29	PRM_SW_VER	ASCII_NonNegative_Integer	PROM S/W Version
30	EEPRM_SW_VER	ASCII_NonNegative_Integer	EEPROM S/W Version
31	PRM_CKS	ASCII_NonNegative_Integer	PROM S/W Checksum
32	EEP_CKS	ASCII_NonNegative_Integer	EEPROM S/W Checksum
33	RAM_FAI_HI	ASCII_NonNegative_Integer	RAM boot fail check first HI address
34	RAM_FAI_LOW	ASCII_NonNegative_Integer	RAM boot fail check first LOW address
35	RAM_NUM_FAI	ASCII_NonNegative_Integer	RAM boot fail check number of wrong locations
36	P3_3V	ASCII_NonNegative_Integer	+3.3 V
37	P5V	ASCII_NonNegative_Integer	+5 V
38	N5V	ASCII_NonNegative_Integer	-5 V
39	P2V	ASCII_NonNegative_Integer	+2 V
40	N2V	ASCII_NonNegative_Integer	-2 V
41	FPGA_TEMP	ASCII_NonNegative_Integer	Main FPGA temperature
42	MPA_VCC	ASCII_NonNegative_Integer	MIPA Vcc
43	MCP_TEMP	ASCII_NonNegative_Integer	MCP temperature
44	HV_NEG_EN	ASCII_NonNegative_Integer	HV Negative analyzer circuit: 1 = enabled, 0 = disabled. Note: The Boot SW does not support this functionality.
45	HV_POS_EN	ASCII_NonNegative_Integer	HV Positive analyzer circuit: 1 = enabled, 0 = disabled. Note: The Boot SW does not support this functionality.
46	HW_ASIC_THRS	ASCII_NonNegative_Integer	HW Asic Threshold. Note: The Boot SW does not support this functionality.
47	SHT_RMS	ASCII_NonNegative_Integer	Shutter RMS
48	N12V	ASCII_NonNegative_Integer	-12V
49	P12V	ASCII_NonNegative_Integer	+12V
50	PCOL_V	ASCII_NonNegative_Integer	Positive collimator HV bias
51	NCOL_V	ASCII_NonNegative_Integer	Negative collimator HV bias
52	MCP_HV	ASCII_NonNegative_Integer	MCP HV
53	PCOL_CUR	ASCII_NonNegative_Integer	Positive collimator HV current
54	NCOL_CUR	ASCII_NonNegative_Integer	Negative collimator HV current
55	MCP_CUR	ASCII_NonNegative_Integer	MCP HV current
56	SHT_TEMP	ASCII_NonNegative_Integer	Shutter temperature
57	DAC_TEMP	ASCII_NonNegative_Integer	DAC temperature
58	END_MARK	ASCII_NonNegative_Integer	Fixed value to 0xCAFE Note: This field is present only in the application SW HK with SID 1, in the reduced SW this field is not present.

***Table A-1** – ELENA Raw housekeeping data products fields description*

Column #	Title	Data Type	description

1	PACKET_NUM	ASCII_NonNegative_Integer	Packet number as in the telemetry sequence (Not internal instrument sequence count)
2	VALIDITY	ASCII_NonNegative_Integer	Packet validity flag (0=perfect (valid), 1=packet length disparity, 2=wrong end word, 3=unsynchronized time)
3	SCET	ASCII_NonNegative_Integer	Spacecraft elapsed time in seconds
4	FRAC_SEC	ASCII_NonNegative_Integer	Spacecraft time - fractional ticks (in 1/65536 sec)
5	TIME_UTC	ASCII_Date_Time_YMD_UTC	UTC TIME: YYYY-MM-DDTHH:MM:SS.SSSZ
6	SEQ_COUNT	ASCII_NonNegative_Integer	Sequence counter for this APID.
7	SID	ASCII_NonNegative_Integer	Structure ID. 0 = Reduced SW, 1 = Application SW
8	SECT	ASCII_NonNegative_Integer	Science mode: 4 = Event-by-event mode.
9	NUM_FRAG	ASCII_NonNegative_Integer	Fragment number is a counter that starts from 1
10	TOT_FRAG	ASCII_NonNegative_Integer	Total number of fragments (maximum 2). The value represents the total number of packets expected associated to the same measurement cycle.
11	COMPR	ASCII_NonNegative_Integer	Data compression: 0 = None; 1 = Compressed.
12	EVE_BYTES	ASCII_NonNegative_Integer	Total number of bytes of events, N tot (maximum is 1024 Bytes which corresponds to 512 events) Being the Maximum total number of bytes 1024 bytes then the maximum total length for one single fragment packets including the headers (primary header + secondary header + science) is 1060 Bytes.
13	SEC_MASK	ASCII_NonNegative_Integer	Sector mask is a 32-bit mask where each bit represents one anode: 1 = Enabled; 0 = Disabled
14	START_TIME	ASCII_NonNegative_Integer	Start measurement time (in seconds)
15	DATA_TYP	ASCII_NonNegative_Integer	Science data: 1 = Simulated; 0 = Sampled.
16	SHT	ASCII_NonNegative_Integer	Shutter enabled/disabled: 1 = Enabled; 0 = Disabled
17	SHT_FRQ	ASCII_NonNegative_Integer	Shutter frequency
18	AMPL	ASCII_NonNegative_Integer	Amplitude
19	TEMP	ASCII_NonNegative_Integer	Temperature
20-3085 (511 reps)	EVENT_OR_NO	ASCII_Integer	Word type: 0 = event, 1 = no event, -2 = not a valid word.
	OBT	ASCII_Integer	On-board time
	T_SINCE_INTRPT	ASCII_Integer	Elapsed time since last 25 ms interrupt
	T_AFTER_INI	ASCII_Integer	Time after initial time
	LAST_A_OVER_TSH	ASCII_Integer	Last anode found over S/W threshold out the 32 Elena anodes
	MULTIPL	ASCII_Integer	Multiplicity - events over threshold: 0 - no events, 1 - one event, 2 - two

			or three events, 3 - four or more events.
3086	DEAD_POS	ASCII_NonNegative_Integer	Position of the 0xDEAD word in the array of events.
3087	DEAD_WORD	ASCII_NonNegative_Integer	Value of the 0xDEAD word for consistency check.
3088	ACQ_COUNT	ASCII_NonNegative_Integer	Acquisition counter - provides the number of bytes of events (the double of the number of events) in the measurement cycle (max 2 packets * 511 events = 1022).
3089	SCI_MARK	ASCII_NonNegative_Integer	Constant value 0xCAFE
3090	PLANET_SUN_X	ASCII_Real	X coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
3091	PLANET_SUN_Y	ASCII_Real	Y coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
3092	PLANET_SUN_Z	ASCII_Real	Z coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
3093	PLANET_SUN_DIST	ASCII_Real	Distance Earth-Sun, Venus-Sun or Mercury-Sun. Equals to -1 during cruise.
3094	PLANET_TAA	ASCII_Real	True anomaly angle of Earth, Venus or Mercury on its orbit around the Sun. Equals to -1 during cruise.
3095	MPO_SUN_X	ASCII_Real	X coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
3096	MPO_SUN_Y	ASCII_Real	Y coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
3097	MPO_SUN_Z	ASCII_Real	Z coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
3098	MPO_SUN_DIST	ASCII_Real	MPO heliocentric distance.
3099	MPO_PLANET_X	ASCII_Real	X coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
3100	MPO_PLANET_Y	ASCII_Real	Y coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
3101	MPO_PLANET_Z	ASCII_Real	Z coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
3102	MPO_PLANET_VX	ASCII_Real	Velocity in the X direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
3103	MPO_PLANET_VY	ASCII_Real	Velocity in the Y direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
3104	MPO_PLANET_VZ	ASCII_Real	Velocity in the Z direction with respect to Earth, Venus or Mercury

			in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
3105	MPO_PLANET_DIST	ASCII_Real	Distance MPO-Earth, MPO-Venus or MPO-Mercury. Equals to -1 during cruise.
3106	ANGLE_MPO_PLANET_Z_PLUS	ASCII_Real	Angle between MPO-Planet vector and +Z of "MPO Spacecraft" (off-nadir pointing). Equals to -1 during cruise.
3107	SUB_MPO_LON	ASCII_Real	Longitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
3108	SUB_MPO_LAT	ASCII_Real	Latitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
3109	SUB_MPO_ALT	ASCII_Real	Altitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
3110	MPO_LOC_SOL_TIME	ASCII_Real	Local solar time of MPO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
3111	ANGLE_MPO_PLANET_SUN	ASCII_Real	Angle between MPO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
3112	MPO_POS_PSORF_X	ASCII_Real	X coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
3113	MPO_POS_PSORF_Y	ASCII_Real	Y coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
3114	MPO_POS_PSORF_Z	ASCII_Real	Z coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
3115	MPO_LON_PSORF	ASCII_Real	Longitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
3116	MPO_LAT_PSORF	ASCII_Real	Latitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
3117	MPO_POS_PSMRF_X	ASCII_Real	X coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3118	MPO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3119	MPO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3120	MPO_LON_PSMRF	ASCII_Real	Longitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3121	MPO_LAT_PSMRF	ASCII_Real	Latitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3122	MMO_PLANET_DIST	ASCII_Real	Distance MMO-Earth, MMO-Venus or MMO-Mercury. Equals to -1 during cruise.
3123	MMO_LOC_SOL_TIME	ASCII_Real	Local solar time of MMO's position at Earth, Venus or Mercury. Equals to -1 during cruise.

3124	ANGLE_MMO_PLANET_SUN	ASCII_Real	Angle between MMO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
3125	MMO_POS_PSMRF_X	ASCII_Real	X coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3126	MMO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3127	MMO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3128	MMO_LON_PSMRF	ASCII_Real	Longitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3129	MMO_LAT_PSMRF	ASCII_Real	Latitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
3130	MPO_MMO_DIST	ASCII_Real	MPO-MMO distance.
3131	ANGLE_MPO_PLANET_MMO	ASCII_Real	Angle between MPO-Planet and MMO-Planet vectors. Equals to -1 during cruise.

Table A-2 – *ELENA Raw science data products fields description, mode R*

Column #	Title	Data Type	description
1	PACKET_NUM	ASCII_NonNegative_Integer	Packet number as in the telemetry sequence (Not internal instrument sequence count)
2	VALIDITY	ASCII_NonNegative_Integer	Packet validity flag (0=perfect (valid), 1=packet length disparity, 2=wrong end word, 3=unsynchronized time)
3	SCET	ASCII_NonNegative_Integer	Spacecraft elapsed time in seconds
4	FRAC_SEC	ASCII_NonNegative_Integer	Spacecraft time - fractional ticks (in 1/65536 sec)
5	TIME_UTC	ASCII_Date_Time_YMD_UTC	UTC TIME: YYYY-MM-DDTHH:MM:SS.SSSZ
6	SEQ_COUNT	ASCII_NonNegative_Integer	Sequence counter for this APID.
7	SID	ASCII_NonNegative_Integer	Structure ID. 0 = Reduced SW, 1 = Application SW
8	SECT	ASCII_NonNegative_Integer	32 = 32 sectors. 4 = Extended Histogram type containing multiplicity information: CH1 = Total event without channels over S/W Thresholds CH2 = Total event with one channel over S/W Thresholds CH3 = Total event with two channels over S/W Thresholds CH4 = Total event with three or more channels over S/W Thresholds
9	ACCTM	ASCII_NonNegative_Integer	Accumulation Time
10	DATA_TYP	ASCII_NonNegative_Integer	Science data: 1 = Simulated; 0 = Sampled.

11	SHT	ASCII_NonNegative_Integer	Shutter enabled/disabled: 1 = Enabled; 0 = Disabled
12	SHT_FRQ	ASCII_NonNegative_Integer	Shutter frequency
13	HV1_CUR	ASCII_NonNegative_Integer	HV1 current
14	HV2_CUR	ASCII_NonNegative_Integer	HV2 current
15	MCP_CUR	ASCII_NonNegative_Integer	HV MCP current
16	MCP_TEMP	ASCII_NonNegative_Integer	MCP temperature
17	HIST_CH1	ASCII_NonNegative_Integer	Sector Histogram Channel 1
18	HIST_CH2	ASCII_NonNegative_Integer	Sector Histogram Channel 2
19	HIST_CH3	ASCII_NonNegative_Integer	Sector Histogram Channel 3
20	HIST_CH4	ASCII_NonNegative_Integer	Sector Histogram Channel 4
21	HIST_CH5	ASCII_NonNegative_Integer	Sector Histogram Channel 5
22	HIST_CH6	ASCII_NonNegative_Integer	Sector Histogram Channel 6
23	HIST_CH7	ASCII_NonNegative_Integer	Sector Histogram Channel 7
24	HIST_CH8	ASCII_NonNegative_Integer	Sector Histogram Channel 8
25	HIST_CH9	ASCII_NonNegative_Integer	Sector Histogram Channel 9
26	HIST_CH10	ASCII_NonNegative_Integer	Sector Histogram Channel 10
27	HIST_CH11	ASCII_NonNegative_Integer	Sector Histogram Channel 11
28	HIST_CH12	ASCII_NonNegative_Integer	Sector Histogram Channel 12
29	HIST_CH13	ASCII_NonNegative_Integer	Sector Histogram Channel 13
30	HIST_CH14	ASCII_NonNegative_Integer	Sector Histogram Channel 14
31	HIST_CH15	ASCII_NonNegative_Integer	Sector Histogram Channel 15
32	HIST_CH16	ASCII_NonNegative_Integer	Sector Histogram Channel 16
33	HIST_CH17	ASCII_NonNegative_Integer	Sector Histogram Channel 17
34	HIST_CH18	ASCII_NonNegative_Integer	Sector Histogram Channel 18
35	HIST_CH19	ASCII_NonNegative_Integer	Sector Histogram Channel 19
36	HIST_CH20	ASCII_NonNegative_Integer	Sector Histogram Channel 20
37	HIST_CH21	ASCII_NonNegative_Integer	Sector Histogram Channel 21
38	HIST_CH22	ASCII_NonNegative_Integer	Sector Histogram Channel 22
39	HIST_CH23	ASCII_NonNegative_Integer	Sector Histogram Channel 23
40	HIST_CH24	ASCII_NonNegative_Integer	Sector Histogram Channel 24
41	HIST_CH25	ASCII_NonNegative_Integer	Sector Histogram Channel 25
42	HIST_CH26	ASCII_NonNegative_Integer	Sector Histogram Channel 26
43	HIST_CH27	ASCII_NonNegative_Integer	Sector Histogram Channel 27
44	HIST_CH28	ASCII_NonNegative_Integer	Sector Histogram Channel 28
45	HIST_CH29	ASCII_NonNegative_Integer	Sector Histogram Channel 29
46	HIST_CH30	ASCII_NonNegative_Integer	Sector Histogram Channel 30
47	HIST_CH31	ASCII_NonNegative_Integer	Sector Histogram Channel 31
48	HIST_CH32	ASCII_NonNegative_Integer	Sector Histogram Channel 32
49	SCI_MARK	ASCII_NonNegative_Integer	Constant value 0xCAFE
50	PLANET_SUN_X	ASCII_Real	X coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
51	PLANET_SUN_Y	ASCII_Real	Y coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
52	PLANET_SUN_Z	ASCII_Real	Z coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.

53	PLANET_SUN_DIST	ASCII_Real	Distance Earth-Sun, Venus-Sun or Mercury-Sun. Equals to -1 during cruise.
54	PLANET_TAA	ASCII_Real	True anomaly angle of Earth, Venus or Mercury on its orbit around the Sun. Equals to -1 during cruise.
55	MPO_SUN_X	ASCII_Real	X coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
56	MPO_SUN_Y	ASCII_Real	Y coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
57	MPO_SUN_Z	ASCII_Real	Z coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
58	MPO_SUN_DIST	ASCII_Real	MPO heliocentric distance.
59	MPO_PLANET_X	ASCII_Real	X coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
60	MPO_PLANET_Y	ASCII_Real	Y coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
61	MPO_PLANET_Z	ASCII_Real	Z coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
62	MPO_PLANET_VX	ASCII_Real	Velocity in the X direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
63	MPO_PLANET_VY	ASCII_Real	Velocity in the Y direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
64	MPO_PLANET_VZ	ASCII_Real	Velocity in the Z direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
65	MPO_PLANET_DIST	ASCII_Real	Distance MPO-Earth, MPO-Venus or MPO-Mercury. Equals to -1 during cruise.
66	ANGLE_MPO_PLANET_Z_PLUS	ASCII_Real	Angle between MPO-Planet vector and +Z of "MPO Spacecraft" (off-nadir pointing). Equals to -1 during cruise.
67	SUB_MPO_LON	ASCII_Real	Longitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
68	SUB_MPO_LAT	ASCII_Real	Latitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
69	SUB_MPO_ALT	ASCII_Real	Altitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
70	MPO_LOC_SOL_TIME	ASCII_Real	Local solar time of MPO's position at Earth, Venus or Mercury. Equals to -1 during cruise.

71	ANGLE_MPO_PLANET_SUN	ASCII_Real	Angle between MPO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
72	MPO_POS_PSORF_X	ASCII_Real	X coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
73	MPO_POS_PSORF_Y	ASCII_Real	Y coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
74	MPO_POS_PSORF_Z	ASCII_Real	Z coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
75	MPO_LON_PSORF	ASCII_Real	Longitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
76	MPO_LAT_PSORF	ASCII_Real	Latitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
77	MPO_POS_PSMRF_X	ASCII_Real	X coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
78	MPO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
79	MPO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
80	MPO_LON_PSMRF	ASCII_Real	Longitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
81	MPO_LAT_PSMRF	ASCII_Real	Latitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
82	MMO_PLANET_DIST	ASCII_Real	Distance MMO-Earth, MMO-Venus or MMO-Mercury. Equals to -1 during cruise.
83	MMO_LOC_SOL_TIME	ASCII_Real	Local solar time of MMO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
84	ANGLE_MMO_PLANET_SUN	ASCII_Real	Angle between MMO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
85	MMO_POS_PSMRF_X	ASCII_Real	X coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
86	MMO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
87	MMO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
88	MMO_LON_PSMRF	ASCII_Real	Longitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
89	MMO_LAT_PSMRF	ASCII_Real	Latitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
90	MPO_MMO_DIST	ASCII_Real	MPO-MMO distance.

91	ANGLE_MPO_PLANET_MMO	ASCII_Real	Angle between MPO-Planet and MMO-Planet vectors. Equals to -1 during cruise.

Table A-3 – *ELENA Raw science data products fields description, mode S*

A.1.2 ELENA Partially Processed Data Products Fields Description

Column #	Title	Data Type	description
1	PACKET_NUM	ASCII_NonNegative_Integer	Packet number as in the telemetry sequence (Not internal instrument sequence count)
2	VALIDITY	ASCII_NonNegative_Integer	Packet validity flag (0=perfect (valid), 1=packet length disparity, 2=wrong end word, 3=unsynchronized time)
3	SCET	ASCII_NonNegative_Integer	Spacecraft elapsed time in seconds
4	FRAC_SEC	ASCII_NonNegative_Integer	Spacecraft time - fractional ticks (in 1/65536 sec)
5	TIME_UTC	ASCII_Date_Time_YMD_UTC	UTC TIME: YYYY-MM-DDTHH:MM:SS.SSSZ
6	SEQ_COUNT	ASCII_NonNegative_Integer	Sequence counter for this APID.
7	SID	ASCII_NonNegative_Integer	Structure ID. 0 = Reduced SW, 1 = Application SW
8	SECT	ASCII_NonNegative_Integer	32 = 32 sectors. 4 = Extended Histogram type containing multiplicity information: CH1 = Total event without channels over S/W Thresholds CH2 = Total event with one channel over S/W Thresholds CH3 = Total event with two channels over S/W Thresholds CH4 = Total event with three or more channels over S/W Thresholds
9	ACCTM	ASCII_NonNegative_Integer	Accumulation Time
10	DATA_TYP	ASCII_NonNegative_Integer	Science data: 1 = Simulated; 0 = Sampled.
11	SHT	ASCII_NonNegative_Integer	Shutter enabled/disabled: 1 = Enabled; 0 = Disabled
12	SHT_FRQ	ASCII_NonNegative_Integer	Shutter frequency
13	NUM_FRAG	ASCII_NonNegative_Integer	Fragment number (max 2 fragments)
14	TOT_FRAG	ASCII_NonNegative_Integer	Total number of fragments (max 2). The value represents the total number of packets expected associated to the same measurement cycle.
15	COMPR	ASCII_NonNegative_Integer	Data compression.
16	EVE_BYTES	ASCII_NonNegative_Integer	Total number of events for the acquisition. Minimum 40 - when packets contain only time events. Maximum 1024 - corresponds to 2 saturated packets

			with as minimum 1 time event in the first frame, plus 2 acquisition counters and a maximum of 1021 particle events contained in the 2 frame packets.
17	SEC_MASK	ASCII_NonNegative_Integer	Sector mask is a 32-bit mask where each bit represents one anode: 1 = Enabled, 0 = Disabled.
18	START_TIME	ASCII_NonNegative_Integer	Start measurement time: Elapsed time to configure and re-arm the measurement of new packet since first 25 ms interrupt. Read value can be from 0 to 255. Read value must be subtracted from 0xFF and multiplied by 62.5 us to know how much time is passed to configure and re-arm the measurement of new packet since first 25 ms synch tick.
19	AMPL	ASCII_NonNegative_Integer	Amplitude (Note: shutter is always disabled for FM and FS).
20	TEMP	ASCII_NonNegative_Integer	MCP temperature
21	NO_EVTS	ASCII_NonNegative_Integer	No event markers in the word sequence.
22	NUL_EVTS	ASCII_NonNegative_Integer	Null event markers in the word sequence.
23	HIST_CH1	ASCII_NonNegative_Integer	Sector Histogram Channel 1
24	HIST_CH2	ASCII_NonNegative_Integer	Sector Histogram Channel 2
25	HIST_CH3	ASCII_NonNegative_Integer	Sector Histogram Channel 3
26	HIST_CH4	ASCII_NonNegative_Integer	Sector Histogram Channel 4
27	HIST_CH5	ASCII_NonNegative_Integer	Sector Histogram Channel 5
28	HIST_CH6	ASCII_NonNegative_Integer	Sector Histogram Channel 6
29	HIST_CH7	ASCII_NonNegative_Integer	Sector Histogram Channel 7
30	HIST_CH8	ASCII_NonNegative_Integer	Sector Histogram Channel 8
31	HIST_CH9	ASCII_NonNegative_Integer	Sector Histogram Channel 9
32	HIST_CH10	ASCII_NonNegative_Integer	Sector Histogram Channel 10
33	HIST_CH11	ASCII_NonNegative_Integer	Sector Histogram Channel 11
34	HIST_CH12	ASCII_NonNegative_Integer	Sector Histogram Channel 12
35	HIST_CH13	ASCII_NonNegative_Integer	Sector Histogram Channel 13
36	HIST_CH14	ASCII_NonNegative_Integer	Sector Histogram Channel 14
37	HIST_CH15	ASCII_NonNegative_Integer	Sector Histogram Channel 15
38	HIST_CH16	ASCII_NonNegative_Integer	Sector Histogram Channel 16
39	HIST_CH17	ASCII_NonNegative_Integer	Sector Histogram Channel 17
40	HIST_CH18	ASCII_NonNegative_Integer	Sector Histogram Channel 18
41	HIST_CH19	ASCII_NonNegative_Integer	Sector Histogram Channel 19
42	HIST_CH20	ASCII_NonNegative_Integer	Sector Histogram Channel 20
43	HIST_CH21	ASCII_NonNegative_Integer	Sector Histogram Channel 21
44	HIST_CH22	ASCII_NonNegative_Integer	Sector Histogram Channel 22
45	HIST_CH23	ASCII_NonNegative_Integer	Sector Histogram Channel 23
46	HIST_CH24	ASCII_NonNegative_Integer	Sector Histogram Channel 24
47	HIST_CH25	ASCII_NonNegative_Integer	Sector Histogram Channel 25
48	HIST_CH26	ASCII_NonNegative_Integer	Sector Histogram Channel 26
49	HIST_CH27	ASCII_NonNegative_Integer	Sector Histogram Channel 27
50	HIST_CH28	ASCII_NonNegative_Integer	Sector Histogram Channel 28
51	HIST_CH29	ASCII_NonNegative_Integer	Sector Histogram Channel 29

52	HIST_CH30	ASCII_NonNegative_Integer	Sector Histogram Channel 30
53	HIST_CH31	ASCII_NonNegative_Integer	Sector Histogram Channel 31
54	HIST_CH32	ASCII_NonNegative_Integer	Sector Histogram Channel 32
55	SCI_MARK	ASCII_NonNegative_Integer	Constant value 0xCAFE
56	PLANET_SUN_X	ASCII_Real	X coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
57	PLANET_SUN_Y	ASCII_Real	Y coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
58	PLANET_SUN_Z	ASCII_Real	Z coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
59	PLANET_SUN_DIST	ASCII_Real	Distance Earth-Sun, Venus-Sun or Mercury-Sun. Equals to -1 during cruise.
60	PLANET_TAA	ASCII_Real	True anomaly angle of Earth, Venus or Mercury on its orbit around the Sun. Equals to -1 during cruise.
61	MPO_SUN_X	ASCII_Real	X coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
62	MPO_SUN_Y	ASCII_Real	Y coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
63	MPO_SUN_Z	ASCII_Real	Z coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
64	MPO_SUN_DIST	ASCII_Real	MPO heliocentric distance.
65	MPO_PLANET_X	ASCII_Real	X coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
66	MPO_PLANET_Y	ASCII_Real	Y coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
67	MPO_PLANET_Z	ASCII_Real	Z coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
68	MPO_PLANET_VX	ASCII_Real	Velocity in the X direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
69	MPO_PLANET_VY	ASCII_Real	Velocity in the Y direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
70	MPO_PLANET_VZ	ASCII_Real	Velocity in the Z direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
71	MPO_PLANET_DIST	ASCII_Real	Distance MPO-Earth, MPO-Venus or MPO-Mercury. Equals to -1 during cruise.
72	ANGLE_MPO_PLANET_Z_PLUS	ASCII_Real	Angle between MPO-Planet vector and +Z of "MPO Spacecraft" (off-

			nadir pointing). Equals to -1 during cruise.
73	SUB_MPO_LON	ASCII_Real	Longitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
74	SUB_MPO_LAT	ASCII_Real	Latitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
75	SUB_MPO_ALT	ASCII_Real	Altitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
76	MPO_LOC_SOL_TIME	ASCII_Real	Local solar time of MPO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
77	ANGLE_MPO_PLANET_SUN	ASCII_Real	Angle between MPO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
78	MPO_POS_PSORF_X	ASCII_Real	X coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
79	MPO_POS_PSORF_Y	ASCII_Real	Y coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
80	MPO_POS_PSORF_Z	ASCII_Real	Z coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
81	MPO_LON_PSORF	ASCII_Real	Longitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
82	MPO_LAT_PSORF	ASCII_Real	Latitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
83	MPO_POS_PSMRF_X	ASCII_Real	X coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
84	MPO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
85	MPO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
86	MPO_LON_PSMRF	ASCII_Real	Longitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
87	MPO_LAT_PSMRF	ASCII_Real	Latitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
88	MMO_PLANET_DIST	ASCII_Real	Distance MMO-Earth, MMO-Venus or MMO-Mercury. Equals to -1 during cruise.
89	MMO_LOC_SOL_TIME	ASCII_Real	Local solar time of MMO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
90	ANGLE_MMO_PLANET_SUN	ASCII_Real	Angle between MMO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
91	MMO_POS_PSMRF_X	ASCII_Real	X coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.

92	MMO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
93	MMO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
94	MMO_LON_PSMRF	ASCII_Real	Longitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
95	MMO_LAT_PSMRF	ASCII_Real	Latitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
96	MPO_MMO_DIST	ASCII_Real	MPO-MMO distance.
97	ANGLE_MPO_PLANET_MMO	ASCII_Real	Angle between MPO-Planet and MMO-Planet vectors. Equals to -1 during cruise.

Table A-4 – *ELENA Partially Processed science data products fields description, mode R*

A.1.3 ELENA Calibrated Data Products Fields Description

Column #	Title	Data Type	description
1	PACKET_NUM	ASCII_NonNegative_Integer	Packet number as in the telemetry sequence (Not internal instrument sequence count)
2	VALIDITY	ASCII_NonNegative_Integer	Packet validity flag (0=perfect (valid), 1=packet length disparity, 2=wrong end word, 3=unsynchronized time)
3	SCET	ASCII_NonNegative_Integer	Spacecraft elapsed time in seconds
4	FRAC_SEC	ASCII_NonNegative_Integer	Spacecraft time - fractional ticks (in 1/65536 sec)
5	TIME_UTC	ASCII_Date_Time_YMD_UTC	UTC TIME: YYYY-MM-DDTHH:MM:SS.SSSZ
6	SEQ_COUNT	ASCII_NonNegative_Integer	Sequence counter for this APID.
7	SID	ASCII_NonNegative_Integer	Structure ID. 0 = Reduced SW, 1 = Application SW
8	ACQ_TIME	ASCII_NonNegative_Integer	HK acquisition period res. 1 s range 1..100 sec
9	CUR_MODE	ASCII_NonNegative_Integer	Current Mode: 0 = Stand-by; 1 = Science.
10	PREV_MODE	ASCII_NonNegative_Integer	Previous Mode: 0 = Stand-by; 1 = Science.
11	COMPR	ASCII_NonNegative_Integer	Science data compression: 1 = Enabled; 0 = Disabled; Note. The Boot SW (mode 0) does not support this functionality.
12	SHUT_EN	ASCII_NonNegative_Integer	Shutter: 1 = Enabled; 0 = Disabled; Note. The Boot SW does not support this functionality.
13	MCP_EN	ASCII_NonNegative_Integer	MCP HV circuit: 1 = Enabled; 0 = Disabled; Note. The Boot SW does not support this functionality.
14	ANL_EN	ASCII_NonNegative_Integer	Analyzer circuits: 1 = Enabled; 0 = Disabled; Note. The Boot SW does not support this functionality.
15	TC_REJ	ASCII_NonNegative_Integer	Last TC rej cause. Last Error. Standard Failure ID: 0 = Illegal APID /None 1 = Incomplete or invalid length Packet (failed to receive whole packet within time out period) 2 = Incorrect checksum. 3 = Illegal packet type 4 = Illegal packet subtype

			7 = Command cannot be executed at this time (incorrect status of application to allow command execution).
16	ERR_CRT	ASCII_NonNegative_Integer	Err Last Crit. Last Critical Error in short coding format. 0 = None, 2 = Anomaly; 3 = Anomaly-ground; 4 = Anomaly-Onboard Action.
17	TC_CRT	ASCII_NonNegative_Integer	TC critical flag: 1 = Armed; 0 = None. Note. The Boot SW does not support this functionality.
18	EE_WR	ASCII_NonNegative_Integer	EEPROM Write Flag: 1 = Enabled; 0 = Disabled; Note. The Boot SW does not support this functionality.
19	ERR_CNT	ASCII_NonNegative_Integer	Error counter
20	TC_CNT	ASCII_NonNegative_Integer	Total received TC counter
21	LST_TC_TYP_ACC	ASCII_NonNegative_Integer	Last accepted TC type
22	LST_TC_STYP_ACC	ASCII_NonNegative_Integer	Last accepted TC sub-type
23	LST_TC_TYP_EXE	ASCII_NonNegative_Integer	Last executed TC type
24	LST_TC_STYP_EXE	ASCII_NonNegative_Integer	Last executed TC sub-type
25	LST_TC_TYP_REJ	ASCII_NonNegative_Integer	Last rejected TC type
26	LST_TC_STYP_REJ	ASCII_NonNegative_Integer	Last rejected TC sub-type
27	LST_TC_TYP_FEX	ASCII_NonNegative_Integer	Last execution failed TC type
28	LST_TC_STYP_FEX	ASCII_NonNegative_Integer	Last execution failed TC sub-type
29	PRM_SW_VER	ASCII_NonNegative_Integer	PROM S/W Version
30	EEPRM_SW_VER	ASCII_NonNegative_Integer	EEPROM S/W Version
31	PRM_CKS	ASCII_NonNegative_Integer	PROM S/W Checksum
32	EEP_CKS	ASCII_NonNegative_Integer	EEPROM S/W Checksum
33	RAM_FAI_HI	ASCII_NonNegative_Integer	RAM boot fail check first HI address
34	RAM_FAI_LOW	ASCII_NonNegative_Integer	RAM boot fail check first LOW address
35	RAM_NUM_FAI	ASCII_NonNegative_Integer	RAM boot fail check number of wrong locations
36	P3_3V	ASCII_Real	+3.3 V
37	P5V	ASCII_Real	+5 V
38	N5V	ASCII_Real	-5 V
39	P2V	ASCII_Real	+2 V
40	N2V	ASCII_Real	-2 V
41	FPGA_TEMP	ASCII_Real	Main FPGA temperature
42	MPA_VCC	ASCII_Real	MIPA Vcc
43	MCP_TEMP	ASCII_Real	MCP temperature
44	HV_NEG_EN	ASCII_NonNegative_Integer	HV Negative analyzer circuit: 1 = enabled, 0 = disabled. Note: The Boot SW does not support this functionality.
45	HV_POS_EN	ASCII_NonNegative_Integer	HV Positive analyzer circuit: 1 = enabled, 0 = disabled. Note: The Boot SW does not support this functionality.
46	HW_ASIC_THRS	ASCII_NonNegative_Integer	HW Asic Threshold. Note: The Boot SW does not support this functionality.
47	SHT_RMS	ASCII_NonNegative_Integer	Shutter RMS
48	N12V	ASCII_Real	-12V
49	P12V	ASCII_Real	+12V
50	PCOL_V	ASCII_Real	Positive collimator HV bias

51	NCOL_V	ASCII_Real	Negative collimator HV bias
52	MCP_HV	ASCII_Real	MCP HV
53	PCOL_CUR	ASCII_Real	Positive collimator HV current
54	NCOL_CUR	ASCII_Real	Negative collimator HV current
55	MCP_CUR	ASCII_Real	MCP HV current
56	SHT_TEMP	ASCII_Real	Shutter temperature
57	DAC_TEMP	ASCII_Real	DAC temperature
58	END_MARK	ASCII_NonNegative_Integer	Fixed value to 0xCAFE Note: This field is present only in the application SW HK with SID 1, in the reduced SW this field is not present.

***Table A-5** – ELENA Calibrated housekeeping data products fields description*

Column #	Title	Data Type	description
1	PACKET_NUM	ASCII_NonNegative_Integer	Packet number as in the telemetry sequence (Not internal instrument sequence count)
2	VALIDITY	ASCII_NonNegative_Integer	Packet validity flag (0=perfect (valid), 1=packet length disparity, 2=wrong end word, 3=unsynchronized time)
3	SCET	ASCII_NonNegative_Integer	Spacecraft elapsed time in seconds
4	FRAC_SEC	ASCII_NonNegative_Integer	Spacecraft time - fractional ticks (in 1/65536 sec)
5	TIME_UTC	ASCII_Date_Time_YMD_UTC	UTC TIME: YYYY-MM-DDTHH:MM:SS.SSSZ
6	SEQ_COUNT	ASCII_NonNegative_Integer	Sequence counter for this APID.
7	SID	ASCII_NonNegative_Integer	Structure ID. 0 = Reduced SW, 1 = Application SW
8	SECT	ASCII_NonNegative_Integer	32 = 32 sectors. 4 = Extended Histogram type containing multiplicity information: CH1 = Total event without channels over S/W Thresholds CH2 = Total event with one channel over S/W Thresholds CH3 = Total event with two channels over S/W Thresholds CH4 = Total event with three or more channels over S/W Thresholds
9	ACCTM	ASCII_NonNegative_Integer	Accumulation Time
10	DATA_TYP	ASCII_NonNegative_Integer	Science data: 1 = Simulated; 0 = Sampled.
11	SHT	ASCII_NonNegative_Integer	Shutter enabled/disabled: 1 = Enabled; 0 = Disabled
12	SHT_FRQ	ASCII_NonNegative_Integer	Shutter frequency
13	NUM_FRAG	ASCII_NonNegative_Integer	Fragment number (max 2 fragments)
14	TOT_FRAG	ASCII_NonNegative_Integer	Total number of fragments (max 2). The value represents the total number of packets expected associated to the same measurement cycle.
15	COMPR	ASCII_NonNegative_Integer	Data compression.

16	EVE_BYTES	ASCII_NonNegative_Integer	Total number of events for the acquisition. Minimum 40 - when packets contain only time events. Maximum 1024 - corresponds to 2 saturated packets with as minimum 1 time event in the first frame, plus 2 acquisition counters and a maximum of 1021 particle events contained in the 2 frame packets.
17	SEC_MASK	ASCII_NonNegative_Integer	Sector mask is a 32-bit mask where each bit represents one anode: 1 = Enabled, 0 = Disabled.
18	START_TIME	ASCII_Real	Start measurement time: Elapsed time to configure and re-arm the measurement of new packet since first 25 ms interrupt. Read value can be from 0 to 255. Read value must be subtracted from 0xFF and multiplied by 62.5 us to know how much time is passed to configure and re-arm the measurement of new packet since first 25 ms synch tick.
19	AMPL	ASCII_NonNegative_Integer	Amplitude (Note: shutter is always disabled for FM and FS).
20	TEMP	ASCII_Real	MCP temperature
21	NO_EVTS	ASCII_NonNegative_Integer	No event markers in the word sequence.
22	NUL_EVTS	ASCII_NonNegative_Integer	Null event markers in the word sequence.
23	HIST_CH1	ASCII_Real	Sector Histogram Channel 1
24	HIST_CH2	ASCII_Real	Sector Histogram Channel 2
25	HIST_CH3	ASCII_Real	Sector Histogram Channel 3
26	HIST_CH4	ASCII_Real	Sector Histogram Channel 4
27	HIST_CH5	ASCII_Real	Sector Histogram Channel 5
28	HIST_CH6	ASCII_Real	Sector Histogram Channel 6
29	HIST_CH7	ASCII_Real	Sector Histogram Channel 7
30	HIST_CH8	ASCII_Real	Sector Histogram Channel 8
31	HIST_CH9	ASCII_Real	Sector Histogram Channel 9
32	HIST_CH10	ASCII_Real	Sector Histogram Channel 10
33	HIST_CH11	ASCII_Real	Sector Histogram Channel 11
34	HIST_CH12	ASCII_Real	Sector Histogram Channel 12
35	HIST_CH13	ASCII_Real	Sector Histogram Channel 13
36	HIST_CH14	ASCII_Real	Sector Histogram Channel 14
37	HIST_CH15	ASCII_Real	Sector Histogram Channel 15
38	HIST_CH16	ASCII_Real	Sector Histogram Channel 16
39	HIST_CH17	ASCII_Real	Sector Histogram Channel 17
40	HIST_CH18	ASCII_Real	Sector Histogram Channel 18
41	HIST_CH19	ASCII_Real	Sector Histogram Channel 19
42	HIST_CH20	ASCII_Real	Sector Histogram Channel 20
43	HIST_CH21	ASCII_Real	Sector Histogram Channel 21
44	HIST_CH22	ASCII_Real	Sector Histogram Channel 22
45	HIST_CH23	ASCII_Real	Sector Histogram Channel 23
46	HIST_CH24	ASCII_Real	Sector Histogram Channel 24

47	HIST_CH25	ASCII_Real	Sector Histogram Channel 25
48	HIST_CH26	ASCII_Real	Sector Histogram Channel 26
49	HIST_CH27	ASCII_Real	Sector Histogram Channel 27
50	HIST_CH28	ASCII_Real	Sector Histogram Channel 28
51	HIST_CH29	ASCII_Real	Sector Histogram Channel 29
52	HIST_CH30	ASCII_Real	Sector Histogram Channel 30
53	HIST_CH31	ASCII_Real	Sector Histogram Channel 31
54	HIST_CH32	ASCII_Real	Sector Histogram Channel 32
55	SCI_MARK	ASCII_NonNegative_Integer	Constant value 0xCAFE
56	PLANET_SUN_X	ASCII_Real	X coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
57	PLANET_SUN_Y	ASCII_Real	Y coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
58	PLANET_SUN_Z	ASCII_Real	Z coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
59	PLANET_SUN_DIST	ASCII_Real	Distance Earth-Sun, Venus-Sun or Mercury-Sun. Equals to -1 during cruise.
60	PLANET_TAA	ASCII_Real	True anomaly angle of Earth, Venus or Mercury on its orbit around the Sun. Equals to -1 during cruise.
61	MPO_SUN_X	ASCII_Real	X coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
62	MPO_SUN_Y	ASCII_Real	Y coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
63	MPO_SUN_Z	ASCII_Real	Z coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
64	MPO_SUN_DIST	ASCII_Real	MPO heliocentric distance.
65	MPO_PLANET_X	ASCII_Real	X coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
66	MPO_PLANET_Y	ASCII_Real	Y coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
67	MPO_PLANET_Z	ASCII_Real	Z coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
68	MPO_PLANET_VX	ASCII_Real	Velocity in the X direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
69	MPO_PLANET_VY	ASCII_Real	Velocity in the Y direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
70	MPO_PLANET_VZ	ASCII_Real	Velocity in the Z direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.

71	MPO_PLANET_DIST	ASCII_Real	Distance MPO-Earth, MPO-Venus or MPO-Mercury. Equals to -1 during cruise.
72	ANGLE_MPO_PLANET_Z_PLUS	ASCII_Real	Angle between MPO-Planet vector and +Z of "MPO Spacecraft" (off-nadir pointing). Equals to -1 during cruise.
73	SUB_MPO_LON	ASCII_Real	Longitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
74	SUB_MPO_LAT	ASCII_Real	Latitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
75	SUB_MPO_ALT	ASCII_Real	Altitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
76	MPO_LOC_SOL_TIME	ASCII_Real	Local solar time of MPO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
77	ANGLE_MPO_PLANET_SUN	ASCII_Real	Angle between MPO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
78	MPO_POS_PSORF_X	ASCII_Real	X coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
79	MPO_POS_PSORF_Y	ASCII_Real	Y coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
80	MPO_POS_PSORF_Z	ASCII_Real	Z coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
81	MPO_LON_PSORF	ASCII_Real	Longitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
82	MPO_LAT_PSORF	ASCII_Real	Latitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
83	MPO_POS_PSMRF_X	ASCII_Real	X coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
84	MPO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
85	MPO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
86	MPO_LON_PSMRF	ASCII_Real	Longitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
87	MPO_LAT_PSMRF	ASCII_Real	Latitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
88	MMO_PLANET_DIST	ASCII_Real	Distance MMO-Earth, MMO-Venus or MMO-Mercury. Equals to -1 during cruise.
89	MMO_LOC_SOL_TIME	ASCII_Real	Local solar time of MMO's position at Earth, Venus or Mercury. Equals to -1 during cruise.

90	ANGLE_MMO_PLANET_SUN	ASCII_Real	Angle between MMO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
91	MMO_POS_PSMRF_X	ASCII_Real	X coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
92	MMO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
93	MMO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
94	MMO_LON_PSMRF	ASCII_Real	Longitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
95	MMO_LAT_PSMRF	ASCII_Real	Latitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
96	MPO_MMO_DIST	ASCII_Real	MPO-MMO distance.
97	ANGLE_MPO_PLANET_MMO	ASCII_Real	Angle between MPO-Planet and MMO-Planet vectors. Equals to -1 during cruise.

Table A-6 – *ELENA Calibrated science data products fields description, mode R*

Column #	Title	Data Type	description
1	PACKET_NUM	ASCII_NonNegative_Integer	Packet number as in the telemetry sequence (Not internal instrument sequence count)
2	VALIDITY	ASCII_NonNegative_Integer	Packet validity flag (0=perfect (valid), 1=packet length disparity, 2=wrong end word, 3=unsynchronized time)
3	SCET	ASCII_NonNegative_Integer	Spacecraft elapsed time in seconds
4	FRAC_SEC	ASCII_NonNegative_Integer	Spacecraft time - fractional ticks (in 1/65536 sec)
5	TIME_UTC	ASCII_Date_Time_YMD_UTC	UTC TIME: YYYY-MM-DDTHH:MM:SS.SSSZ
6	SEQ_COUNT	ASCII_NonNegative_Integer	Sequence counter for this APID.
7	SID	ASCII_NonNegative_Integer	Structure ID. 0 = Reduced SW, 1 = Application SW
8	SECT	ASCII_NonNegative_Integer	32 = 32 sectors. 4 = Extended Histogram type containing multiplicity information: CH1 = Total event without channels over S/W Thresholds CH2 = Total event with one channel over S/W Thresholds CH3 = Total event with two channels over S/W Thresholds CH4 = Total event with three or more channels over S/W Thresholds
9	ACCTM	ASCII_NonNegative_Integer	Accumulation Time
10	DATA_TYP	ASCII_NonNegative_Integer	Science data: 1 = Simulated; 0 = Sampled.

11	SHT	ASCII_NonNegative_Integer	Shutter enabled/disabled: 1 = Enabled; 0 = Disabled
12	SHT_FRQ	ASCII_NonNegative_Integer	Shutter frequency
13	HV1_CUR	ASCII_Real	HV1 current
14	HV2_CUR	ASCII_Real	HV2 current
15	MCP_CUR	ASCII_Real	HV MCP current
16	MCP_TEMP	ASCII_Real	MCP temperature
17	HIST_CH1	ASCII_Real	Sector Histogram Channel 1
18	HIST_CH2	ASCII_Real	Sector Histogram Channel 2
19	HIST_CH3	ASCII_Real	Sector Histogram Channel 3
20	HIST_CH4	ASCII_Real	Sector Histogram Channel 4
21	HIST_CH5	ASCII_Real	Sector Histogram Channel 5
22	HIST_CH6	ASCII_Real	Sector Histogram Channel 6
23	HIST_CH7	ASCII_Real	Sector Histogram Channel 7
24	HIST_CH8	ASCII_Real	Sector Histogram Channel 8
25	HIST_CH9	ASCII_Real	Sector Histogram Channel 9
26	HIST_CH10	ASCII_Real	Sector Histogram Channel 10
27	HIST_CH11	ASCII_Real	Sector Histogram Channel 11
28	HIST_CH12	ASCII_Real	Sector Histogram Channel 12
29	HIST_CH13	ASCII_Real	Sector Histogram Channel 13
30	HIST_CH14	ASCII_Real	Sector Histogram Channel 14
31	HIST_CH15	ASCII_Real	Sector Histogram Channel 15
32	HIST_CH16	ASCII_Real	Sector Histogram Channel 16
33	HIST_CH17	ASCII_Real	Sector Histogram Channel 17
34	HIST_CH18	ASCII_Real	Sector Histogram Channel 18
35	HIST_CH19	ASCII_Real	Sector Histogram Channel 19
36	HIST_CH20	ASCII_Real	Sector Histogram Channel 20
37	HIST_CH21	ASCII_Real	Sector Histogram Channel 21
38	HIST_CH22	ASCII_Real	Sector Histogram Channel 22
39	HIST_CH23	ASCII_Real	Sector Histogram Channel 23
40	HIST_CH24	ASCII_Real	Sector Histogram Channel 24
41	HIST_CH25	ASCII_Real	Sector Histogram Channel 25
42	HIST_CH26	ASCII_Real	Sector Histogram Channel 26
43	HIST_CH27	ASCII_Real	Sector Histogram Channel 27
44	HIST_CH28	ASCII_Real	Sector Histogram Channel 28
45	HIST_CH29	ASCII_Real	Sector Histogram Channel 29
46	HIST_CH30	ASCII_Real	Sector Histogram Channel 30
47	HIST_CH31	ASCII_Real	Sector Histogram Channel 31
48	HIST_CH32	ASCII_Real	Sector Histogram Channel 32
49	SCI_MARK	ASCII_NonNegative_Integer	Constant value 0xCAFE
50	PLANET_SUN_X	ASCII_Real	X coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
51	PLANET_SUN_Y	ASCII_Real	Y coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
52	PLANET_SUN_Z	ASCII_Real	Z coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.

53	PLANET_SUN_DIST	ASCII_Real	Distance Earth-Sun, Venus-Sun or Mercury-Sun. Equals to -1 during cruise.
54	PLANET_TAA	ASCII_Real	True anomaly angle of Earth, Venus or Mercury on its orbit around the Sun. Equals to -1 during cruise.
55	MPO_SUN_X	ASCII_Real	X coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
56	MPO_SUN_Y	ASCII_Real	Y coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
57	MPO_SUN_Z	ASCII_Real	Z coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
58	MPO_SUN_DIST	ASCII_Real	MPO heliocentric distance.
59	MPO_PLANET_X	ASCII_Real	X coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
60	MPO_PLANET_Y	ASCII_Real	Y coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
61	MPO_PLANET_Z	ASCII_Real	Z coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
62	MPO_PLANET_VX	ASCII_Real	Velocity in the X direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
63	MPO_PLANET_VY	ASCII_Real	Velocity in the Y direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
64	MPO_PLANET_VZ	ASCII_Real	Velocity in the Z direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
65	MPO_PLANET_DIST	ASCII_Real	Distance MPO-Earth, MPO-Venus or MPO-Mercury. Equals to -1 during cruise.
66	ANGLE_MPO_PLANET_Z_PLUS	ASCII_Real	Angle between MPO-Planet vector and +Z of "MPO Spacecraft" (off-nadir pointing). Equals to -1 during cruise.
67	SUB_MPO_LON	ASCII_Real	Longitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
68	SUB_MPO_LAT	ASCII_Real	Latitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
69	SUB_MPO_ALT	ASCII_Real	Altitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
70	MPO_LOC_SOL_TIME	ASCII_Real	Local solar time of MPO's position at Earth, Venus or Mercury. Equals to -1 during cruise.

71	ANGLE_MPO_PLANET_SUN	ASCII_Real	Angle between MPO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
72	MPO_POS_PSORF_X	ASCII_Real	X coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
73	MPO_POS_PSORF_Y	ASCII_Real	Y coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
74	MPO_POS_PSORF_Z	ASCII_Real	Z coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
75	MPO_LON_PSORF	ASCII_Real	Longitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
76	MPO_LAT_PSORF	ASCII_Real	Latitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
77	MPO_POS_PSMRF_X	ASCII_Real	X coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
78	MPO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
79	MPO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
80	MPO_LON_PSMRF	ASCII_Real	Longitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
81	MPO_LAT_PSMRF	ASCII_Real	Latitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
82	MMO_PLANET_DIST	ASCII_Real	Distance MMO-Earth, MMO-Venus or MMO-Mercury. Equals to -1 during cruise.
83	MMO_LOC_SOL_TIME	ASCII_Real	Local solar time of MMO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
84	ANGLE_MMO_PLANET_SUN	ASCII_Real	Angle between MMO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
85	MMO_POS_PSMRF_X	ASCII_Real	X coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
86	MMO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
87	MMO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
88	MMO_LON_PSMRF	ASCII_Real	Longitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
89	MMO_LAT_PSMRF	ASCII_Real	Latitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
90	MPO_MMO_DIST	ASCII_Real	MPO-MMO distance.

91	ANGLE_MPO_PLANET_MMO	ASCII_Real	Angle between MPO-Planet and MMO-Planet vectors. Equals to -1 during cruise.

Table A-7 *– ELENA Calibrated science data products fields description, mode S*

A.1.4 ELENA Derived Data Products Fields Description

TBD. ***Table A-8*** *– ELENA Derived science data fields description*

A.2 STROFIO Data Products Fields Description

A.2.1 STROFIO Raw Data Products Fields Description

Column #	Title	Data Type	Description
1	UTC_TIME	Short	Measurement time in UTC
2	SCLK	Long	Measurement time in spacecraft clock
3	MCP_HV_TRIP	Short	MCP HV over-current detect
4	MCP_HV_SHUTDOWN	Short	Status of automatic MCP HV over-current shutdown
5	HV_FULL_SCALE_ENB	Short	HV full scale enable (from safing plug)
6	HV_ALL_ENB	Short	HV all enable (from safing plug)
7	MCP_HV_CURR_MON_ENB	Short	MCP HV current monitor enable
8	RTM_SYNC_SOURCE	Short	RTM synchronization source
9	HV_ENB	Short	HV enable
10	RTM_ENB	Short	RTM enable
11	EIS_BIAS_HIGH_ENB	Short	EIS bias high enable
12	EIS_CURRENT_HIGH_ENB	Short	EIS current high enable
13	EIS_BIAS_POWER_ENB	Short	EIS bias power enable
14	EIS_HEATER_POWER_ENB	Short	EIS heater power enable
15	EIS_CATHODE_1A_ENB	Short	EIS cathode 1A enable
16	EIS_CATHODE_1B_ENB	Short	EIS cathode 1B enable
17	EIS_CATHODE_2A_ENB	Short	EIS cathode 2A enable
18	EIS_CATHODE_2B_ENB	Short	EIS cathode 2B enable
19	FIFO_ALL	Short	All events into FIFO enable
20	TIME_TOF_DIVIDER	Short	Time TOF chip clock divider
21	POS_TAP	Short	Position TOF chip tap select
22	TIME_TAP	Short	Time TOF chip tap select
23	CFD_LEFT_START_VDD	Short	CFD left start Vdd
24	CFD_LEFT_STOP_VDD	Short	CFD left stop Vdd
25	CFD_RIGHT_START_VDD	Short	CFD right start Vdd
26	CFD_RIGHT_STOP_VDD	Short	CFD right stop Vdd
27	CFD_LEFT_START_THRESH	Short	CFD left start threshold
28	CFD_LEFT_STOP_THRESH	Short	CFD left stop threshold
29	CFD_RIGHT_START_THRESH	Short	CFD right start threshold
30	CFD_RIGHT_STOP_THRESH	Short	CFD right stop threshold
31	EIS_HEATER_VOLTAGE_1	Short	EIS heater voltage 1 (coarse)
32	EIS_BIAS_VOLTAGE	Short	EIS bias voltage
33	EIS_HEATER_VOLTAGE_2	Short	EIS heater voltage 2 (fine)

34	MCP_HV_CURR_LIMIT	Short	MCP HV current monitor limit
35	RTM_PH0_LEVEL	Short	RTM phase 0 voltage level
36	RTM_PH60_LEVEL	Short	RTM phase 60 voltage level
37	RTM_PH120_LEVEL	Short	RTM phase 120 voltage level
38	HV_POS_15V_LEVEL	Short	HV +15V voltage level
39	HV_POS_600V_A_LEVEL	Short	HV +600V A voltage level
40	HV_POS_600V_B_LEVEL	Short	HV +600V B voltage level
41	HV_NEG_80V_A_LEVEL	Short	HV -80V A voltage level
42	HV_NEG_80V_B_LEVEL	Short	HV -80V B voltage level
43	HV_NEG_125V_LEVEL	Short	HV -125V voltage level
44	HV_NEG_1KV_B_LEVEL	Short	HV -1kV B voltage level
45	HV_NEG_2_9KV_MCP_LEVEL	Short	HV -2.9kV MCP voltage level
46	HV_NEG_50V_TO_POS_50V_A_LEVEL	Short	HV -50V to +50V A voltage level
47	HV_NEG_50V_TO_POS_50V_B_LEVEL	Short	HV -50V to +50V B voltage level
48	HV_NEG_200V_TO_POS_200V_A_LEVEL	Short	HV -200V to +200V A voltage level
49	HV_NEG_200V_TO_POS_200V_B_LEVEL	Short	HV -200V to +200V B voltage level
50	HV_NEG_1KV_TO_POS_400V_A_LEVEL	Short	HV -1kV to +400V A voltage level
51	HV_NEG_1KV_TO_POS_400V_B_LEVEL	Short	HV -1kV to +400V B voltage level
52	HV_POS_20V_A_LEVEL	Int	HV +20V A voltage level
53	HV_POS_20V_B_LEVEL	Int	HV +20V B voltage level
54	HV_NEG_350V_A_LEVEL	Int	HV -350V A voltage level
55	HV_NEG_350V_B_LEVEL	Int	HV -350V B voltage level
56	HV_NEG_1_5KV_LEVEL	Int	HV -1.5kV voltage level
57	HV_NEG_800V_B_LEVEL	Int	HV -800V B voltage level
58	HV_NEG_2_9KV_LEVEL	Int	HV -2.9kV voltage level
59	HV_NEG_1KV_A_LEVEL	Int	HV -1kV A voltage level
60	HV_NEG_900V_LEVEL	Int	HV -900V voltage level
61	LEFT_ANODE_ENB	Short	Pulsar configuration
62	RIGHT_ANODE_ENB	Short	Pulsar configuration
63	LEFT_START_CFD_ENB	Short	Pulsar configuration
64	LEFT_STOP_CFD_ENB	Short	Pulsar configuration
65	RIGHT_START_CFD_ENB	Short	Pulsar configuration
66	RIGHT_STOP_CFD_ENB	Short	Pulsar configuration
67	START_TO_SYNC_DELAY	Short	Pulsar configuration
68	START_TO_STOP_DELAY	Short	Pulsar configuration
69	RTM_PHASE_0_TO_60	Int	Measurement of RTM phase 0 to phase 60 (25/256 ns)
70	RTM_PHASE_0_TO_120	Int	Measurement of RTM phase 0 to phase 120 (25/256 ns)
71	LVPS_0	Int	+1.5V Monitor
72	LVPS_1	Int	+3.3V Monitor
73	LVPS_2	Int	+5V Monitor
74	LVPS_3	Int	+12V Monitor
75	LVPS_4	Int	-12V Monitor
76	LVPS_5	Int	+12V I Monitor

77	LVPS_6	Int	+5V I Monitor
78	LVPS_7	Int	+3.3V I Monitor
79	LVPS_8	Int	+1.5V I Monitor
80	LVPS_9	Int	-12V I Monitor
81	LVPS_10	Int	Primary I Monitor
82	LVPS_11	Int	Heater I Monitor
83	LVPS_12	Int	Heater V Monitor
84	LVPS_13	Int	Bias I Monitor
85	LVPS_14	Int	Bias V Monitor
86	LVPS_15	Int	LVPS Temp Monitor
87	RTM_0	Int	RTM Phase 0 Voltage Monitor
88	RTM_1	Int	RTM Phase 60 Voltage Monitor
89	RTM_2	Int	RTM Phase 120 Voltage Monitor
90	RTM_3	Int	RTM Phase 0 AGC Monitor
91	RTM_4	Int	RTM Phase 60 AGC Monitor
92	RTM_5	Int	RTM Phase 120 AGC Monitor
93	RTM_6	Int	RTM +3.3V Monitor
94	RTM_7	Int	Spare
95	RTM_8	Int	RTM +12V Monitor
96	RTM_9	Int	RTM +5V Monitor
97	RTM_10	Int	Spare
98	RTM_11	Int	Spare
99	RTM_12	Int	Spare
100	RTM_13	Int	EIS Temp 1 Monitor
101	RTM_14	Int	EIS Temp 2 Monitor
102	RTM_15	Int	RTM Temp Monitor
103	HV1_0	Int	HV +3.3V Monitor
104	HV1_1	Int	HV -2.9kV MCP Monitor
105	HV1_2	Int	HV -2.9kV MCP I Monitor
106	HV1_3	Int	HV -2.9kV Out Monitor
107	HV1_4	Int	HV -1.5kV Monitor
108	HV1_5	Int	HV -125V Monitor
109	HV1_6	Int	HV -1kV A Monitor
110	HV1_7	Int	HV -1kV B Monitor
111	HV1_8	Int	HV -900V Monitor
112	HV1_9	Int	HV -800V B Monitor
113	HV1_10	Int	HV -350V A Monitor
114	HV1_11	Int	HV -350V B Monitor
115	HV1_12	Int	Spare
116	HV1_13	Int	Spare
117	HV1_14	Int	Spare
118	HV1_15	Int	HV Board 1 Temp Monitor
119	HV2_0	Int	HV -1kV to +400V A Monitor
120	HV2_1	Int	HV -1kV to +400V B Monitor
121	HV2_2	Int	HV -200V to +200V A Monitor
122	HV2_3	Int	HV -200V to +200V B Monitor
123	HV2_4	Int	HV -50V to +50V A Monitor
124	HV2_5	Int	HV -50V to +50V B Monitor
125	HV2_6	Int	HV +600V A Monitor

126	HV2_7	Int	HV +600V B Monitor
127	HV2_8	Int	HV -80V A Monitor
128	HV2_9	Int	HV -80V B Monitor
129	HV2_10	Int	HV +20V A Monitor
130	HV2_11	Int	HV +20V B Monitor
131	HV2_12	Int	HV +15V Monitor
132	HV2_13	Int	HV +15V I Monitor
133	HV2_14	Int	Spare
134	HV2_15	Int	HV Board 2 Temp Monitor
135	STATUS_INTERVAL	Int	Status interval (seconds)
136	MACRO_BLOCKS	Int	Number of macro blocks free
137	TELEMETRY_VOLUME	Int	Telemetry volume produced (KB)
138	WATCH_ADDRESS	Int	Memory watch address
139	WATCH_MEMORY	Short	Memory watch id (page no.)
140	WATCH_DATA	Int	Watched memory
141	SOFTWARE_VERSION	Short	Software version number
142	ALARM_ID	Short	Latest alarm Id
143	ALARM_TYPE	Short	Latest alarm type
144	ALARM_COUNT	Short	Count of alarms
145	CMD_EXEC	Short	Commands executed
146	CMD_REJECT	Short	Commands rejected
147	MACRO_EXEC	Short	Macro commands executed
148	MACRO_REJECT	Short	Macro commands rejected
149	MACRO_ID	Short	Id of most recent macro executed
150	MACRO_LEARN	Short	Macro learn mode
151	MONITOR_RESPONSE	Short	Monitor response
152	WRITE_ENB	Short	Memory write enable
153	ECHO_ENB	Short	Command echo enable
154	DIAGNOSTIC_TABLE_ENB	Short	Diagnostic data processing table enable
155	RAW_EVENT_FILTER	Short	Filter used for selecting events for raw data
156	TABLES	Short	Data processing lookup tables
157	SAFING_TIME	Int	Time-out interval (seconds)
158	INTEGRATION_MULT_N2	Short	Integration multiplier, N2
159	REBINNED_LOW_QUAL_TOF_SPECT	Short	Rebinned low-quality TOF spectrum
160	LOW_QUAL_TOF_SPECT	Short	Low-quality TOF spectrum
161	REBINNED_HIGH_QUAL_TOF_SPEC T	Short	Rebinned high-quality TOF spectrum
162	HIGH_QUAL_TOF_SPECT	Short	High-quality TOF spectrum
163	BASIC_RATES	Short	Basic rates enable
164	RAW_EVENTS	Short	Number of raw events to collect
165	INTEGRATION_TIME	Short	Fast integration time T (seconds)
166	INTEGRATION_TIME_N1	Short	Integration multiplier, N1
167	RTM_PH0_LIMIT	Short	RTM phase 0 voltage limit
168	RTM_PH60_LIMIT	Short	RTM phase 60 voltage limit
169	RTM_PH120_LIMIT	Short	RTM phase 120 voltage limit
170	HV_POS_15V_LIMIT	Short	HV +15V voltage limit
171	HV_POS_600V_A_LIMIT	Short	HV +600V A voltage limit
172	HV_POS_600V_B_LIMIT	Short	HV +600V B voltage limit
173	HV_NEG_80V_A_LIMIT	Short	HV -80V A voltage limit

174	HV_NEG_80V_B_LIMIT	Short	HV -80V B voltage limit
175	HV_NEG_125V_LIMIT	Short	HV -125V voltage limit
176	HV_NEG_1KV_B_LIMIT	Short	HV -1kV B voltage limit
177	HV_NEG_2_9KV_MCP_LIMIT	Short	HV -2.9kV MCP voltage limit
178	HV_NEG_50V_TO_POS_50V_A_LIMIT	Short	HV -50V to +50V A voltage limit
179	HV_NEG_50V_TO_POS_50V_B_LIMIT	Short	HV -50V to +50V B voltage limit
180	HV_NEG_200V_TO_POS_200V_A_LIMIT	Short	HV -200V to +200V A voltage limit
181	HV_NEG_200V_TO_POS_200V_B_LIMIT	Short	HV -200V to +200V B voltage limit
182	HV_NEG_1KV_TO_POS_400V_A_LIMIT	Int	HV -1kV to +400V A voltage limit
183	HV_NEG_1KV_TO_POS_400V_B_LIMIT	Int	HV -1kV to +400V B voltage limit
184	HV_POS_20V_A_LIMIT	Int	HV +20V A voltage limit
185	HV_POS_20V_B_LIMIT	Int	HV +20V B voltage limit
186	HV_NEG_350V_A_LIMIT	Int	HV -350V A voltage limit
187	HV_NEG_350V_B_LIMIT	Int	HV -350V B voltage limit
188	HV_NEG_1_5KV_LIMIT	Int	HV -1.5kV voltage limit
189	HV_NEG_800V_B_LIMIT	Int	HV -800V B voltage limit
190	HV_NEG_2_9KV_LIMIT	Int	HV -2.9kV voltage limit
191	HV_NEG_1KV_A_LIMIT	Int	HV -1kV A voltage limit
192	HV_NEG_900V_LIMIT	Int	HV -900V voltage limit
193	RTM_PH0_GOAL	Short	RTM phase 0 voltage goal
194	RTM_PH60_GOAL	Short	RTM phase 60 voltage goal
195	RTM_PH120_GOAL	Short	RTM phase 120 voltage goal
196	EIS_BIAS_LEVEL	Short	EIS bias level
197	HV_POS_15V_GOAL	Short	HV +15V voltage goal
198	HV_POS_600V_A_GOAL	Short	HV +600V A voltage goal
199	HV_POS_600V_B_GOAL	Short	HV +600V B voltage goal
200	HV_NEG_80V_A_GOAL	Short	HV -80V A voltage goal
201	HV_NEG_80V_B_GOAL	Short	HV -80V B voltage goal
202	HV_NEG_125V_GOAL	Short	HV -125V voltage goal
203	HV_NEG_1KV_B_GOAL	Short	HV -1kV B voltage goal
204	HV_NEG_2_9KV_MCP_GOAL	Short	HV -2.9kV MCP voltage goal
205	HV_NEG_50V_TO_POS_50V_A_GOAL	Byte	HV -50V to +50V A voltage goal
206	HV_NEG_50V_TO_POS_50V_B_GOAL	Byte	HV -50V to +50V B voltage goal
207	HV_NEG_200V_TO_POS_200V_A_GOAL	Byte	HV -200V to +200V A voltage goal
208	HV_NEG_200V_TO_POS_200V_B_GOAL	Byte	HV -200V to +200V B voltage goal
209	HV_NEG_1KV_TO_POS_400V_A_GOAL	Short	HV -1kV to +400V A voltage goal
210	HV_NEG_1KV_TO_POS_400V_B_GOAL	Short	HV -1kV to +400V B voltage goal
211	HV_POS_20V_A_GOAL	Int	HV +20V A voltage goal
212	HV_POS_20V_B_GOAL	Int	HV +20V B voltage goal
213	HV_NEG_350V_A_GOAL	Int	HV -350V A voltage goal
214	HV_NEG_350V_B_GOAL	Int	HV -350V B voltage goal

215	HV_NEG_1_5KV_GOAL	Int	HV -1.5kV voltage goal
216	HV_NEG_800V_B_GOAL	Int	HV -800V B voltage goal
217	HV_NEG_2_9KV_GOAL	Int	HV -2.9kV voltage goal
218	HV_NEG_1KV_A_GOAL	Int	HV -1kV A voltage goal
219	HV_NEG_900V_GOAL	Int	HV -900V voltage goal
220	EIS_BIAS_LIMIT	Short	EIS bias limit
221	EIS_BIAS_GOAL	Short	EIS bias goal
222	EIS_HEATER_LIMIT	Int	EIS heater limit
223	EIS_HEATER_GOAL	Int	EIS heater goal
224	EIS_HEATER_LEVEL	Int	EIS heater level
225	RAW_EVENT_FILTER_THRESHOLD	Short	Raw event filter abundance threshold

***Table A-9** – STROFIO Raw housekeeping status data fields description*

Column #	Title	Data Type	Description
1	UTC_TIME	String	Measurement time in UTC
2	SCLK	String	Measurement time in SCLK
3	Abort_Flag	Short	Integration aborted?
4	Integration_Time	Int	Integration time
5	Left_Start	Long	Counts start pulses from left anode
6	Left_Stop	Long	Counts stop pulses from left anode
7	Left_Position_Only	Long	Counts position measurements without corresponding time measurement from left anode
8	Left_Time_Only	Long	Counts time measurements without corresponding position measurement from left anode
9	Left_Paired_Event	Long	Counts coincident position and time measurements, i.e. paired events, from left anode
10	Right_Start	Long	Counts start pulses from right anode
11	Right_Stop	Long	Counts stop pulses from right anode
12	Right_Position_Only	Long	Counts position measurements without corresponding time measurement from right anode
13	Right_Time_Only	Long	Counts time measurements without corresponding position measurement from right anode
14	Right_Paired_Event	Long	Counts coincident position and time measurements, i.e. paired events, from right anode
15	Rotation_Sync	Long	Counts rotation synchronization pulses

***Table A-10** – STROFIO Raw science data fields description (basic rates)*

Column #	Title	Data Type	Description
1	UTC_TIME	String	Measurement time in UTC
2	SCLK	String	Measurement time in SCLK
3	Integration_Time	Int	Integration time
4	TOF_Spectrum	Long[]	High-quality TOF spectrum

***Table A-11** – STROFIO Raw science data fields description (HQ TOF)*

Column #	Title	Data Type	Description
1	UTC_TIME	String	Measurement time in UTC

2	SCLK	String	Measurement time in SCLK
3	Integration_Time	Int	Integration time
4	TOF_Spectrum	Long[]	Low-quality TOF spectrum

***Table A-12** – STROFIO Raw science data fields description (LQ TOF)*

Column #	Title	Data Type	Description
1	UTC_TIME	String	Measurement time in UTC
2	SCLK	String	Measurement time in SCLK
3	Integration_Time	Int	Integration time
4	TOF_Spectrum	Long[]	Rebinned High-quality TOF spectrum

***Table A-13** – STROFIO Raw science data fields description (Re-HQ TOF)*

Column #	Title	Data Type	Description
1	UTC_TIME	String	Measurement time in UTC
2	SCLK	String	Measurement time in SCLK
3	Integration_Time	Int	Integration time
4	TOF_Spectrum	Long[]	Rebinned Low-quality TOF spectrum

***Table A-14** – STROFIO Raw science data fields description (Re-LQ TOF)*

A.2.2 STROFIO Calibrated Data Products Fields Description

***Table A-15** – STROFIO* Partially processed *data fields description*

A.2.3 STROFIO Calibrated Data Products Fields Description

Column #	Title	Data Type	Description
1	UTC_TIME	Short	Measurement time in UTC
2	SCLK	Long	Measurement time in spacecraft clock
3	MCP_HV_TRIP	Short	MCP HV over-current detect
4	MCP_HV_SHUTDOWN	Short	Status of automatic MCP HV over-current shutdown
5	HV_FULL_SCALE_ENB	Short	HV full scale enable (from safing plug)
6	HV_ALL_ENB	Short	HV all enable (from safing plug)
7	MCP_HV_CURR_MON_ENB	Short	MCP HV current monitor enable
8	RTM_SYNC_SOURCE	Short	RTM synchronization source
9	HV_ENB	Short	HV enable
10	RTM_ENB	Short	RTM enable
11	EIS_BIAS_HIGH_ENB	Short	EIS bias high enable
12	EIS_CURRENT_HIGH_ENB	Short	EIS current high enable
13	EIS_BIAS_POWER_ENB	Short	EIS bias power enable
14	EIS_HEATER_POWER_ENB	Short	EIS heater power enable
15	EIS_CATHODE_1A_ENB	Short	EIS cathode 1A enable
16	EIS_CATHODE_1B_ENB	Short	EIS cathode 1B enable
17	EIS_CATHODE_2A_ENB	Short	EIS cathode 2A enable

18	EIS_CATHODE_2B_ENB	Short	EIS cathode 2B enable
19	FIFO_ALL	Short	All events into FIFO enable
20	TIME_TOF_DIVIDER	Short	Time TOF chip clock divider
21	POS_TAP	Short	Position TOF chip tap select
22	TIME_TAP	Short	Time TOF chip tap select
23	CFD_LEFT_START_VDD	Short	CFD left start Vdd
24	CFD_LEFT_STOP_VDD	Short	CFD left stop Vdd
25	CFD_RIGHT_START_VDD	Short	CFD right start Vdd
26	CFD_RIGHT_STOP_VDD	Short	CFD right stop Vdd
27	CFD_LEFT_START_THRESH	Short	CFD left start threshold
28	CFD_LEFT_STOP_THRESH	Short	CFD left stop threshold
29	CFD_RIGHT_START_THRESH	Short	CFD right start threshold
30	CFD_RIGHT_STOP_THRESH	Short	CFD right stop threshold
31	EIS_HEATER_VOLTAGE_1	Short	EIS heater voltage 1 (coarse)
32	EIS_BIAS_VOLTAGE	Short	EIS bias voltage
33	EIS_HEATER_VOLTAGE_2	Short	EIS heater voltage 2 (fine)
34	MCP_HV_CURR_LIMIT	Short	MCP HV current monitor limit
35	RTM_PH0_LEVEL	Short	RTM phase 0 voltage level
36	RTM_PH60_LEVEL	Short	RTM phase 60 voltage level
37	RTM_PH120_LEVEL	Short	RTM phase 120 voltage level
38	HV_POS_15V_LEVEL	Short	HV +15V voltage level
39	HV_POS_600V_A_LEVEL	Short	HV +600V A voltage level
40	HV_POS_600V_B_LEVEL	Short	HV +600V B voltage level
41	HV_NEG_80V_A_LEVEL	Short	HV -80V A voltage level
42	HV_NEG_80V_B_LEVEL	Short	HV -80V B voltage level
43	HV_NEG_125V_LEVEL	Short	HV -125V voltage level
44	HV_NEG_1KV_B_LEVEL	Short	HV -1kV B voltage level
45	HV_NEG_2_9KV_MCP_LEVEL	Short	HV -2.9kV MCP voltage level
46	HV_NEG_50V_TO_POS_50V_A_LEVEL	Short	HV -50V to +50V A voltage level
47	HV_NEG_50V_TO_POS_50V_B_LEVEL	Short	HV -50V to +50V B voltage level
48	HV_NEG_200V_TO_POS_200V_A_LEVEL	Short	HV -200V to +200V A voltage level
49	HV_NEG_200V_TO_POS_200V_B_LEVEL	Short	HV -200V to +200V B voltage level
50	HV_NEG_1KV_TO_POS_400V_A_LEVEL	Short	HV -1kV to +400V A voltage level
51	HV_NEG_1KV_TO_POS_400V_B_LEVEL	Short	HV -1kV to +400V B voltage level
52	HV_POS_20V_A_LEVEL	Int	HV +20V A voltage level
53	HV_POS_20V_B_LEVEL	Int	HV +20V B voltage level
54	HV_NEG_350V_A_LEVEL	Int	HV -350V A voltage level
55	HV_NEG_350V_B_LEVEL	Int	HV -350V B voltage level
56	HV_NEG_1_5KV_LEVEL	Int	HV -1.5kV voltage level
57	HV_NEG_800V_B_LEVEL	Int	HV -800V B voltage level
58	HV_NEG_2_9KV_LEVEL	Int	HV -2.9kV voltage level
59	HV_NEG_1KV_A_LEVEL	Int	HV -1kV A voltage level
60	HV_NEG_900V_LEVEL	Int	HV -900V voltage level
61	LEFT_ANODE_ENB	Short	Pulsar configuration

62	RIGHT_ANODE_ENB	Short	Pulsar configuration
63	LEFT_START_CFD_ENB	Short	Pulsar configuration
64	LEFT_STOP_CFD_ENB	Short	Pulsar configuration
65	RIGHT_START_CFD_ENB	Short	Pulsar configuration
66	RIGHT_STOP_CFD_ENB	Short	Pulsar configuration
67	START_TO_SYNC_DELAY	Short	Pulsar configuration
68	START_TO_STOP_DELAY	Short	Pulsar configuration
69	RTM_PHASE_0_TO_60	Int	Measurement of RTM phase 0 to phase 60 (25/256 ns)
70	RTM_PHASE_0_TO_120	Int	Measurement of RTM phase 0 to phase 120 (25/256 ns)
71	LVPS_0	Int	+1.5V Monitor
72	LVPS_1	Int	+3.3V Monitor
73	LVPS_2	Int	+5V Monitor
74	LVPS_3	Int	+12V Monitor
75	LVPS_4	Int	-12V Monitor
76	LVPS_5	Int	+12V I Monitor
77	LVPS_6	Int	+5V I Monitor
78	LVPS_7	Int	+3.3V I Monitor
79	LVPS_8	Int	+1.5V I Monitor
80	LVPS_9	Int	-12V I Monitor
81	LVPS_10	Int	Primary I Monitor
82	LVPS_11	Int	Heater I Monitor
83	LVPS_12	Int	Heater V Monitor
84	LVPS_13	Int	Bias I Monitor
85	LVPS_14	Int	Bias V Monitor
86	LVPS_15	Int	LVPS Temp Monitor
87	RTM_0	Int	RTM Phase 0 Voltage Monitor
88	RTM_1	Int	RTM Phase 60 Voltage Monitor
89	RTM_2	Int	RTM Phase 120 Voltage Monitor
90	RTM_3	Int	RTM Phase 0 AGC Monitor
91	RTM_4	Int	RTM Phase 60 AGC Monitor
92	RTM_5	Int	RTM Phase 120 AGC Monitor
93	RTM_6	Int	RTM +3.3V Monitor
94	RTM_7	Int	Spare
95	RTM_8	Int	RTM +12V Monitor
96	RTM_9	Int	RTM +5V Monitor
97	RTM_10	Int	Spare
98	RTM_11	Int	Spare
99	RTM_12	Int	Spare
100	RTM_13	Int	EIS Temp 1 Monitor
101	RTM_14	Int	EIS Temp 2 Monitor
102	RTM_15	Int	RTM Temp Monitor
103	HV1_0	Int	HV +3.3V Monitor
104	HV1_1	Int	HV -2.9kV MCP Monitor
105	HV1_2	Int	HV -2.9kV MCP I Monitor
106	HV1_3	Int	HV -2.9kV Out Monitor
107	HV1_4	Int	HV -1.5kV Monitor
108	HV1_5	Int	HV -125V Monitor

109	HV1_6	Int	HV -1kV A Monitor
110	HV1_7	Int	HV -1kV B Monitor
111	HV1_8	Int	HV -900V Monitor
112	HV1_9	Int	HV -800V B Monitor
113	HV1_10	Int	HV -350V A Monitor
114	HV1_11	Int	HV -350V B Monitor
115	HV1_12	Int	Spare
116	HV1_13	Int	Spare
117	HV1_14	Int	Spare
118	HV1_15	Int	HV Board 1 Temp Monitor
119	HV2_0	Int	HV -1kV to +400V A Monitor
120	HV2_1	Int	HV -1kV to +400V B Monitor
121	HV2_2	Int	HV -200V to +200V A Monitor
122	HV2_3	Int	HV -200V to +200V B Monitor
123	HV2_4	Int	HV -50V to +50V A Monitor
124	HV2_5	Int	HV -50V to +50V B Monitor
125	HV2_6	Int	HV +600V A Monitor
126	HV2_7	Int	HV +600V B Monitor
127	HV2_8	Int	HV -80V A Monitor
128	HV2_9	Int	HV -80V B Monitor
129	HV2_10	Int	HV +20V A Monitor
130	HV2_11	Int	HV +20V B Monitor
131	HV2_12	Int	HV +15V Monitor
132	HV2_13	Int	HV +15V I Monitor
133	HV2_14	Int	Spare
134	HV2_15	Int	HV Board 2 Temp Monitor
135	STATUS_INTERVAL	Int	Status interval (seconds)
136	MACRO_BLOCKS	Int	Number of macro blocks free
137	TELEMETRY_VOLUME	Int	Telemetry volume produced (KB)
138	WATCH_ADDRESS	Int	Memory watch address
139	WATCH_MEMORY	Short	Memory watch id (page no.)
140	WATCH_DATA	Int	Watched memory
141	SOFTWARE_VERSION	Short	Software version number
142	ALARM_ID	Short	Latest alarm Id
143	ALARM_TYPE	Short	Latest alarm type
144	ALARM_COUNT	Short	Count of alarms
145	CMD_EXEC	Short	Commands executed
146	CMD_REJECT	Short	Commands rejected
147	MACRO_EXEC	Short	Macro commands executed
148	MACRO_REJECT	Short	Macro commands rejected
149	MACRO_ID	Short	Id of most recent macro executed
150	MACRO_LEARN	Short	Macro learn mode
151	MONITOR_RESPONSE	Short	Monitor response
152	WRITE_ENB	Short	Memory write enable
153	ECHO_ENB	Short	Command echo enable
154	DIAGNOSTIC_TABLE_ENB	Short	Diagnostic data processing table enable
155	RAW_EVENT_FILTER	Short	Filter used for selecting events for raw data
156	TABLES	Short	Data processing lookup tables
157	SAFING_TIME	Int	Time-out interval (seconds)

158	INTEGRATION_MULT_N2	Short	Integration multiplier, N2
159	REBINNED_LOW_QUAL_TOF_SPECT	Short	Rebinned low-quality TOF spectrum
160	LOW_QUAL_TOF_SPECT	Short	Low-quality TOF spectrum
161	REBINNED_HIGH_QUAL_TOF_SPECT	Short	Rebinned high-quality TOF spectrum
162	HIGH_QUAL_TOF_SPECT	Short	High-quality TOF spectrum
163	BASIC_RATES	Short	Basic rates enable
164	RAW_EVENTS	Short	Number of raw events to collect
165	INTEGRATION_TIME	Short	Fast integration time T (seconds)
166	INTEGRATION_TIME_N1	Short	Integration multiplier, N1
167	RTM_PH0_LIMIT	Short	RTM phase 0 voltage limit
168	RTM_PH60_LIMIT	Short	RTM phase 60 voltage limit
169	RTM_PH120_LIMIT	Short	RTM phase 120 voltage limit
170	HV_POS_15V_LIMIT	Short	HV +15V voltage limit
171	HV_POS_600V_A_LIMIT	Short	HV +600V A voltage limit
172	HV_POS_600V_B_LIMIT	Short	HV +600V B voltage limit
173	HV_NEG_80V_A_LIMIT	Short	HV -80V A voltage limit
174	HV_NEG_80V_B_LIMIT	Short	HV -80V B voltage limit
175	HV_NEG_125V_LIMIT	Short	HV -125V voltage limit
176	HV_NEG_1KV_B_LIMIT	Short	HV -1kV B voltage limit
177	HV_NEG_2_9KV_MCP_LIMIT	Short	HV -2.9kV MCP voltage limit
178	HV_NEG_50V_TO_POS_50V_A_LIMIT	Short	HV -50V to +50V A voltage limit
179	HV_NEG_50V_TO_POS_50V_B_LIMIT	Short	HV -50V to +50V B voltage limit
180	HV_NEG_200V_TO_POS_200V_A_LIMIT	Short	HV -200V to +200V A voltage limit
181	HV_NEG_200V_TO_POS_200V_B_LIMIT	Short	HV -200V to +200V B voltage limit
182	HV_NEG_1KV_TO_POS_400V_A_LIMIT	Int	HV -1kV to +400V A voltage limit
183	HV_NEG_1KV_TO_POS_400V_B_LIMIT	Int	HV -1kV to +400V B voltage limit
184	HV_POS_20V_A_LIMIT	Int	HV +20V A voltage limit
185	HV_POS_20V_B_LIMIT	Int	HV +20V B voltage limit
186	HV_NEG_350V_A_LIMIT	Int	HV -350V A voltage limit
187	HV_NEG_350V_B_LIMIT	Int	HV -350V B voltage limit
188	HV_NEG_1_5KV_LIMIT	Int	HV -1.5kV voltage limit
189	HV_NEG_800V_B_LIMIT	Int	HV -800V B voltage limit
190	HV_NEG_2_9KV_LIMIT	Int	HV -2.9kV voltage limit
191	HV_NEG_1KV_A_LIMIT	Int	HV -1kV A voltage limit
192	HV_NEG_900V_LIMIT	Int	HV -900V voltage limit
193	RTM_PH0_GOAL	Short	RTM phase 0 voltage goal
194	RTM_PH60_GOAL	Short	RTM phase 60 voltage goal
195	RTM_PH120_GOAL	Short	RTM phase 120 voltage goal
196	EIS_BIAS_LEVEL	Short	EIS bias level
197	HV_POS_15V_GOAL	Short	HV +15V voltage goal
198	HV_POS_600V_A_GOAL	Short	HV +600V A voltage goal
199	HV_POS_600V_B_GOAL	Short	HV +600V B voltage goal
200	HV_NEG_80V_A_GOAL	Short	HV -80V A voltage goal
201	HV_NEG_80V_B_GOAL	Short	HV -80V B voltage goal

202	HV_NEG_125V_GOAL	Short	HV -125V voltage goal
203	HV_NEG_1KV_B_GOAL	Short	HV -1kV B voltage goal
204	HV_NEG_2_9KV_MCP_GOAL	Short	HV -2.9kV MCP voltage goal
205	HV_NEG_50V_TO_POS_50V_A_GOAL	Byte	HV -50V to +50V A voltage goal
206	HV_NEG_50V_TO_POS_50V_B_GOAL	Byte	HV -50V to +50V B voltage goal
207	HV_NEG_200V_TO_POS_200V_A_GOAL	Byte	HV -200V to +200V A voltage goal
208	HV_NEG_200V_TO_POS_200V_B_GOAL	Byte	HV -200V to +200V B voltage goal
209	HV_NEG_1KV_TO_POS_400V_A_GOAL	Short	HV -1kV to +400V A voltage goal
210	HV_NEG_1KV_TO_POS_400V_B_GOAL	Short	HV -1kV to +400V B voltage goal
211	HV_POS_20V_A_GOAL	Int	HV +20V A voltage goal
212	HV_POS_20V_B_GOAL	Int	HV +20V B voltage goal
213	HV_NEG_350V_A_GOAL	Int	HV -350V A voltage goal
214	HV_NEG_350V_B_GOAL	Int	HV -350V B voltage goal
215	HV_NEG_1_5KV_GOAL	Int	HV -1.5kV voltage goal
216	HV_NEG_800V_B_GOAL	Int	HV -800V B voltage goal
217	HV_NEG_2_9KV_GOAL	Int	HV -2.9kV voltage goal
218	HV_NEG_1KV_A_GOAL	Int	HV -1kV A voltage goal
219	HV_NEG_900V_GOAL	Int	HV -900V voltage goal
220	EIS_BIAS_LIMIT	Short	EIS bias limit
221	EIS_BIAS_GOAL	Short	EIS bias goal
222	EIS_HEATER_LIMIT	Int	EIS heater limit
223	EIS_HEATER_GOAL	Int	EIS heater goal
224	EIS_HEATER_LEVEL	Int	EIS heater level
225	RAW_EVENT_FILTER_THRESHOLD	Short	Raw event filter abundance threshold

Table A-16 *– STROFIO Calibrated housekeeping status data fields description*

Column #	Title	Data Type	Description
1	UTC	String	Measurement time in UTC
2	SCLK	String	Measurement time in SCLK
3	Mass	Long	Mass
4	Compound	String	Assumed compound
5	Density	Double	Density

Table A-17 *– STROFIO Calibrated science data fields description (HQ TOF)*

Column #	Title	Data Type	Description
1	UTC	String	Measurement time in UTC
2	SCLK	String	Measurement time in SCLK
3	Mass	Long	Mass
4	Compound	String	Assumed Compound
5	Density	Double	Density

Table A-18 *– STROFIO Calibrated science data fields description (LQ TOF)*

Column #	Title	Data Type	Description
1	UTC	String	Measurement time in UTC
2	SCLK	String	Measurement time in SCLK
3	Mass	Long	Mass
4	Compound	String	Assumed Compound
5	Density	Double	Density

***Table A-19** – STROFIO Calibrated science data fields description (Re-HQ TOF)*

Column #	Title	Data Type	Description
1	UTC	String	Measurement time in UTC
2	SCLK	String	Measurement time in SCLK
3	Mass	Long	Mass
4	Compound	String	Assumed Compound
5	Density	Double	Density

***Table A-20** – STROFIO Calibrated science data fields description (Re-LQ TOF)*

A.2.4 STROFIO Derived Data Products Fields Description

*TBD. **Table A-21** – STROFIO Derived science data fields description*

A.3 MIPA Data Products Fields Description

A.3.1 MIPA Raw Data Products Fields Description

Column #	Title	Data Type	Description
1	SEQ	ASCII_NonNegative_Integer	Packet sequence
2	SEQCNT	ASCII_NonNegative_Integer	Packet sequence count
3	LENGTH	ASCII_NonNegative_Integer	Data length
4	OBT	ASCII_String	Onboard time
5	DATETIME_UTC	Date_Time_YMD_UTC	Observation time in UTC
6	CMODE	ASCII_String	Current system mode
7	PMODE	ASCII_String	Previous system mode
8	ERR	ASCII_NonNegative_Integer	Error
9	ERRCNT	ASCII_NonNegative_Integer	Error count
10	FIFOEMPTY	ASCII_NonNegative_Integer	FIFO empty
11	FIFOOVER	ASCII_NonNegative_Integer	FIFO overflow
12	BLOCKSIZE	ASCII_NonNegative_Integer	Block size
13	ERRCRIT	ASCII_NonNegative_Integer	Error last crit
14	TYPE_ACC	ASCII_NonNegative_Integer	Type accepted
15	STYPE_ACC	ASCII_NonNegative_Integer	Subtype accepted
16	TYPE_EXEC	ASCII_NonNegative_Integer	Type executed
17	STYPE_EXEC	ASCII_NonNegative_Integer	Subtype executed
18	TYPE_REJ	ASCII_NonNegative_Integer	Type rejected
19	STYPE_REJ	ASCII_NonNegative_Integer	Subtype rejected
20	ILL	ASCII_NonNegative_Integer	HK Updated
21	REJCAUSE	ASCII_NonNegative_Integer	Rejection cause
22	TCCNT	ASCII_NonNegative_Integer	TC counter
23	STATUS	ASCII_NonNegative_Integer	Status
24	MAIN	ASCII_NonNegative_Integer	Main high voltage

25	CEM	ASCII_NonNegative_Integer	CEM high voltage
26	DEFL1	ASCII_NonNegative_Integer	Deflector 1 monitor
27	DEFL2	ASCII_NonNegative_Integer	Deflector 2 monitor
28	ANLYZ	ASCII_NonNegative_Integer	Analyser monitor
29	DEFL3	ASCII_NonNegative_Integer	Deflector 3 monitor
30	TEMP	ASCII_NonNegative_Integer	Temperature
31	VREF	ASCII_NonNegative_Integer	Voltage reference
32	CURRENT	ASCII_NonNegative_Integer	MIPA current

Table A-22 – *MIPA Raw housekeeping data products fields description*

Column #	Title	Data Type	Description
1	SEQCNT	ASCII_NonNegative_Integer	Packet sequence count
2	LENGTH	ASCII_NonNegative_Integer	Data length
3	OBT_CCSDS	ASCII_String	Onboard time at CCSDS creation
4	DATETIME_UTC_CCSDS	ASCII_Date_Time_YMD_UTC	Obs time in UTC at CCSDS creation
5	ACCOFFS	ASCII_NonNegative_Integer	Accumulation offset
6	VERSION	ASCII_NonNegative_Integer	S/W version
7	STATUS	ASCII_NonNegative_Integer	Status byte
8	MASS	ASCII_NonNegative_Integer	Number of mass bins
9	ENERGY	ASCII_NonNegative_Integer	Number of energy bins
10	DEFL	ASCII_NonNegative_Integer	Number of deflection directions
11	TABLE	ASCII_NonNegative_Integer	Energy table number
12	PROCMODE	ASCII_NonNegative_Integer	Procedure mode
13	RICE	ASCII_NonNegative_Integer	RICE compression
14	RICEPARAM	ASCII_NonNegative_Integer	Option parameter
15	CYCLE	ASCII_NonNegative_Integer	Measurement cycle number
16	BLKSIZE	ASCII_NonNegative_Integer	Block size
17	OBT	ASCII_NonNegative_Integer	Onboard time
18	DATETIME_UTC	ASCII_NonNegative_Integer	Observation time in UTC
19	MAIN	ASCII_NonNegative_Integer	Main high voltage
20	CEM	ASCII_NonNegative_Integer	CEM high voltage
21	DEFL1	ASCII_NonNegative_Integer	Deflector 1 monitor
22	DEFL2	ASCII_NonNegative_Integer	Deflector 2 monitor
23	ANLYZ	ASCII_NonNegative_Integer	Analyser monitor
24	DEFL3	ASCII_NonNegative_Integer	Deflector 3 monitor
25	TEMP	ASCII_NonNegative_Integer	Temperature
26	VREF	ASCII_NonNegative_Integer	Voltage reference
27	nD	ASCII_NonNegative_Integer	Number of deflection bins
28	nE	ASCII_NonNegative_Integer	Number of energy bins
29	nM	ASCII_NonNegative_Integer	Number of mass bins
30	TOTAL_BITS	ASCII_NonNegative_Integer	Packet size in bits
31	PLANET_SUN_X	ASCII_Real	Depending on the mission phase this is the X coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
32	PLANET_SUN_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate of either Earth-Sun, Venus-Sun or Mercury-

			Sun vector in the HEE reference frame, or -1 for cruise
33	PLANET_SUN_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
34	PLANET_SUN_DIST	ASCII_Real	Distance Earth-Sun, Venus-Sun or Mercury-Sun. Equals to -1 during cruise.
35	MPO_SUN_X	ASCII_Real	X coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
36	MPO_SUN_Y	ASCII_Real	Y coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
37	MPO_SUN_Z	ASCII_Real	Z coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
38	MPO_SUN_DIST	ASCII_Real	MPO heliocentric distance.
39	MPO_PLANET_X	ASCII_Real	X coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
40	MPO_PLANET_Y	ASCII_Real	Y coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
41	MPO_PLANET_Z	ASCII_Real	Z coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
42	ANGLE_MPO_PLANET_SUN	ASCII_Real	Angle between MPO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
43	MPO_MMO_X	ASCII_Real	X coordinate of MPO-MMO vector in the "MPO Spacecraft" reference frame.
44	MPO_MMO_Y	ASCII_Real	Y coordinate of MPO-MMO vector in the "MPO Spacecraft" reference frame.
45	MPO_MMO_Z	ASCII_Real	Z coordinate of MPO-MMO vector in the "MPO Spacecraft" reference frame.
46	MPO_ALT	ASCII_Real	Altitude of MPO in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
47	MPO_DIST_PLANET	ASCII_Real	Distance from MPO to center of the planet (Earth, Venus, or Mercury). Equals to -1 during cruise.
48	MMO_ALT	ASCII_Real	Altitude of MMO in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
49	MMO_DIST_PLANET	ASCII_Real	Distance from MMO to center of the planet (Earth, Venus, or Mercury). Equals to -1 during cruise.
50	MPO_LAT	ASCII_Real	Latitude of MPO in GSM, VSO, or MSM reference frame. Equals to -1 during cruise.

51	MPO_LON	ASCII_Real	Longitude of MPO in GSM, VSO, or MSM reference frame. Equals to -1 during cruise.
52	MPO_LATLON_RAD	ASCII_Real	Radius related to magnetic latitude and longitude, GSM, VSO, or MSM. Equals to -1 during cruise.
53	SO_FRAME	ASCII_String	Solar orbital reference frame rotation matrix from MPO S/C to GSE, VSO, MSO, or HEE (cruise) depending on mission phase.
54	SO_M11	ASCII_Real	Component M11 of the rotation matrix to solar-orbital reference frame
55	SO_M12	ASCII_Real	Component M12 of the rotation matrix to solar-orbital reference frame
56	SO_M13	ASCII_Real	Component M13 of the rotation matrix to solar-orbital reference frame
57	SO_M21	ASCII_Real	Component M21 of the rotation matrix to solar-orbital reference frame
58	SO_M22	ASCII_Real	Component M22 of the rotation matrix to solar-orbital reference frame
59	SO_M23	ASCII_Real	Component M23 of the rotation matrix to solar-orbital reference frame
60	SO_M31	ASCII_Real	Component M31 of the rotation matrix to solar-orbital reference frame
61	SO_M32	ASCII_Real	Component M32 of the rotation matrix to solar-orbital reference frame
62	SO_M33	ASCII_String	Component M33 of the rotation matrix to solar-orbital reference frame
63	SM_FRAME	ASCII_Real	Solar magnetic reference frame rotation matrix from MPO S/C to GSM, VSO, MSM, or HEE (cruise) depending on mission phase.
64	SM_M11	ASCII_Real	Component M11 of the rotation matrix to solar-magnetic reference frame
65	SM_M12	ASCII_Real	Component M12 of the rotation matrix to solar-magnetic reference frame
66	SM_M13	ASCII_Real	Component M13 of the rotation matrix to solar-magnetic reference frame
67	SM_M21	ASCII_Real	Component M21 of the rotation matrix to solar-magnetic reference frame
68	SM_M22	ASCII_Real	Component M22 of the rotation matrix to solar-magnetic reference frame
69	SM_M23	ASCII_Real	Component M23 of the rotation matrix to solar-magnetic reference frame

70	SM_M31	ASCII_Real	Component M31 of the rotation matrix to solar-magnetic reference frame
71	SM_M32	ASCII_Real	Component M32 of the rotation matrix to solar-magnetic reference frame
72	SM_M33	ASCII_Real	Component M33 of the rotation matrix to solar-magnetic reference frame
73	ENERGY_MASS_MATRIX	ASCII_NonNegative_Integer	Mass energy matrix for time instance
74	START_COUNTER	ASCII_NonNegative_Integer	Start counter matrix
75	STOP_COUNTER	ASCII_NonNegative_Integer	Stop counter matrix
76	OVER_COUNTER	ASCII_NonNegative_Integer	Over counter matrix
77	UNDER_COUNTER	ASCII_NonNegative_Integer	Under counter matrix
78	N_TOF_COUNTER	ASCII_NonNegative_Integer	Time-of-flight counter matrix

Table A-23 *– MIPA Raw science data products fields description*

A.3.2 MIPA Calibrated Data Products Fields Description

Column #	Title	Data Type	Description
1	SEQCNT	ASCII_NonNegative_Integer	Packet sequence count
2	OBT	ASCII_String	Onboard time
3	DATETIME_UTC	Date_Time_YMD_UTC	Observation time in UTC
4	CMODE	ASCII_String	Current system mode
5	PMODE	ASCII_String	Previous system mode
6	ERR	ASCII_NonNegative_Integer	Error
7	ERRCNT	ASCII_NonNegative_Integer	Error count
8	BLOCKSIZE	ASCII_NonNegative_Integer	Block size
9	ERRCRIT	ASCII_String	Error last crit
10	TYPE_ACC	ASCII_NonNegative_Integer	Last TC type accepted
11	STYPE_ACC	ASCII_NonNegative_Integer	Last TC subtype accepted
12	TYPE_EXEC	ASCII_NonNegative_Integer	Last TC type executed
13	STYPE_EXEC	ASCII_NonNegative_Integer	Last TC subtype executed
14	TYPE_REJ	ASCII_NonNegative_Integer	Last TC type rejected
15	STYPE_REJ	ASCII_NonNegative_Integer	Last TC subtype rejected
16	ILL	ASCII_NonNegative_Integer	HK Updated
17	REJCAUSE	ASCII_String	Rejection cause
18	TCCNT	ASCII_NonNegative_Integer	TC counter
19	MAIN	ASCII_Real	Main high voltage (V)
20	CEM	ASCII_Real	CEM high voltage (V)
21	DEFL1	ASCII_Real	Deflector 1 monitor (V)
22	DEFL2	ASCII_Real	Deflector 2 monitor (V)
23	ANLYZ	ASCII_Real	Analyser monitor (V)
24	DEFL3	ASCII_Real	Deflector 3 monitor (V)
25	TEMP	ASCII_Real	Temperature (°C)
26	VREF	ASCII_Real	Voltage reference (V)
27	CURRENT	ASCII_Real	MIPA current (mA)
28	TOF_IRQ_STATUS	ASCII_NonNegative_Integer	Set by TDC interrupt
29	SAMPLING	ASCII_NonNegative_Integer	MIPA internal mode
30	MEMORY_BANK	ASCII_NonNegative_Integer	Select Memory Bank
31	HVPS	ASCII_NonNegative_Integer	HVPS oscillator status

32	TDC_STATUS	ASCII_NonNegative_Integer	TDC latch up detection
33	TDC_PROTECTION	ASCII_NonNegative_Integer	TDC latch up protection
34	TDC_POWER	ASCII_NonNegative_Integer	TDC power status

***Table A-24** – MIPA Calibrated housekeeping data products fields description*

Column #	Title	Data Type	Description
1	SEQCNT	ASCII_NonNegative_Integer	Packet sequence count
2	OBT_CCSDS	ASCII_String	Onboard time at CCSDS creation
3	DATETIME_UTC_CCSDS	ASCII_Date_Time_YMD_UTC	Obs time in UTC at CCSDS creation
4	ACCOFFS	ASCII_NonNegative_Integer	Accumulation offset
5	STATUS	ASCII_NonNegative_Integer	Status byte
6	MASS	ASCII_NonNegative_Integer	Number of mass bins
7	ENERGY	ASCII_NonNegative_Integer	Number of energy bins
8	DEFL	ASCII_NonNegative_Integer	Number of deflection directions
9	TABLE	ASCII_NonNegative_Integer	Energy table number
10	PROCMODE	ASCII_NonNegative_Integer	Procedure mode
11	CYCLE	ASCII_NonNegative_Integer	Measurement cycle number
12	OBT	ASCII_String	Onboard time
13	DATETIME_UTC	ASCII_Date_Time_YMD_UTC	Observation time in UTC
14	MAIN	ASCII_Real	Main high voltage
15	CEM	ASCII_Real	CEM high voltage
16	DEFL1	ASCII_Real	Deflector 1 monitor
17	DEFL2	ASCII_Real	Deflector 2 monitor
18	ANLYZ	ASCII_Real	Analyser monitor
19	DEFL3	ASCII_Real	Deflector 3 monitor
20	TEMP	ASCII_Real	Temperature
21	VREF	ASCII_Real	Voltage reference
22	nD	ASCII_NonNegative_Integer	Number of deflection bins
23	nE	ASCII_NonNegative_Integer	Number of energy bins
24	nM	ASCII_NonNegative_Integer	Number of mass bins
25	TOTAL_BITS	ASCII_NonNegative_Integer	Packet size in bits
26	PLANET_SUN_X	ASCII_Real	Depending on the mission phase this is the X coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
27	PLANET_SUN_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise

28	PLANET_SUN_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
29	PLANET_SUN_DIST	ASCII_Real	Distance Earth-Sun, Venus-Sun or Mercury-Sun. Equals to -1 during cruise.
30	MPO_SUN_X	ASCII_Real	X coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
31	MPO_SUN_Y	ASCII_Real	Y coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
32	MPO_SUN_Z	ASCII_Real	Z coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
33	MPO_SUN_DIST	ASCII_Real	MPO heliocentric distance.
34	MPO_PLANET_X	ASCII_Real	X coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
35	MPO_PLANET_Y	ASCII_Real	Y coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
36	MPO_PLANET_Z	ASCII_Real	Z coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
37	ANGLE_MPO_PLANET_SUN	ASCII_Real	Angle between MPO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
38	MPO_MMO_X	ASCII_Real	X coordinate of MPO-MMO vector in the "MPO Spacecraft" reference frame.
39	MPO_MMO_Y	ASCII_Real	Y coordinate of MPO-MMO vector in the "MPO Spacecraft" reference frame.
40	MPO_MMO_Z	ASCII_Real	Z coordinate of MPO-MMO vector in the "MPO Spacecraft" reference frame.
41	MPO_ALT	ASCII_Real	Altitude of MPO in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
42	MPO_DIST_PLANET	ASCII_Real	Distance from MPO to center of the planet (Earth, Venus, or Mercury). Equals to -1 during cruise.
43	MMO_ALT	ASCII_Real	Altitude of MMO in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
44	MMO_DIST_PLANET	ASCII_Real	Distance from MMO to center of the planet (Earth, Venus, or Mercury). Equals to -1 during cruise.
45	MPO_LAT	ASCII_Real	Latitude of MPO in GSM, VSO, or MSM reference frame. Equals to -1 during cruise.
46	MPO_LON	ASCII_Real	Longitude of MPO in GSM, VSO, or MSM reference frame. Equals to -1 during cruise.

47	MPO_LATLON_RAD	ASCII_Real	Radius related to magnetic latitude and longitude, GSM, VSO, or MSM. Equals to -1 during cruise.
48	SO_FRAME	ASCII_String	Solar orbital reference frame rotation matrix from MPO S/C to GSE, VSO, MSO, or HEE (cruise) depending on mission phase.
49	SO_M11	ASCII_Real	Component M11 of the rotation matrix to solar-orbital reference frame
50	SO_M12	ASCII_Real	Component M12 of the rotation matrix to solar-orbital reference frame
51	SO_M13	ASCII_Real	Component M13 of the rotation matrix to solar-orbital reference frame
52	SO_M21	ASCII_Real	Component M21 of the rotation matrix to solar-orbital reference frame
53	SO_M22	ASCII_Real	Component M22 of the rotation matrix to solar-orbital reference frame
54	SO_M23	ASCII_Real	Component M23 of the rotation matrix to solar-orbital reference frame
55	SO_M31	ASCII_Real	Component M31 of the rotation matrix to solar-orbital reference frame
56	SO_M32	ASCII_Real	Component M32 of the rotation matrix to solar-orbital reference frame
57	SO_M33	ASCII_String	Component M33 of the rotation matrix to solar-orbital reference frame
58	SM_FRAME	ASCII_Real	Solar magnetic reference frame rotation matrix from MPO S/C to GSM, VSO, MSM, or HEE (cruise) depending on mission phase.
59	SM_M11	ASCII_Real	Component M11 of the rotation matrix to solar-magnetic reference frame
60	SM_M12	ASCII_Real	Component M12 of the rotation matrix to solar-magnetic reference frame
61	SM_M13	ASCII_Real	Component M13 of the rotation matrix to solar-magnetic reference frame
62	SM_M21	ASCII_Real	Component M21 of the rotation matrix to solar-magnetic reference frame
63	SM_M22	ASCII_Real	Component M22 of the rotation matrix to solar-magnetic reference frame
64	SM_M23	ASCII_Real	Component M23 of the rotation matrix to solar-magnetic reference frame
65	SM_M31	ASCII_Real	Component M31 of the rotation matrix to solar-magnetic reference frame

66	SM_M32	ASCII_Real	Component M32 of the rotation matrix to solar-magnetic reference frame
67	SM_M33	ASCII_Real	Component M33 of the rotation matrix to solar-magnetic reference frame
68	ENERGY_MASS_MATRIX	ASCII_Real	Mass energy matrix for time instance in differential flux (#/cm2 s sr eV), shape [nD * nE * nM]
69	START_COUNTER	ASCII_Real	Start counter matrix in differential flux (#/cm2 s sr eV), shape [nD * nE * 1]
70	STOP_COUNTER	ASCII_Real	Stop counter matrix in differential flux (#/cm2 s sr eV), shape [nD * nE * 1]
71	N_TOF_COUNTER	ASCII_Real	Time-of-flight counter matrix in differential flux (#/cm2 s sr eV), shape [nD * nE * 1]

Table A-25 *– MIPA Calibrated science data products fields description*

A.3.3 MIPA Derived Data Products Fields Description

TBD. ***Table A-26*** *– MIPA Derived science data products fields description*

A.4 PICAM Data Products Fields Description

A.4.1 PICAM Raw Data Products Fields Description

Column #	Title	Data Type	Description
1	TIME_UTC	ASCII_Date_Time_YMD	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.SSS
2	TIME_OBT	ASCII_String	S/C CLOCK AT OBSERVATION TIME: SSSSSSSSSS.FFFFF
3	ORBNUM	ASCII_NonNegative_Integer	Orbit number (0 in non-Mercury mission phases)
4	SEQ_CNT	ASCII_NonNegative_Integer	Packet sequence counter
5	QUALITY	ASCII_NonNegative_Integer	Data quality (bit combination of: 0=perfect [no error], 1=checksum error, 2=missing HK params, 4=missing gate params, 8=incomplete sweep, 16=packet index out of range, 32=decompression error, 64=hadamard decoding error, 128=missing measurement time)
6	SPID	ASCII_NonNegative_Integer	Packet SPID

7	HW_VERSION	ASCII_NonNegative_Integer	Hardware version (NSE0P001)
8	SW_V_MAJOR	ASCII_NonNegative_Integer	Software major version (NSE0P002H)
9	SW_V_MINOR	ASCII_NonNegative_Integer	S/W minor version (NSE0P002L)
10	SW_REVISION	ASCII_NonNegative_Integer	Software revision number (NSE0P003)
11	SW_REV_STAT	ASCII_NonNegative_Integer	Software revision status
12	STATUS_2_MODID	ASCII_NonNegative_Integer	PICAM model Id (NSEDP052)
13	STATUS_1_RC	ASCII_NonNegative_Integer	RAM check (NSEDP043)
14	STATUS_1_EEPCK	ASCII_NonNegative_Integer	EEPROM check (NSEDP045)
15	STATUS_1_EEPWE	ASCII_NonNegative_Integer	EEPROM write enabled (NSEDP044)
16	PGM_CRC_SAVE	ASCII_NonNegative_Integer	Program checksum stored in EEPROM (NSE0P006)
17	PGM_CRC_CALC	ASCII_NonNegative_Integer	Program checksum calculated (NSE0P007)
18	STATUS_1_HVCS	ASCII_NonNegative_Integer	HV connector status (NSEDP041)
19	STATUS_2_TPO	ASCII_NonNegative_Integer	TIMPO output status (NSEDP054)
20	STATUS_2_DC	ASCII_NonNegative_Integer	Timpo control lines enabled/disabled (0/1) (NSEDP051)
21	STATUS_1_WS	ASCII_NonNegative_Integer	Watchdog status (NSEDP042)
22	STATUS_2_SPW	ASCII_NonNegative_Integer	SPW address error bit (NSEDP055)
23	STATUS_2_CPU	ASCII_NonNegative_Integer	CPU mode active (NSEDP050)
24	STATUS_2_OPM	ASCII_NonNegative_Integer	Operating mode (NSEDP056)
25	TC_BUF_UTIL	ASCII_NonNegative_Integer	TC buffer utilisation (NSE0P080)
26	PROC_LOAD	ASCII_NonNegative_Integer	CPU utilisation (NSE0P020)
27	LAST_TC_ACC	ASCII_NonNegative_Integer	Last TC accepted by PICAM
28	LAST_TC_REJ	ASCII_NonNegative_Integer	Last TC rejected by PICAM
29	LAST_TC_REJ_CAUSE	ASCII_NonNegative_Integer	Failure ID of last TC rejected by PICAM (NSE0P014)
30	LAST_TC_REJ_INDEX	ASCII_NonNegative_Integer	Invalid parameter offset (NSE0P012)
31	LAST_TC_EXE	ASCII_NonNegative_Integer	Last TC successfully executed
32	LAST_TC_ERR	ASCII_NonNegative_Integer	Last TC not executed properly
33	LAST_TC_ERR_CAUSE	ASCII_NonNegative_Integer	Failure ID of last erroneous TC (NSE0P013)
34	LAST_TC_ERR_INDEX	ASCII_NonNegative_Integer	Invalid parameter offset (NSE0P019)
35	STATUS_1_TCAPID	ASCII_NonNegative_Integer	TC packet APID error (NSEDP040)
36	STATUS_1_TCTIMO	ASCII_NonNegative_Integer	TC packet timeout (NSEDP046)
37	STATUS_1_TCCSUM	ASCII_NonNegative_Integer	TC packet CRC error (NSEDP047)
38	TC_COUNTER	ASCII_NonNegative_Integer	Number of TCs received since power on (NSE0P022)
39	HOT_TEMP	ASCII_NonNegative_Integer	TempHot (NSE0P029)
40	DPU_TEMP	ASCII_NonNegative_Integer	TempDPU (NSE0P023)
41	P3_3_V_MON	ASCII_NonNegative_Integer	+3.3V voltage monitor (NSE0P024)
42	P1_5_V_MON	ASCII_NonNegative_Integer	+1.5V voltage monitor (NSE0P025)
43	P5_V_MON	ASCII_NonNegative_Integer	+5V voltage monitor (NSE0P026)
44	P12_V_MON	ASCII_NonNegative_Integer	+12V voltage monitor (NSE0P027)
45	N12_V_MON	ASCII_NonNegative_Integer	-12V voltage monitor (NSE0P028)
46	HK_ADDR_1	ASCII_NonNegative_Integer	Memory dump address 1 (NSE0P076)
47	HK_DATA_1	ASCII_NonNegative_Integer	Value of memory address 1 (NSE0P078)
48	HK_ADDR_2	ASCII_NonNegative_Integer	Memory dump address 2 (NSE0P077)
49	HK_DATA_2	ASCII_NonNegative_Integer	Value of memory address 2 (NSE0P079)

Table A-27 – *PICAM Raw housekeeping data products fields description (HK1)*

Column #	Title	Data Type	Description

1	TIME_UTC	ASCII_Date_Time_YMD	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.SSS
2	TIME_OBT	ASCII_String	S/C CLOCK AT OBSERVATION TIME: SSSSSSSSSS.FFFFF
3	ORBNUM	ASCII_NonNegative_Integer	Orbit number (0 in non-Mercury mission phases)
4	SEQ_CNT	ASCII_NonNegative_Integer	Packet sequence counter
5	QUALITY	ASCII_NonNegative_Integer	Data quality (bit combination of: 0=perfect [no error], 1=checksum error, 2=missing HK params, 4=missing gate params, 8=incomplete sweep, 16=packet index out of range, 32=decompression error, 64=hadamard decoding error, 128=missing measurement time)
6	SPID	ASCII_NonNegative_Integer	Packet SPID
7	HV_SW_ENA	ASCII_NonNegative_Integer	HVC S/W enabled flag
8	UDFL_SET_VAL	ASCII_NonNegative_Integer	Udfl HV value (NSE0P056)
9	UDFL_SET_MON	ASCII_NonNegative_Integer	Deflector voltage set value (NSE0P051)
10	UDFL_MON	ASCII_NonNegative_Integer	Deflector voltage monitor (NSE0P044)
11	UG_V_RANGE	ASCII_NonNegative_Integer	Gate voltage range (NSEDP857)
12	UDFL_SET_INC	ASCII_NonNegative_Integer	Deflector voltage increment (NSE0P117)
13	UDFL_SET_MAX	ASCII_NonNegative_Integer	Deflector voltage set limit (NSE0P116)
14	HVC_TEMP	ASCII_NonNegative_Integer	High voltage converter temperature (NSE0P046)
15	DET_HK_TEMP	ASCII_NonNegative_Integer	Detector temperature (NSE0P047)
16	GED_HK_TEMP	ASCII_NonNegative_Integer	Gate electronics temperature (NSE0P054)
17	RELAY_STAT	ASCII_NonNegative_Integer	Relay status (NSEGP085)
18	ADC_FACTOR	ASCII_NonNegative_Integer	ADC averaging factor (NSEDP864)
19	ADC_SCAN	ASCII_NonNegative_Integer	ADC scan status (NSEDP867)
20	TST_TIMER	ASCII_NonNegative_Integer	Timer counter value (NSE0P107)
21	LCL_CONTROL	ASCII_NonNegative_Integer	LCL control register value (NSEGP068)
22	LCL_STATUS	ASCII_NonNegative_Integer	LCL status register value (NSEGP069)
23	MODE_CFG_U1	ASCII_NonNegative_Integer	Mirror 1 voltage lookup table selection
24	U1_MIN_RANGE	ASCII_NonNegative_Integer	U1 LUT calculation range
25	U1_FUNCTION	ASCII_NonNegative_Integer	U1 LUT calculation increment/factor
26	U1_INC_FAC	ASCII_NonNegative_Integer	U1 LUT calculation increment/factor
27	U1_MIN_VAL	ASCII_NonNegative_Integer	U1 LUT calculation start value
28	U1_MAX_VAL	ASCII_NonNegative_Integer	U1 LUT calculation end value
29	MODECFG_MEM	ASCII_NonNegative_Integer	Take mode configuration from memory
30	U1_CALC_MEM	ASCII_NonNegative_Integer	Recalculate U1 from memory settings
31	DAQ_STATUS	ASCII_NonNegative_Integer	Data acquisition cycle status
32	TM_TX_MASK	ASCII_NonNegative_Integer	Telemetry data transfer mask (NSEGP098)
33	MSET_ADDR	ASCII_NonNegative_Integer	Memory set address (NSE0P111)
34	MSET_MSB	ASCII_NonNegative_Integer	Memory set MSB (NSE0P112)
35	MSET_LSB	ASCII_NonNegative_Integer	Memory set LSB (NSE0P113)
36	CHECKSUM_OK	ASCII_NonNegative_Integer	Checksum test ok flag
37	GATE_POWER	ASCII_NonNegative_Integer	Gate power enabled flag (NSEDP855)
38	UG_SET_VAL	ASCII_NonNegative_Integer	Gate voltage set value (NSE0P058)
39	UG_SET_MON	ASCII_NonNegative_Integer	Gate control voltage (NSE0P052)
40	HK_U_GATE_P	ASCII_NonNegative_Integer	Positive gate voltage (NSE0P048)
41	HK_U_GATE_N	ASCII_NonNegative_Integer	Negative gate voltage (NSE0P049)

42	UG_SET_INC	ASCII_NonNegative_Integer	Gate voltage increment (NSE0P121)
43	UG_SET_MAX	ASCII_NonNegative_Integer	Gate voltage set limit (NSE0P120)
44	DIG1_STATUS	ASCII_NonNegative_Integer	HV and DC/DC controls status (NSEGP033)
45	DIG2_STATUS	ASCII_NonNegative_Integer	EEPROM and MRAM bank select status (NSEGP034)
46	DIG3_STATUS	ASCII_NonNegative_Integer	Detector and GED control/status (NSEGP035)
47	DIG4_STATUS	ASCII_NonNegative_Integer	Event handler control/status (NSEGP036)
48	MEAS_MODE	ASCII_NonNegative_Integer	Measurement mode (NSEDP374)
49	MODE_OPTN	ASCII_NonNegative_Integer	Measurement mode option (NSEGP037)
50	DRT_INDEX	ASCII_NonNegative_Integer	Data reduction table index (NSE0P038)
51	DRT_VERSION	ASCII_NonNegative_Integer	Data reduction table version
52	ENERGY_SET	ASCII_NonNegative_Integer	Energy set value (NSE0P032)
53	ENERGY_IDX	ASCII_NonNegative_Integer	Current energy index (NSE0P031)
54	ENERGY_MAX	ASCII_NonNegative_Integer	Maximum energy index (NSE0P030)
55	DAC_STATUS	ASCII_NonNegative_Integer	DAC control status (NSEGP062)
56	DET_PHD_CNT_A	ASCII_NonNegative_Integer	DET PHD counter A (NSE0P108)
57	DET_PHD_CNT_B	ASCII_NonNegative_Integer	DET PHD counter B (NSE0P109)
58	DISCR_LEVEL	ASCII_NonNegative_Integer	TIMPO discriminator level
59	MCP_POWER	ASCII_NonNegative_Integer	MCP high voltage enabled flag (NSEDP337)
60	MCP_SET_VAL	ASCII_NonNegative_Integer	MCP HV set value (NSE0P057)
61	MCP_SET_MON	ASCII_NonNegative_Integer	MCP HV set value (NSE0P053)
62	MCP_U_MON	ASCII_NonNegative_Integer	MCP front voltage monitor (NSE0P040)
63	MCP_I_MON	ASCII_NonNegative_Integer	MCP front current monitor (NSE0P039)
64	MCP_SET_INC	ASCII_NonNegative_Integer	MCP HV increment (NSE0P119)
65	MCP_SET_MAX	ASCII_NonNegative_Integer	MCP HV set limit (NSE0P118)
66	HK1_CYCLE	ASCII_NonNegative_Integer	HK1 packet rate (NSE0P123)
67	NSD_CYCLE	ASCII_NonNegative_Integer	NSD packet rate (NSE0P125)
68	HK2_CYCLE	ASCII_NonNegative_Integer	HK2 packet rate
69	RAW_CYCLE	ASCII_NonNegative_Integer	RAW packet rate (NSE0P124)
70	HK4_CYCLE	ASCII_NonNegative_Integer	HK4 packet rate (NSE0P126)
71	MODE_CFG	ASCII_NonNegative_Integer	Measurement mode configuration
72	LUT_MODEL	ASCII_NonNegative_Integer	Lookup table model ID
73	LUT_MATCH	ASCII_NonNegative_Integer	Lookup table compliance flag
74	LUT_VERSION	ASCII_NonNegative_Integer	Lookup table version (NSE0P110)
75	LUT_CONTROL	ASCII_NonNegative_Integer	Lookup table control byte (NSEGP066)
76	UM1_POWER	ASCII_NonNegative_Integer	U1 high voltage enabled flag (NSEDP336)
77	U1_SET_VAL	ASCII_NonNegative_Integer	U1 HV set value (NSE0P055)
78	U1_SET_MON	ASCII_NonNegative_Integer	U1 voltage set value (NSE0P050)
79	U1_MON	ASCII_NonNegative_Integer	U1 voltage monitor; in science mode products where U1 is on, this value is calculated from the selected lookup table (NSE0P042)
80	U1_V_RANGE	ASCII_NonNegative_Integer	U1 voltage range (NSEDP335)
81	U1_SET_INC	ASCII_NonNegative_Integer	U1 HV increment (NSE0P115)
82	U1_SET_MAX	ASCII_NonNegative_Integer	U1 HV set limit (NSE0P114)
83	DET_CMD	ASCII_NonNegative_Integer	Last detector command (NSE0P081)
84	DET_RBK	ASCII_NonNegative_Integer	Detector status readback (NSE0P082)
85	GED_CMD	ASCII_NonNegative_Integer	Last GED command (NSE0P083)
86	GED_RBK	ASCII_NonNegative_Integer	GED status readback (NSE0P084)
87	TofNfact	ASCII_NonNegative_Integer	TOF norm factor (NSE0P087)
88	EStpsPerPkt	ASCII_NonNegative_Integer	Number of energy steps per TM packet (NSE0P088)
89	PktsPerEStp	ASCII_NonNegative_Integer	Number of TM packets per energy step (NSE0P089)

90	AGrpsPerEStp	ASCII_NonNegative_Integer	Number of anode groups per energy step (NSE0P090)
91	NsdTxTmrCnt	ASCII_NonNegative_Integer	NSD packet transfer timer countdown (NSE0P092)
92	NsdTxTmrSet	ASCII_NonNegative_Integer	NSD packet transfer timer set value (NSE0P091)
93	EvnCountShift	ASCII_NonNegative_Integer	Event counter normalisation factor (shift value)
94	LongTermData	ASCII_NonNegative_Integer	Long-term science data transfer status (NSE0P091)
95	LtsCycleCnt	ASCII_NonNegative_Integer	Long-term data cumulation sweeps countdown (NSE0P095)
96	LtsCycleSet	ASCII_NonNegative_Integer	Long-term data cumulation sweeps set value (NSE0P094)
97	LtsTxTmrCnt	ASCII_NonNegative_Integer	Long-term data transfer countdown (NSE0P096)
98	DIGSTAT1	ASCII_NonNegative_Integer	HV and DC/DC controls status (NSEGP033)
99	MCPHVSDN	ASCII_NonNegative_Integer	MCP HV shutdown flag (NSEDP337)
100	MU1HVSDN	ASCII_NonNegative_Integer	U1 HV shutdown flag (NSEDP336)
101	MU1RANGE	ASCII_NonNegative_Integer	U1 range status (NSEDP335)
102	DCDCMODE	ASCII_NonNegative_Integer	DC/DC pulser mode (NSEDP334)
103	HVARMING	ASCII_NonNegative_Integer	HV arming plug status (NSEDP332)
104	DETOVFLW	ASCII_NonNegative_Integer	Detector overflow (NSEDP330)
105	DIGSTAT2	ASCII_NonNegative_Integer	EEPROM and MRAM bank select status (NSEGP034)
106	EEPRBANK	ASCII_NonNegative_Integer	EEPROM bank selection (NSEDP345)
107	MRAMBANK	ASCII_NonNegative_Integer	MRAM bank selection (NSEDP342)
108	MRAMBLCK	ASCII_NonNegative_Integer	NSD MRAM block selection (NSEDP341)
109	LTMMBLCK	ASCII_NonNegative_Integer	LTS MRAM block selection (NSEDP340)
110	DIGSTAT3	ASCII_NonNegative_Integer	Detector and GED control/status (NSEGP035)
111	DETRESET	ASCII_NonNegative_Integer	TIMPO reset bit (NSEDP357)
112	EVFIFORS	ASCII_NonNegative_Integer	TIMPO clear FIFO bit (NSEDP356)
113	TOFDATEN	ASCII_NonNegative_Integer	TOF enable bit (NSEDP355)
114	TOFREFEN	ASCII_NonNegative_Integer	TOF reference enable bit (NSEDP354)
115	EVPROCEN	ASCII_NonNegative_Integer	Event handling enable bit (NSEDP353)
116	SINGLEEV	ASCII_NonNegative_Integer	Single events mode status (NSEDP352)
117	EVPOLLEN	ASCII_NonNegative_Integer	Event polling enable bit (NSEDP351)
118	TESTMODE	ASCII_NonNegative_Integer	Test mode active flag (NSEDP350)
119	DIGSTAT4	ASCII_NonNegative_Integer	Event handler control/status (NSEGP036)
120	VARINCEN	ASCII_NonNegative_Integer	Variable pixel increment enable bit (NSEDP367)
121	MANPIXEN	ASCII_NonNegative_Integer	Manual pixel addressing enable bit (NSEDP366)
122	TOFCHKEN	ASCII_NonNegative_Integer	TOF multicycle check enable bit (NSEDP365)
123	EVFIFOCL	ASCII_NonNegative_Integer	Event FIFO kept clear bit (NSEDP364)
124	PIXGRPEN	ASCII_NonNegative_Integer	Pixel grouping enable bit (NSEDP363)
125	RXTIMOEN	ASCII_NonNegative_Integer	Event packet timeout enable bit (NSEDP362)
126	SECINCEN	ASCII_NonNegative_Integer	Auto-increment fine time seconds counter (NSEDP361)
127	FHTREADY	ASCII_NonNegative_Integer	FHT read status bit (NSEDP360)

***Table A-28 –** PICAM Raw housekeeping data products fields description (HK2)*

Column #	Title	Data Type	Description
1	TIME_UTC	ASCII_Date_Time_YMD	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.SSS
2	TIME_OBT	ASCII_String	S/C CLOCK AT OBSERVATION TIME: SSSSSSSSSS.FFFFF

3	ORBNUM	ASCII_NonNegative_Integer	Orbit number (0 in non-Mercury mission phases)
4	SEQ_CNT	ASCII_NonNegative_Integer	Packet sequence counter
5	QUALITY	ASCII_NonNegative_Integer	Data quality (bit combination of: 0=perfect [no error], 1=checksum error, 2=missing HK params, 4=missing gate params, 8=incomplete sweep, 16=packet index out of range, 32=decompression error, 64=hadamard decoding error, 128=missing measurement time)
6	SPID	ASCII_NonNegative_Integer	Packet SPID
7	RELAY_STAT	ASCII_NonNegative_Integer	Relay status (NSEGP085)
8	HK_U_GATE_P	ASCII_NonNegative_Integer	Positive gate voltage (NSE0P048)
9	HK_U_GATE_N	ASCII_NonNegative_Integer	Negative gate voltage (NSE0P049)
10	DIG1_STATUS	ASCII_NonNegative_Integer	HV and DC/DC controls status (NSEGP033)
11	ENERGY_MAX	ASCII_NonNegative_Integer	Maximum energy index (NSE0P030)
12	NSD_CYCLE	ASCII_NonNegative_Integer	NSD packet rate (NSE0P125)
13	LUT_MODEL	ASCII_NonNegative_Integer	Lookup table model ID
14	LUT_VERSION	ASCII_NonNegative_Integer	Lookup table version (NSE0P110)
15	LUT_CONTROL	ASCII_NonNegative_Integer	Lookup table control byte (NSEGP066)
16	U1_SET_VAL	ASCII_NonNegative_Integer	U1 HV set value (NSE0P055)
17	U1_SET_MON	ASCII_NonNegative_Integer	U1 voltage set value (NSE0P050)
18	U1_MON	ASCII_NonNegative_Integer	U1 voltage monitor; in science mode products where U1 is on, this value is calculated from the selected lookup table (NSE0P042)
19	TofNfact	ASCII_NonNegative_Integer	TOF norm factor (NSE0P087)
20	NsdTxTmrSet	ASCII_NonNegative_Integer	NSD packet transfer timer set value (NSE0P091)
21	GED_CHIP_TIME	ASCII_NonNegative_Integer	GED chip time
22	NSD_STRUCTID	ASCII_NonNegative_Integer	Structure identifier
23	NSD_MEASMODE	ASCII_NonNegative_Integer	Measurment mode
24	NSD_NUMENERG	ASCII_NonNegative_Integer	Number of energies per packet
25	NSD_NUMAGRPS	ASCII_NonNegative_Integer	Number of anode groups per energy
26	NSD_TABLEIDX	ASCII_NonNegative_Integer	Data reduction table index
27	NSD_TABLEVER	ASCII_NonNegative_Integer	Data reduction table version
28	NSD_NUMTOFS	ASCII_NonNegative_Integer	Number of TOFs to be considered
29	NSD_MEASTIME	ASCII_Date_Time_YMD	Measurement time: YYYY-MM-DDTHH:MM:SS.SSS
30	NSD_IDXENERG	ASCII_NonNegative_Integer	Index of first energy in packet
31	NSD_IDXAGRPS	ASCII_NonNegative_Integer	Index of first group within energy
32	NSD_OPTIONS	ASCII_NonNegative_Integer	Measurement mode options
33	PLANET_SUN_X	ASCII_Real	Depending on the mission phase this is the X coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
34	PLANET_SUN_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
35	PLANET_SUN_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise

36	MPO_SUN_X	ASCII_Real	This is the X coordinate in the MPO S/C reference frame of the vector MPO-SUN
37	MPO_SUN_Y	ASCII_Real	This is the Y coordinate in the MPO S/C reference frame of the vector MPO-SUN
38	MPO_SUN_Z	ASCII_Real	This is the Z coordinate in the MPO S/C reference frame of the vector MPO-SUN
39	MPO_PLANET_X	ASCII_Real	Depending on the mission phase this is the X coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
40	MPO_PLANET_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
41	MPO_PLANET_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
42	ANGLE_PLANET_SUN_MPO	ASCII_Real	Depending on the mission phase this is the angle between either Earth-Sun vector and Earth-MPO vector, Venus-Sun vector and Venus-MPO vector or Mercury-Sun vector and Mercury-MPO vector, or -1 for cruise
43	MPO_MMO_X	ASCII_Real	X coordinate of the vector MPO-MMO in the MPO S/C reference frame
44	MPO_MMO_Y	ASCII_Real	Y coordinate of the vector MPO-MMO in the MPO S/C reference frame
45	MPO_MMO_Z	ASCII_Real	Z coordinate of the vector MPO-MMO in the MPO S/C reference frame
46	MPO_ALTITUDE	ASCII_Real	Depending on the mission phase this is the MPO altitude over either Earth, Venus or Mercury surface, or -1 for cruise
47	MMO_ALTITUDE	ASCII_Real	Depending on the mission phase this is the MMO altitude over either Earth, Venus or Mercury surface, or -1 for cruise
48	MPO_DIST_PLANET	ASCII_Real	Depending on the mission phase this is the distance of MPO to the center of either Earth, Venus or Mercury, or -1 for cruise
49	MMO_DIST_PLANET	ASCII_Real	Depending on the mission phase this is the distance of MMO to the center of either Earth, Venus or Mercury, or -1 for cruise
50	LATITUDE	ASCII_Real	Depending on the mission phase this is the MPO latitude in either GSM, MSM or VSO system or -1 for cruise
51	LONGITUDE	ASCII_Real	Depending on the mission phase this is the MPO longitude in either GSM, MSM or VSO system or -1 for cruise
52	LATLON_RAD	ASCII_Real	Radius related to magnetic latitude and longitude of MPO
53	FRAME1	ASCII_String	Depending on the mission phase this is the rotation matrix1 to rotate vectors from MPO S/C frame into either GSE, VSO, MSO or HEE reference frame (for cruise)
54	M1_A11	ASCII_Real	Component M11 of rotation matrix 1
55	M1_A12	ASCII_Real	Component M12 of rotation matrix 1

56	M1_A13	ASCII_Real	Component M13 of rotation matrix 1
57	M1_A21	ASCII_Real	Component M21 of rotation matrix 1
58	M1_A22	ASCII_Real	Component M22 of rotation matrix 1
59	M1_A23	ASCII_Real	Component M23 of rotation matrix 1
60	M1_A31	ASCII_Real	Component M31 of rotation matrix 1
61	M1_A32	ASCII_Real	Component M32 of rotation matrix 1
62	M1_A33	ASCII_Real	Component M33 of rotation matrix 1
63	FRAME2	ASCII_String	Depending on the mission phase this is the rotation matrix2 to rotate vectors from MPO S/C frame into either GSM or MSM frame or VSO or HEE frame (for cruise)
64	M2_A11	ASCII_Real	Component M11 of rotation matrix 2
65	M2_A12	ASCII_Real	Component M12 of rotation matrix 2
66	M2_A13	ASCII_Real	Component M13 of rotation matrix 2
67	M2_A21	ASCII_Real	Component M21 of rotation matrix 2
68	M2_A22	ASCII_Real	Component M22 of rotation matrix 2
69	M2_A23	ASCII_Real	Component M23 of rotation matrix 2
70	M2_A31	ASCII_Real	Component M31 of rotation matrix 2
71	M2_A32	ASCII_Real	Component M32 of rotation matrix 2
72	M2_A33	ASCII_Real	Component M33 of rotation matrix 2
73	COMPRESSED	ASCII_NonNegative_Integer	0=no compression, 1=Huffman compressed by SCU, 2=Huffman/Semilog compressed by SCU, 3=Huffman compressed by PICAM
74	DECOMPRESSED	ASCII_NonNegative_Integer	Packet is decompressed
75	SWEEP_PACKET_NUMBER	ASCII_NonNegative_Integer	The part of a sweep a packet belongs to (counts from 0 to PacketsPerSweep - 1)
76	HADAMARD_CODED	ASCII_NonNegative_Integer	Packet is hadamard coded
77	HADAMARD_DECODED	ASCII_NonNegative_Integer	0=no decoding, 1=Hadamard deconvolution done by archive S/W, 2=inverse Hadamard done by PICAM
78	SWEEP_INDEX	ASCII_NonNegative_Integer	A consecutive number marking the rows that make up an energy sweep
79	ACCU_TIME	ASCII_Real	Accumulation time
80	DEAD_TIME	ASCII_Real	Dead time after changing U1 energy
81	ENERGY_INDEX	ASCII_NonNegative_Integer	Actual energy index of data in this row
82	ENERGY_STEP	ASCII_Real	Energy step value
83	ANODE_INDEX	ASCII_NonNegative_Integer	Actual anode group index of the science data in this row
84-595	B (0-511)	ASCII_Integer	Ion counts per Time-of-Flight bin

Table A-29 *– PICAM Raw science data products fields description (ToF mode)*

Column #	Title	Data Type	description
1	TIME_UTC	ASCII_Date_Time_YMD	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.SSS
2	TIME_OBT	ASCII_String	S/C CLOCK AT OBSERVATION TIME: SSSSSSSSSS.FFFFF
3	ORBNUM	ASCII_NonNegative_Integer	Orbit number (0 in non-Mercury mission phases)
4	SEQ_CNT	ASCII_NonNegative_Integer	Packet sequence counter
5	QUALITY	ASCII_NonNegative_Integer	Data quality (bit combination of: 0=perfect [no error], 1=checksum error,

			2=missing HK params, 4=missing gate params, 8=incomplete sweep, 16=packet index out of range, 32=decompression error, 64=hadamard decoding error, 128=missing measurement time)
6	SPID	ASCII_NonNegative_Integer	Packet SPID
7	RELAY_STAT	ASCII_NonNegative_Integer	Relay status (NSEGP085)
8	HK_U_GATE_P	ASCII_NonNegative_Integer	Positive gate voltage (NSE0P048)
9	HK_U_GATE_N	ASCII_NonNegative_Integer	Negative gate voltage (NSE0P049)
10	DIG1_STATUS	ASCII_NonNegative_Integer	HV and DC/DC controls status (NSEGP033)
11	ENERGY_MAX	ASCII_NonNegative_Integer	Maximum energy index (NSE0P030)
12	NSD_CYCLE	ASCII_NonNegative_Integer	NSD packet rate (NSE0P125)
13	LUT_MODEL	ASCII_NonNegative_Integer	Lookup table model ID
14	LUT_VERSION	ASCII_NonNegative_Integer	Lookup table version (NSE0P110)
15	LUT_CONTROL	ASCII_NonNegative_Integer	Lookup table control byte (NSEGP066)
16	U1_SET_VAL	ASCII_NonNegative_Integer	U1 HV set value (NSE0P055)
17	U1_SET_MON	ASCII_NonNegative_Integer	U1 voltage set value (NSE0P050)
18	U1_MON	ASCII_NonNegative_Integer	U1 voltage monitor; in science mode products where U1 is on, this value is calculated from the selected lookup table (NSE0P042)
19	TofNfact	ASCII_NonNegative_Integer	TOF norm factor (NSE0P087)
20	NsdTxTmrSet	ASCII_NonNegative_Integer	NSD packet transfer timer set value (NSE0P091)
21	GED_CHIP_TIME	ASCII_NonNegative_Integer	GED chip time
22	NSD_STRUCTID	ASCII_NonNegative_Integer	Structure identifier
23	NSD_MEASMODE	ASCII_NonNegative_Integer	Measurment mode
24	NSD_NUMENERG	ASCII_NonNegative_Integer	Number of energies per packet
25	NSD_NUMAGRPS	ASCII_NonNegative_Integer	Number of anode groups per energy
26	NSD_TABLEIDX	ASCII_NonNegative_Integer	Data reduction table index
27	NSD_TABLEVER	ASCII_NonNegative_Integer	Data reduction table version
28	NSD_NUMTOFS	ASCII_NonNegative_Integer	Number of TOFs
29	NSD_MEASTIME	ASCII_Date_Time_YMD	Measurement time: YYYY-MM-DDTHH:MM:SS.SSS
30	NSD_IDXENERG	ASCII_NonNegative_Integer	Index of first energy in packet
31	NSD_IDXAGRPS	ASCII_NonNegative_Integer	Index of first group within energy
32	NSD_OPTIONS	ASCII_NonNegative_Integer	Measurement mode options
33	PLANET_SUN_X	ASCII_Real	Depending on the mission phase this is the X coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
34	PLANET_SUN_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
35	PLANET_SUN_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
36	MPO_SUN_X	ASCII_Real	This is the X coordinate in the MPO S/C reference frame of the vector MPO-SUN
37	MPO_SUN_Y	ASCII_Real	This is the Y coordinate in the MPO S/C reference frame of the vector MPO-SUN
38	MPO_SUN_Z	ASCII_Real	This is the Z coordinate in the MPO S/C reference frame of the vector MPO-SUN

39	MPO_PLANET_X	ASCII_Real	Depending on the mission phase this is the X coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
40	MPO_PLANET_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
41	MPO_PLANET_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
42	ANGLE_PLANET_SUN_MPO	ASCII_Real	Depending on the mission phase this is the angle between either Earth-Sun vector and Earth-MPO vector, Venus-Sun vector and Venus-MPO vector or Mercury-Sun vector and Mercury-MPO vector, or -1 for cruise
43	MPO_MMO_X	ASCII_Real	X coordinate of the vector MPO-MMO in the MPO S/C reference frame
44	MPO_MMO_Y	ASCII_Real	Y coordinate of the vector MPO-MMO in the MPO S/C reference frame
45	MPO_MMO_Z	ASCII_Real	Z coordinate of the vector MPO-MMO in the MPO S/C reference frame
46	MPO_ALTITUDE	ASCII_Real	Depending on the mission phase this is the MPO altitude over either Earth, Venus or Mercury surface, or -1 for cruise
47	MMO_ALTITUDE	ASCII_Real	Depending on the mission phase this is the MMO altitude over either Earth, Venus or Mercury surface, or -1 for cruise
48	MPO_DIST_PLANET	ASCII_Real	Depending on the mission phase this is the distance of MPO to the center of either Earth, Venus or Mercury, or -1 for cruise
49	MMO_DIST_PLANET	ASCII_Real	Depending on the mission phase this is the distance of MMO to the center of either Earth, Venus or Mercury, or -1 for cruise
50	LATITUDE	ASCII_Real	Depending on the mission phase this is the MPO magnetic latitude in either GSM or MSM system, or -1 for Venus and cruise
51	LONGITUDE	ASCII_Real	Depending on the mission phase this is the MPO magnetic longitude in either GSM or MSM system, or -1 for Venus and cruise
52	LATLON_RAD	ASCII_Real	Radius related to magnetic latitude and longitude of MPO
53	FRAME1	ASCII_String	Depending on the mission phase this is the rotation matrix1 to rotate vectors from MPO S/C frame into either GSE, VSO, MSO or HEE reference frame (for cruise)
54	M1_A11	ASCII_Real	Component M11 of rotation matrix 1
55	M1_A12	ASCII_Real	Component M12 of rotation matrix 1
56	M1_A13	ASCII_Real	Component M13 of rotation matrix 1
57	M1_A21	ASCII_Real	Component M21 of rotation matrix 1
58	M1_A22	ASCII_Real	Component M22 of rotation matrix 1
59	M1_A23	ASCII_Real	Component M23 of rotation matrix 1

60	M1_A31	ASCII_Real	Component M31 of rotation matrix 1
61	M1_A32	ASCII_Real	Component M32 of rotation matrix 1
62	M1_A33	ASCII_Real	Component M33 of rotation matrix 1
63	FRAME2	ASCII_String	Depending on the mission phase this is the rotation matrix2 to rotate vectors from MPO S/C frame into either GSM or MSM frame or VSO or HEE frame (for cruise)
64	M2_A11	ASCII_Real	Component M11 of rotation matrix 2
65	M2_A12	ASCII_Real	Component M12 of rotation matrix 2
66	M2_A13	ASCII_Real	Component M13 of rotation matrix 2
67	M2_A21	ASCII_Real	Component M21 of rotation matrix 2
68	M2_A22	ASCII_Real	Component M22 of rotation matrix 2
69	M2_A23	ASCII_Real	Component M23 of rotation matrix 2
70	M2_A31	ASCII_Real	Component M31 of rotation matrix 2
71	M2_A32	ASCII_Real	Component M32 of rotation matrix 2
72	M2_A33	ASCII_Real	Component M33 of rotation matrix 2
73	COMPRESSED	ASCII_NonNegative_Integer	0=no compression, 1=Huffman compressed by SCU, 2=Huffman/Semilog compressed by SCU, 3=Huffman compressed by PICAM
74	DECOMPRESSED	ASCII_NonNegative_Integer	Packet is decompressed
75	SWEEP_PACKET_NUMBER	ASCII_NonNegative_Integer	The part of a sweep a packet belongs to (counts from 0 to PacketsPerSweep - 1)
76	SWEEP_INDEX	ASCII_NonNegative_Integer	A consecutive number marking the rows that make up an energy sweep
77	ACCU_TIME	ASCII_Real	Accumulation time
78	DEAD_TIME	ASCII_Real	Dead time after changing U1 energy
79	ENERGY_INDEX	ASCII_NonNegative_Integer	Actual energy index of data in this row
80	ENERGY_STEP	ASCII_Real	Energy step value
81-112	A (0-31)	ASCII_Integer	Ion counts per anodegroup

Table A-30 – *PICAM Raw science data products fields description (Mode 1 to 6)*

A.4.2 PICAM Calibrated Data Products Fields Description

Column #	Title	Data Type	Description
1	TIME_UTC	ASCII_Date_Time_YMD	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.SSS
2	TIME_OBT	ASCII_String	S/C CLOCK AT OBSERVATION TIME: SSSSSSSSSS.FFFFF
3	ORBNUM	ASCII_NonNegative_Integer	Orbit number (0 in non-Mercury mission phases)
4	SEQ_CNT	ASCII_NonNegative_Integer	Packet sequence counter
5	QUALITY	ASCII_NonNegative_Integer	Data quality (bit combination of: 0=perfect [no error], 1=checksum error, 2=missing HK params, 4=missing gate params, 8=incomplete sweep, 16=packet index out of range, 32=decompression error, 64=hadamard decoding error, 128=missing measurement time)
6	SPID	ASCII_NonNegative_Integer	Packet SPID

7	HW_VERSION	ASCII_NonNegative_Integer	Hardware version (NSE0P001)
8	SW_V_MAJOR	ASCII_NonNegative_Integer	Software major version (NSE0P002H)
9	SW_V_MINOR	ASCII_NonNegative_Integer	S/W minor version (NSE0P002L)
10	SW_REVISION	ASCII_NonNegative_Integer	Software revision number (NSE0P003)
11	SW_REV_STAT	ASCII_String	Software revision status
12	STATUS_2_MODID	ASCII_String	PICAM model Id (NSEDP052)
13	STATUS_1_RC	ASCII_String	RAM check (NSEDP043)
14	STATUS_1_EEPCK	ASCII_String	EEPROM check (NSEDP045)
15	STATUS_1_EEPWE	ASCII_String	EEPROM write enabled (NSEDP044)
16	PGM_CRC_SAVE	ASCII_NonNegative_Integer	Program checksum stored in EEPROM (NSE0P006)
17	PGM_CRC_CALC	ASCII_NonNegative_Integer	Program checksum calculated (NSE0P007)
18	STATUS_1_HVCS	ASCII_String	HV connector status (NSEDP041)
19	STATUS_2_TPO	ASCII_String	TIMPO output status (NSEDP054)
20	STATUS_2_DC	ASCII_String	Timpo control lines enabled/disabled (0/1) (NSEDP051)
21	STATUS_1_WS	ASCII_String	Watchdog status (NSEDP042)
22	STATUS_2_SPW	ASCII_String	SPW address error bit (NSEDP055)
23	STATUS_2_CPU	ASCII_String	CPU mode active (NSEDP050)
24	STATUS_2_OPM	ASCII_String	Operating mode (NSEDP056)
25	TC_BUF_UTIL	ASCII_Real	TC buffer utilisation (NSE0P080)
26	PROC_LOAD	ASCII_Real	CPU utilisation (NSE0P020)
27	LAST_TC_ACC	ASCII_String	Last TC accepted by PICAM
28	LAST_TC_REJ	ASCII_String	Last TC rejected by PICAM
29	LAST_TC_REJ_CAUSE	ASCII_String	Failure ID of last TC rejected by PICAM (NSE0P014)
30	LAST_TC_REJ_INDEX	ASCII_NonNegative_Integer	Invalid parameter offset (NSE0P012)
31	LAST_TC_EXE	ASCII_String	Last TC successfully executed
32	LAST_TC_ERR	ASCII_String	Last TC not executed properly
33	LAST_TC_ERR_CAUSE	ASCII_String	Failure ID of last erroneous TC (NSE0P013)
34	LAST_TC_ERR_INDEX	ASCII_NonNegative_Integer	Invalid parameter offset (NSE0P019)
35	STATUS_1_TCAPID	ASCII_String	TC packet APID error (NSEDP040)
36	STATUS_1_TCTIMO	ASCII_String	TC packet timeout (NSEDP046)
37	STATUS_1_TCCSUM	ASCII_String	TC packet CRC error (NSEDP047)
38	TC_COUNTER	ASCII_NonNegative_Integer	Number of TCs received since power on (NSE0P022)
39	HOT_TEMP	ASCII_Real	TempHot (NSE0P029)
40	DPU_TEMP	ASCII_Real	TempDPU (NSE0P023)
41	P3_3_V_MON	ASCII_Real	+3.3V voltage monitor (NSE0P024)

42	P1_5_V_MON	ASCII_Real	+1.5V voltage monitor (NSE0P025)
43	P5_V_MON	ASCII_Real	+5V voltage monitor (NSE0P026)
44	P12_V_MON	ASCII_Real	+12V voltage monitor (NSE0P027)
45	N12_V_MON	ASCII_Real	-12V voltage monitor (NSE0P028)
46	HK_ADDR_1	ASCII_NonNegative_Integer	Memory dump address 1 (NSE0P076)
47	HK_DATA_1	ASCII_NonNegative_Integer	Value of memory address 1 (NSE0P078)
48	HK_ADDR_2	ASCII_NonNegative_Integer	Memory dump address 2 (NSE0P077)
49	HK_ADDR_2	ASCII_NonNegative_Integer	Memory dump address 2 (NSE0P077)

***Table A-31** – PICAM Calibrated housekeeping data products fields description (HK1)*

Column #	Title	Data Type	Description
1	TIME_UTC	ASCII_Date_Time_YMD	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.SSS
2	TIME_OBT	ASCII_String	S/C CLOCK AT OBSERVATION TIME: SSSSSSSSSS.FFFFF
3	ORBNUM	ASCII_NonNegative_Integer	Orbit number (0 in non-Mercury mission phases)
4	SEQ_CNT	ASCII_NonNegative_Integer	Packet sequence counter
5	QUALITY	ASCII_NonNegative_Integer	Data quality (bit combination of: 0=perfect [no error], 1=checksum error, 2=missing HK params, 4=missing gate params, 8=incomplete sweep, 16=packet index out of range, 32=decompression error, 64=hadamard decoding error, 128=missing measurement time)
6	SPID	ASCII_NonNegative_Integer	Packet SPID
7	HV_SW_ENA	ASCII_String	HVC S/W enabled flag
8	UDFL_SET_VAL	ASCII_Real	Udfl HV value (NSE0P056)
9	UDFL_SET_MON	ASCII_Real	Deflector voltage set value (NSE0P051)
10	UDFL_MON	ASCII_Real	Deflector voltage monitor (NSE0P044)
11	UG_V_RANGE	ASCII_String	Gate voltage range (NSEDP857)
12	UDFL_SET_INC	ASCII_Real	Deflector voltage increment (NSE0P117)
13	UDFL_SET_MAX	ASCII_Real	Deflector voltage set limit (NSE0P116)
14	HVC_TEMP	ASCII_Real	High voltage converter temperature (NSE0P046)
15	DET_HK_TEMP	ASCII_Real	Detector temperature (NSE0P047)
16	GED_HK_TEMP	ASCII_Real	Gate electronics temperature (NSE0P054)
17	RELAY_STAT	ASCII_NonNegative_Integer	Relay status (NSEGP085)
18	ADC_FACTOR	ASCII_String	ADC averaging factor (NSEDP864)
19	ADC_SCAN	ASCII_String	ADC scan status (NSEDP867)
20	TST_TIMER	ASCII_Real	Timer counter value (NSE0P107)
21	LCL_CONTROL	ASCII_Numeric_Base2	LCL control register value (NSEGP068)

22	LCL_STATUS	ASCII_Numeric_Base2	LCL status register value (NSEGP069)
23	MODE_CFG_U1	ASCII_String	Mirror 1 voltage lookup table selection
24	U1_MIN_RANGE	ASCII_String	U1 LUT calculation range (NSEDPxxx)
25	U1_FUNCTION	ASCII_String	U1 LUT calculation increment/factor (NSEDPxxx)
26	U1_INC_FAC	ASCII_Real	U1 LUT calculation increment/factor (NSEDPxxx)
27	U1_MIN_VAL	ASCII_Real	U1 LUT calculation start value (NSEDPxxx)
28	U1_MAX_VAL	ASCII_Real	U1 LUT calculation end value (NSEDPxxx)
29	MODECFG_MEM	ASCII_String	Take mode configuration from memory (NSEDPxxx)
30	U1_CALC_MEM	ASCII_String	Recalculate U1 from memory settings (NSEDPxxx)
31	DAQ_STATUS	ASCII_String	Data acquisition cycle status
32	TM_TX_MASK	ASCII_Numeric_Base2	Telemetry data transfer mask (NSEGP098)
33	MSET_ADDR	ASCII_NonNegative_Integer	Memory set address (NSE0P111)
34	MSET_MSB	ASCII_NonNegative_Integer	Memory set MSB (NSE0P112)
35	MSET_LSB	ASCII_NonNegative_Integer	Memory set LSB (NSE0P113)
36	CHECKSUM_OK	ASCII_String	Checksum test ok flag
37	GATE_POWER	ASCII_String	Gate power enabled flag (NSEDP855)
38	UG_SET_VAL	ASCII_Real	Gate voltage set value (NSE0P058)
39	UG_SET_MON	ASCII_Real	Gate control voltage (NSE0P052)
40	HK_U_GATE_P	ASCII_Real	Positive gate voltage (NSE0P048)
41	HK_U_GATE_N	ASCII_Real	Negative gate voltage (NSE0P049)
42	UG_SET_INC	ASCII_Real	Gate voltage increment (NSE0P121)
43	UG_SET_MAX	ASCII_Real	Gate voltage set limit (NSE0P120)
44	DIG1_STATUS	ASCII_NonNegative_Integer	HV and DC/DC controls status (NSEGP033)
45	DIG2_STATUS	ASCII_NonNegative_Integer	EEPROM and MRAM bank select status (NSEGP034)
46	DIG3_STATUS	ASCII_NonNegative_Integer	Detector and GED control/status (NSEGP035)
47	DIG4_STATUS	ASCII_NonNegative_Integer	Event handler control/status (NSEGP036)
48	MEAS_MODE	ASCII_String	Measurement mode (NSEDP374)
49	MODE_OPTN	ASCII_String	Measurement mode option (NSEGP037)
50	DRT_INDEX	ASCII_NonNegative_Integer	Data reduction table index (NSE0P038)
51	DRT_VERSION	ASCII_NonNegative_Integer	Data reduction table version
52	ENERGY_SET	ASCII_NonNegative_Integer	Energy set value (NSE0P032)
53	ENERGY_IDX	ASCII_NonNegative_Integer	Current energy index (NSE0P031)
54	ENERGY_MAX	ASCII_NonNegative_Integer	Maximum energy index (NSE0P030)
55	DAC_STATUS	ASCII_Numeric_Base2	DAC control status (NSEGP062)
56	DET_PHD_CNT_A	ASCII_NonNegative_Integer	DET PHD counter A (NSE0P108)

57	DET_PHD_CNT_B	ASCII_NonNegative_Integer	DET PHD counter B (NSE0P109)
58	DISCR_LEVEL	ASCII_NonNegative_Integer	TIMPO discriminator level
59	MCP_POWER	ASCII_String	MCP high voltage enabled flag (NSEDP337)
60	MCP_SET_VAL	ASCII_Real	MCP HV set value (NSE0P057)
61	MCP_SET_MON	ASCII_Real	MCP HV set value (NSE0P053)
62	MCP_U_MON	ASCII_Real	MCP front voltage monitor (NSE0P040)
63	MCP_I_MON	ASCII_Real	MCP front current monitor (NSE0P039)
64	MCP_SET_INC	ASCII_Real	MCP HV increment (NSE0P119)
65	MCP_SET_MAX	ASCII_Real	MCP HV set limit (NSE0P118)
66	HK1_CYCLE	ASCII_NonNegative_Integer	HK1 packet rate (NSE0P123)
67	NSD_CYCLE	ASCII_Real	NSD packet rate (NSE0P125)
68	HK2_CYCLE	ASCII_NonNegative_Integer	HK2 packet rate
69	RAW_CYCLE	ASCII_NonNegative_Integer	RAW packet rate (NSE0P124)
70	HK4_CYCLE	ASCII_NonNegative_Integer	HK4 packet rate (NSE0P126)
71	MODE_CFG	ASCII_NonNegative_Integer	Measurement mode configuration
72	LUT_MODEL	ASCII_String	Lookup table model ID
73	LUT_MATCH	ASCII_String	Lookup table compliance flag
74	LUT_VERSION	ASCII_NonNegative_Integer	Lookup table version (NSE0P110)
75	LUT_CONTROL	ASCII_Numeric_Base2	Lookup table control byte (NSEGP066)
76	UM1_POWER	ASCII_String	U1 high voltage enabled flag (NSEDP336)
77	U1_SET_VAL	ASCII_Real	U1 HV set value (NSE0P055)
78	U1_SET_MON	ASCII_Real	U1 voltage set value (NSE0P050)
79	U1_MON	ASCII_Real	U1 voltage monitor; in science mode products where U1 is on, this value is calculated from the selected lookup table (NSE0P042)
80	U1_V_RANGE	ASCII_String	U1 voltage range (NSEDP335)
81	U1_SET_INC	ASCII_Real	U1 HV increment (NSE0P115)
82	U1_SET_MAX	ASCII_Real	U1 HV set limit (NSE0P114)
83	DET_CMD	ASCII_NonNegative_Integer	Last detector command (NSE0P081)
84	DET_RBK	ASCII_NonNegative_Integer	Detector status readback (NSE0P082)
85	GED_CMD	ASCII_NonNegative_Integer	Last GED command (NSE0P083)
86	GED_RBK	ASCII_NonNegative_Integer	GED status readback (NSE0P084)
87	TofNfact	ASCII_NonNegative_Integer	TOF norm factor (NSE0P087)
88	EStpsPerPkt	ASCII_NonNegative_Integer	Number of energy steps per TM packet (NSE0P088)
89	PktsPerEStp	ASCII_NonNegative_Integer	Number of TM packets per energy step (NSE0P089)
90	AGrpsPerEStp	ASCII_NonNegative_Integer	Number of anode groups per energy step (NSE0P090)

91	NsdTxTmrCnt	ASCII_NonNegative_Integer	NSD packet transfer timer countdown (NSE0P092)
92	NsdTxTmrSet	ASCII_NonNegative_Integer	NSD packet transfer timer set value (NSE0P091)
93	EvnCountShift	ASCII_NonNegative_Integer	Event counter normalisation factor (shift value)
94	LongTermData	ASCII_String	Long-term science data transfer status (NSE0P091)
95	LtsCycleCnt	ASCII_NonNegative_Integer	Long-term data cumulation sweeps countdown (NSE0P095)
96	LtsCycleSet	ASCII_NonNegative_Integer	Long-term data cumulation sweeps set value (NSE0P094)
97	LtsTxTmrCnt	ASCII_NonNegative_Integer	Long-term data transfer countdown (NSE0P096)
98	DIGSTAT1	ASCII_NonNegative_Integer	HV and DC/DC controls status (NSEGP033)
99	MCPHVSDN	ASCII_String	MCP HV shutdown flag (NSEDP337)
100	MU1HVSDN	ASCII_String	U1 HV shutdown flag (NSEDP336)
101	MU1RANGE	ASCII_String	U1 range status (NSEDP335)
102	DCDCMODE	ASCII_String	DC/DC pulser mode (NSEDP334)
103	HVARMING	ASCII_String	HV arming plug status (NSEDP332)
104	DETOVFLW	ASCII_String	Detector overflow (NSEDP330)
105	DIGSTAT2	ASCII_NonNegative_Integer	EEPROM and MRAM bank select status (NSEGP034)
106	EEPRBANK	ASCII_NonNegative_Integer	EEPROM bank selection (NSEDP345)
107	MRAMBANK	ASCII_NonNegative_Integer	MRAM bank selection (NSEDP342)
108	MRAMBLCK	ASCII_NonNegative_Integer	NSD MRAM block selection (NSEDP341)
109	LTMMBLCK	ASCII_NonNegative_Integer	LTS MRAM block selection (NSEDP340)
110	DIGSTAT3	ASCII_NonNegative_Integer	Detector and GED control/status (NSEGP035)
111	DETRESET	ASCII_String	TIMPO reset bit (NSEDP357)
112	EVFIFORS	ASCII_String	TIMPO clear FIFO bit (NSEDP356)
113	TOFDATEN	ASCII_String	TOF enable bit (NSEDP355)
114	TOFREFEN	ASCII_String	TOF reference enable bit (NSEDP354)
115	EVPROCEN	ASCII_String	Event handling enable bit (NSEDP353)
116	SINGLEEV	ASCII_String	Single events mode status (NSEDP352)
117	EVPOLLEN	ASCII_String	Event polling enable bit (NSEDP351)
118	TESTMODE	ASCII_String	Test mode active flag (NSEDP350)
119	DIGSTAT4	ASCII_NonNegative_Integer	Event handler control/status (NSEGP036)
120	VARINCEN	ASCII_String	Variable pixel increment enable bit (NSEDP367)
121	MANPIXEN	ASCII_String	Manual pixel addressing enable bit (NSEDP366)
122	TOFCHKEN	ASCII_String	TOF multicycle check enable bit (NSEDP365)
123	EVFIFOCL	ASCII_String	Event FIFO kept clear bit (NSEDP364)

124	PIXGRPEN	ASCII_String	Pixel grouping enable bit (NSEDP363)
125	RXTIMOEN	ASCII_String	Event packet timeout enable bit (NSEDP362)
126	SECINCEN	ASCII_String	Auto-increment fine time seconds counter (NSEDP361)
127	FHTREADY	ASCII_String	FHT read status bit (NSEDP360)

***Table A-32** – PICAM Calibrated housekeeping data products fields description (HK2)*

Column #	Title	Data Type	Description
1	TIME_UTC	ASCII_Date_Time_YMD	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.SSS
2	TIME_OBT	ASCII_String	S/C CLOCK AT OBSERVATION TIME: SSSSSSSSSS.FFFFF
3	ORBNUM	ASCII_NonNegative_Integer	Orbit number (0 in non-Mercury mission phases)
4	SEQ_CNT	ASCII_NonNegative_Integer	Packet sequence counter
5	QUALITY	ASCII_NonNegative_Integer	Data quality (bit combination of: 0=perfect [no error], 1=checksum error, 2=missing HK params, 4=missing gate params, 8=incomplete sweep, 16=packet index out of range, 32=decompression error, 64=hadamard decoding error, 128=missing measurement time, 256=Semilog decompression not implemented)
6	SPID	ASCII_NonNegative_Integer	Packet SPID
7	HK_U_GATE_P	ASCII_NonNegative_Integer	Positive gate voltage (NSE0P048)
8	HK_U_GATE_N	ASCII_NonNegative_Integer	Negative gate voltage (NSE0P049)
9	U1_SET_VAL	ASCII_NonNegative_Integer	U1 HV set value (NSE0P055)
10	U1_SET_MON	ASCII_NonNegative_Integer	U1 voltage set value (NSE0P050)
11	U1_MON	ASCII_NonNegative_Integer	U1 voltage monitor; in science mode products where U1 is on, this value is calculated from the selected lookup table (NSE0P042)
12	TofNfact	ASCII_NonNegative_Integer	TOF norm factor (NSE0P087)
13	NsdTxTmrSet	ASCII_NonNegative_Integer	NSD packet transfer timer set value (NSE0P091)
14	GED_CHIP_TIME	ASCII_NonNegative_Integer	GED chip time
15	GED_GATE_TIME	ASCII_NonNegative_Integer	GED gate time
16	NSD_STRUCTID	ASCII_NonNegative_Integer	Structure identifier
17	NSD_MEASTIME	ASCII_Date_Time_YMD	Measurement time: YYYY-MM-DDTHH:MM:SS.SSS
18	NSD_OPTIONS	ASCII_NonNegative_Integer	Measurement mode options
19	PLANET_SUN_X	ASCII_Real	Depending on the mission phase this is the X coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
20	PLANET_SUN_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
21	PLANET_SUN_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise

22	MPO_SUN_X	ASCII_Real	This is the X coordinate in the MPO S/C reference frame of the vector MPO-SUN
23	MPO_SUN_Y	ASCII_Real	This is the Y coordinate in the MPO S/C reference frame of the vector MPO-SUN
24	MPO_SUN_Z	ASCII_Real	This is the Z coordinate in the MPO S/C reference frame of the vector MPO-SUN
25	MPO_PLANET_X	ASCII_Real	Depending on the mission phase this is the X coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
26	MPO_PLANET_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
27	MPO_PLANET_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
28	ANGLE_PLANET_SUN_MPO	ASCII_Real	Depending on the mission phase this is the angle between either Earth-Sun vector and Earth-MPO vector, Venus-Sun vector and Venus-MPO vector or Mercury-Sun vector and Mercury-MPO vector, or -1 for cruise
29	MPO_MMO_X	ASCII_Real	X coordinate of the vector MPO-MMO in the MPO S/C reference frame
30	MPO_MMO_Y	ASCII_Real	Y coordinate of the vector MPO-MMO in the MPO S/C reference frame
31	MPO_MMO_Z	ASCII_Real	Z coordinate of the vector MPO-MMO in the MPO S/C reference frame
32	MPO_ALTITUDE	ASCII_Real	Depending on the mission phase this is the MPO altitude over either Earth, Venus or Mercury surface, or -1 for cruise
33	MMO_ALTITUDE	ASCII_Real	Depending on the mission phase this is the MMO altitude over either Earth, Venus or Mercury surface, or -1 for cruise
34	MPO_DIST_PLANET	ASCII_Real	Depending on the mission phase this is the distance of MPO to the center of either Earth, Venus or Mercury, or -1 for cruise
35	MMO_DIST_PLANET	ASCII_Real	Depending on the mission phase this is the distance of MMO to the center of either Earth, Venus or Mercury, or -1 for cruise
36	LATITUDE	ASCII_Real	Depending on the mission phase this is the MPO magnetic latitude in either GSM or MSM system, or -1 for Venus and cruise
37	LONGITUDE	ASCII_Real	Depending on the mission phase this is the MPO magnetic longitude in either GSM or MSM system, or -1 for Venus and cruise
38	LATLON_RAD	ASCII_Real	Radius related to magnetic latitude and longitude of MPO
39	FRAME1	ASCII_String	Depending on the mission phase this is the rotation matrix1 to rotate vectors from MPO S/C frame into either GSE, VSO, MSO or HEE reference frame (for cruise)
40	M1_A11	ASCII_Real	Component M11 of rotation matrix 1

41	M1_A12	ASCII_Real	Component M12 of rotation matrix 1
42	M1_A13	ASCII_Real	Component M13 of rotation matrix 1
43	M1_A21	ASCII_Real	Component M21 of rotation matrix 1
44	M1_A22	ASCII_Real	Component M22 of rotation matrix 1
45	M1_A23	ASCII_Real	Component M23 of rotation matrix 1
46	M1_A31	ASCII_Real	Component M31 of rotation matrix 1
47	M1_A32	ASCII_Real	Component M32 of rotation matrix 1
48	M1_A33	ASCII_Real	Component M33 of rotation matrix 1
49	FRAME2	ASCII_String	Depending on the mission phase this is the rotation matrix2 to rotate vectors from MPO S/C frame into either GSM or MSM frame or VSO or HEE frame (for cruise)
50	M2_A11	ASCII_Real	Component M11 of rotation matrix 2
51	M2_A12	ASCII_Real	Component M12 of rotation matrix 2
52	M2_A13	ASCII_Real	Component M13 of rotation matrix 2
53	M2_A21	ASCII_Real	Component M21 of rotation matrix 2
54	M2_A22	ASCII_Real	Component M22 of rotation matrix 2
55	M2_A23	ASCII_Real	Component M23 of rotation matrix 2
56	M2_A31	ASCII_Real	Component M31 of rotation matrix 2
57	M2_A32	ASCII_Real	Component M32 of rotation matrix 2
58	M2_A33	ASCII_Real	Component M33 of rotation matrix 2
59	HADAMARD_CODED	ASCII_NonNegative_Integer	Packet is hadamard coded
60	HADAMARD_DECODED	ASCII_NonNegative_Integer	0=no decoding, 1=Hadamard deconvolution done by archive S/W, 2=inverse Hadamard done by PICAM
61	SWEEP_INDEX	ASCII_NonNegative_Integer	A consecutive number marking the rows that make up an energy sweep
62	ACCU_TIME	ASCII_Real	Accumulation time
63	DEAD_TIME	ASCII_Real	Dead time after changing U1 energy
64	ENERGY_INDEX	ASCII_NonNegative_Integer	Actual energy index of data in this row
65	ENERGY_STEP	ASCII_Real	Energy step value
66	ANODE_INDEX	ASCII_NonNegative_Integer	Actual anode group index of the science data in this row
67-578	B (0-511)	ASCII_Integer	Ion fluxes per Time-of-Flight bin

***Table A-33** – PICAM Calibrated science data products fields description (ToF mode)*

Column #	Title	Data Type	description
1	TIME_UTC	ASCII_Date_Time_YMD	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.SSS
2	TIME_OBT	ASCII_String	S/C CLOCK AT OBSERVATION TIME: SSSSSSSSSS.FFFFF
3	ORBNUM	ASCII_NonNegative_Integer	Orbit number (0 in non-Mercury mission phases)
4	SEQ_CNT	ASCII_NonNegative_Integer	Packet sequence counter
5	QUALITY	ASCII_NonNegative_Integer	Data quality (bit combination of: 0=perfect [no error], 1=checksum error, 2=missing HK params, 4=missing gate params, 8=incomplete sweep, 16=packet index out of range, 32=decompression error, 64=hadamard decoding error,

			128=missing measurement time, 256=Semilog decompression not implemented)
6	SPID	ASCII_NonNegative_Integer	Packet SPID
7	HK_U_GATE_P	ASCII_NonNegative_Integer	Positive gate voltage (NSE0P048)
8	HK_U_GATE_N	ASCII_NonNegative_Integer	Negative gate voltage (NSE0P049)
9	U1_SET_VAL	ASCII_NonNegative_Integer	U1 HV set value (NSE0P055)
10	U1_SET_MON	ASCII_NonNegative_Integer	U1 voltage set value (NSE0P050)
11	U1_MON	ASCII_NonNegative_Integer	U1 voltage monitor; in science mode products where U1 is on, this value is calculated from the selected lookup table (NSE0P042)
12	NSD_STRUCTID	ASCII_NonNegative_Integer	Structure identifier
13	NSD_MEASTIME	ASCII_Date_Time_YMD	Measurement time: YYYY-MM-DDTHH:MM:SS.SSS
14	NSD_OPTIONS	ASCII_NonNegative_Integer	Measurement mode options
15	PLANET_SUN_X	ASCII_Real	Depending on the mission phase this is the X coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
16	PLANET_SUN_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
17	PLANET_SUN_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate of either Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame, or -1 for cruise
18	MPO_SUN_X	ASCII_Real	This is the X coordinate in the MPO S/C reference frame of the vector MPO-SUN
19	MPO_SUN_Y	ASCII_Real	This is the Y coordinate in the MPO S/C reference frame of the vector MPO-SUN
20	MPO_SUN_Z	ASCII_Real	This is the Z coordinate in the MPO S/C reference frame of the vector MPO-SUN
21	MPO_PLANET_X	ASCII_Real	Depending on the mission phase this is the X coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
22	MPO_PLANET_Y	ASCII_Real	Depending on the mission phase this is the Y coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
23	MPO_PLANET_Z	ASCII_Real	Depending on the mission phase this is the Z coordinate in the MPO S/C reference frame of either MPO-EARTH, MPO-VENUS or MPO-MERCURY vector, or -1 for cruise
24	ANGLE_PLANET_SUN_MPO	ASCII_Real	Depending on the mission phase this is the angle between either Earth-Sun vector and Earth-MPO vector, Venus-Sun vector and Venus-MPO vector or Mercury-Sun vector and Mercury-MPO vector, or -1 for cruise
25	MPO_MMO_X	ASCII_Real	X coordinate of the vector MPO-MMO in the MPO S/C reference frame
26	MPO_MMO_Y	ASCII_Real	Y coordinate of the vector MPO-MMO in the MPO S/C reference frame

27	MPO_MMO_Z	ASCII_Real	Z coordinate of the vector MPO-MMO in the MPO S/C reference frame
28	MPO_ALTITUDE	ASCII_Real	Depending on the mission phase this is the MPO altitude over either Earth, Venus or Mercury surface, or -1 for cruise
29	MMO_ALTITUDE	ASCII_Real	Depending on the mission phase this is the MMO altitude over either Earth, Venus or Mercury surface, or -1 for cruise
30	MPO_DIST_PLANET	ASCII_Real	Depending on the mission phase this is the distance of MPO to the center of either Earth, Venus or Mercury, or -1 for cruise
31	MMO_DIST_PLANET	ASCII_Real	Depending on the mission phase this is the distance of MMO to the center of either Earth, Venus or Mercury, or -1 for cruise
32	LATITUDE	ASCII_Real	Depending on the mission phase this is the MPO magnetic latitude in either GSM or MSM system, or -1 for Venus and cruise
33	LONGITUDE	ASCII_Real	Depending on the mission phase this is the MPO magnetic longitude in either GSM or MSM system, or -1 for Venus and cruise
34	LATLON_RAD	ASCII_Real	Radius related to magnetic latitude and longitude of MPO
35	FRAME1	ASCII_String	Depending on the mission phase this is the rotation matrix1 to rotate vectors from MPO S/C frame into either GSE, VSO, MSO or HEE reference frame (for cruise)
36	M1_A11	ASCII_Real	Component M11 of rotation matrix 1
37	M1_A12	ASCII_Real	Component M12 of rotation matrix 1
38	M1_A13	ASCII_Real	Component M13 of rotation matrix 1
39	M1_A21	ASCII_Real	Component M21 of rotation matrix 1
40	M1_A22	ASCII_Real	Component M22 of rotation matrix 1
41	M1_A23	ASCII_Real	Component M23 of rotation matrix 1
42	M1_A31	ASCII_Real	Component M31 of rotation matrix 1
43	M1_A32	ASCII_Real	Component M32 of rotation matrix 1
44	M1_A33	ASCII_Real	Component M33 of rotation matrix 1
45	FRAME2	ASCII_String	Depending on the mission phase this is the rotation matrix2 to rotate vectors from MPO S/C frame into either GSM or MSM frame or VSO or HEE frame (for cruise)
46	M2_A11	ASCII_Real	Component M11 of rotation matrix 2
47	M2_A12	ASCII_Real	Component M12 of rotation matrix 2
48	M2_A13	ASCII_Real	Component M13 of rotation matrix 2
49	M2_A21	ASCII_Real	Component M21 of rotation matrix 2
50	M2_A22	ASCII_Real	Component M22 of rotation matrix 2
51	M2_A23	ASCII_Real	Component M23 of rotation matrix 2
52	M2_A31	ASCII_Real	Component M31 of rotation matrix 2
53	M2_A32	ASCII_Real	Component M32 of rotation matrix 2
54	M2_A33	ASCII_Real	Component M33 of rotation matrix 2
55	SWEEP_INDEX	ASCII_NonNegative_Integer	A consecutive number marking the rows that make up an energy sweep
56	ACCU_TIME	ASCII_Real	Accumulation time
57	DEAD_TIME	ASCII_Real	Dead time after changing U1 energy
58	ENERGY_INDEX	ASCII_NonNegative_Integer	Actual energy index of data in this row
59	ENERGY_STEP	ASCII_Real	Energy step value

60-91	A (0-31)	ASCII_Integer	Ion fluxes per anodegroup

Table A-34 *– PICAM Calibrated science data products fields description (Image mode)*

A.4.3 PICAM Derived Data Products Fields Description

TBD. ***Table A-35*** *– PICAM Derived science data products fields description*

A.5 SCU Data Products Fields Description

A.5.1 SCU Raw Data Products Fields Description

Column #	Title	Data Type	description
1	PACKET_NUM	ASCII_NonNegative_Integer	Packet number as in the telemetry sequence (Not internal instrument sequence count)
2	VALIDITY	ASCII_NonNegative_Integer	Packet validity flag (0=perfect (valid), 1=packet length disparity, 2=wrong end word, 3=unsynchronized time)
3	SCET	ASCII_NonNegative_Integer	Spacecraft elapsed time in seconds
4	FRAC_SEC	ASCII_NonNegative_Integer	Spacecraft time - fractional ticks (in 1/65536 sec)
5	TIME_UTC	ASCII_Date_Time_YMD_UTC	UTC TIME: YYYY-MM-DDTHH:MM:SS.SSSZ
6	SEQ_COUNT	ASCII_NonNegative_Integer	Sequence counter for this APID.
7	SID	ASCII_NonNegative_Integer	Structure ID. 0 = Reduced SW, 1 = Application SW
8	ACQ_TIME	ASCII_NonNegative_Integer	HK acquisition period res. 1 s range 1..100 sec
9	SPW_LINK	ASCII_NonNegative_Integer	SpaceWire link: 0 = Main, 1 = Redundant
10	ELN	ASCII_NonNegative_Integer	ELENA power: 0 = Off; 1 = On
11	MIP	ASCII_NonNegative_Integer	MIPA power: 0 = Off; 1 = On
12	PCM	ASCII_NonNegative_Integer	PICAM power: 0 = Off; 1 = On
13	STRF	ASCII_NonNegative_Integer	STROFIO power: 0 = Off; 1 = On
14	CUR_MOD	ASCII_NonNegative_Integer	Current Mode 0 to 2 = Standby mode, 3 = FULL SCIENCE mode.
15	PREV_MOD	ASCII_NonNegative_Integer	Previous Mode 0 to 2 = Standby mode, 3 = FULL SCIENCE mode.
16	MODE_TRAN_CAUSE	ASCII_NonNegative_Integer	Mode transition: 0 = Commanded, 1 = Autonomous due to end of mode, 2 = Autonomous due to error, 3 = No mode transition
17	SYNC	ASCII_NonNegative_Integer	Sync: 0 = SERENA Ext. Time SYNC'ed (SpaceWire), 1 = SERENA int. Time SYNC'ed
18	DATAT	ASCII_NonNegative_Integer	Datation: 0 = SERENA External Time Datation, 1 = SERENA Internal Time Datation
19	ERR_LAST	ASCII_NonNegative_Integer	Last Error. Standard Failure ID: 0 = Illegal APID (PAC error)

			1 = Incomplete or invalid length Packet (failed to receive whole packet within time out period) 2 = Incorrect checksum. 3 = Illegal packet type 4 = Illegal packet subtype 7 = Command cannot be executed at this time (incorrect status of application to allow command execution).
20	CRIT_ERR_LAST	ASCII_NonNegative_Integer	Last Critical Error in short coding format. 0 = None, 2 = Anomaly, 3 = Anomaly – Ground Action; 4 = Anomaly – On board action
21	ERR_FIFO_EF	ASCII_NonNegative_Integer	Reporting error FIFO empty flag: 1 = Error, 0 = No Error
22	ERR_FIFO_OVF	ASCII_NonNegative_Integer	Reporting error FIFO overflow flag: 1 = Error, 0 = No Error
23	RST_TYP	ASCII_NonNegative_Integer	0 = System reset (default), 1 = Commanded, 2 = CPU error reset, 3 = Watch Dog reset, 4 = RAM Double Error Detected
24	RES_SCU	ASCII_NonNegative_Integer	RESERVED SCU Proc. Flags System @ Bit 0 (LSB) ELENA @ Bit 1 MIPA @ Bit 2 PICAM @ Bit 3 STROFIO @ Bit 4
25	ERR_CNT	ASCII_NonNegative_Integer	Error counter
26	LST_TC_TYP_ACC	ASCII_NonNegative_Integer	Last accepted TC type
27	LST_TC_STYP_ACC	ASCII_NonNegative_Integer	Last accepted TC sub-type
28	LST_TC_TYP_EXE	ASCII_NonNegative_Integer	Last executed TC type
29	LST_TC_STYP_EXE	ASCII_NonNegative_Integer	Last executed TC sub-type
30	TC_CNT	ASCII_NonNegative_Integer	Total Received TC counter
31	LST_TC_TYP_REJ	ASCII_NonNegative_Integer	Last rejected TC type.
32	LST_TC_STYP_REJ	ASCII_NonNegative_Integer	Last rejected TC sub-type
33	LST_TC_TYP_FEX	ASCII_NonNegative_Integer	Last execution failed TC type
34	LST_TC_STYP_FEX	ASCII_NonNegative_Integer	Last execution failed TC sub-type
35	SURV_PRM_CKS	ASCII_NonNegative_Integer	Survival PROM S/W Checksum
36	SURV_PRM_SW_VER	ASCII_NonNegative_Integer	Survival PROM S/W Version
37	RAM_SEC_COR	ASCII_NonNegative_Integer	RAM Single Error Corrections counter
38	EEPRM_SW_VER	ASCII_NonNegative_Integer	EEPROM S/W Version
39	EEPRM_SEC_COR	ASCII_NonNegative_Integer	EEPROM Single Error Corrections counter
40	EEPRM_CKS	ASCII_NonNegative_Integer	EEPROM S/W Checksum
41	EEPRM_DED_HI	ASCII_NonNegative_Integer	HI Address of the last DED in EEPROM
42	EEPRM_DED_LOW	ASCII_NonNegative_Integer	LOW Address of the last DED in EEPROM
43	RAM_FAI_HI	ASCII_NonNegative_Integer	RAM boot fail check first HI address
44	RAM_FAI_LOW	ASCII_NonNegative_Integer	RAM boot fail check first LOW address
45	RAM_NUM_FAI	ASCII_NonNegative_Integer	RAM boot fail check number of wrong locations
46	SCU_CUR	ASCII_NonNegative_Integer	SCU Current
47	ELE_CUR	ASCII_NonNegative_Integer	ELENA current
48	STR_CUR	ASCII_NonNegative_Integer	STROFIO current

49	PCM_CUR	ASCII_NonNegative_Integer	PICAM current
50	SCU_VCC	ASCII_NonNegative_Integer	SCU Vcc +5V
51	SCU_TMP	ASCII_NonNegative_Integer	SCU Temperature
52	MP_CUR	ASCII_NonNegative_Integer	MIPA Current
53	ELE_VCC	ASCII_NonNegative_Integer	ELENA Vcc +3.3V
54	PLANET_SUN_X	ASCII_Real	X coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
55	PLANET_SUN_Y	ASCII_Real	Y coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
56	PLANET_SUN_Z	ASCII_Real	Z coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
57	PLANET_SUN_DIST	ASCII_Real	Distance Earth-Sun, Venus-Sun or Mercury-Sun. Equals to -1 during cruise.
58	PLANET_TAA	ASCII_Real	True anomaly angle of Earth, Venus or Mercury on its orbit around the Sun. Equals to -1 during cruise.
59	MPO_SUN_X	ASCII_Real	X coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
60	MPO_SUN_Y	ASCII_Real	Y coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
61	MPO_SUN_Z	ASCII_Real	Z coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
62	MPO_SUN_DIST	ASCII_Real	MPO heliocentric distance.
63	MPO_PLANET_X	ASCII_Real	X coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
64	MPO_PLANET_Y	ASCII_Real	Y coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
65	MPO_PLANET_Z	ASCII_Real	Z coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
66	MPO_PLANET_VX	ASCII_Real	Velocity in the X direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
67	MPO_PLANET_VY	ASCII_Real	Velocity in the Y direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
68	MPO_PLANET_VZ	ASCII_Real	Velocity in the Z direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
69	MPO_PLANET_DIST	ASCII_Real	Distance MPO-Earth, MPO-Venus or MPO-Mercury. Equals to -1 during cruise.
70	ANGLE_MPO_PLANET_Z_PLUS	ASCII_Real	Angle between MPO-Planet vector and +Z of "MPO Spacecraft" (off-

			nadir pointing). Equals to -1 during cruise.
71	SUB_MPO_LON	ASCII_Real	Longitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
72	SUB_MPO_LAT	ASCII_Real	Latitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
73	SUB_MPO_ALT	ASCII_Real	Altitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
74	MPO_LOC_SOL_TIME	ASCII_Real	Local solar time of MPO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
75	ANGLE_MPO_PLANET_SUN	ASCII_Real	Angle between MPO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
76	MPO_POS_PSORF_X	ASCII_Real	X coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
77	MPO_POS_PSORF_Y	ASCII_Real	Y coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
78	MPO_POS_PSORF_Z	ASCII_Real	Z coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
79	MPO_LON_PSORF	ASCII_Real	Longitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
80	MPO_LAT_PSORF	ASCII_Real	Latitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
81	MPO_POS_PSMRF_X	ASCII_Real	X coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
82	MPO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
83	MPO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
84	MPO_LON_PSMRF	ASCII_Real	Longitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
85	MPO_LAT_PSMRF	ASCII_Real	Latitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
86	MMO_PLANET_DIST	ASCII_Real	Distance MMO-Earth, MMO-Venus or MMO-Mercury. Equals to -1 during cruise.
87	MMO_LOC_SOL_TIME	ASCII_Real	Local solar time of MMO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
88	ANGLE_MMO_PLANET_SUN	ASCII_Real	Angle between MMO-Planet and Sun-Planet vectors. Equals to -1 during cruise.

89	MMO_POS_PSMRF_X	ASCII_Real	X coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
90	MMO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
91	MMO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
92	MMO_LON_PSMRF	ASCII_Real	Longitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
93	MMO_LAT_PSMRF	ASCII_Real	Latitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
94	MPO_MMO_DIST	ASCII_Real	MPO-MMO distance.
95	ANGLE_MPO_PLANET_MMO	ASCII_Real	Angle between MPO-Planet and MMO-Planet vectors. Equals to -1 during cruise.

Table A-36 – *SCU Raw housekeeping data products fields description*

A.5.2 SCU Calibrated Data Products Fields Description

Column #	Title	Data Type	description
1	PACKET_NUM	ASCII_NonNegative_Integer	Packet number as in the telemetry sequence (Not internal instrument sequence count)
2	VALIDITY	ASCII_NonNegative_Integer	Packet validity flag (0=perfect (valid), 1=packet length disparity, 2=wrong end word, 3=unsynchronized time)
3	SCET	ASCII_NonNegative_Integer	Spacecraft elapsed time in seconds
4	FRAC_SEC	ASCII_NonNegative_Integer	Spacecraft time - fractional ticks (in 1/65536 sec)
5	TIME_UTC	ASCII_Date_Time_YMD_UTC	UTC TIME: YYYY-MM-DDTHH:MM:SS.SSSZ
6	SEQ_COUNT	ASCII_NonNegative_Integer	Sequence counter for this APID.
7	SID	ASCII_NonNegative_Integer	Structure ID. 0 = Reduced SW, 1 = Application SW
8	ACQ_TIME	ASCII_NonNegative_Integer	HK acquisition period res. 1 s range 1..100 sec
9	SPW_LINK	ASCII_NonNegative_Integer	SpaceWire link: 0 = Main, 1 = Redundant
10	ELN	ASCII_NonNegative_Integer	ELENA power: 0 = Off; 1 = On
11	MIP	ASCII_NonNegative_Integer	MIPA power: 0 = Off; 1 = On
12	PCM	ASCII_NonNegative_Integer	PICAM power: 0 = Off; 1 = On
13	STRF	ASCII_NonNegative_Integer	STROFIO power: 0 = Off; 1 = On
14	CUR_MOD	ASCII_NonNegative_Integer	Current Mode 0 to 2 = Standby mode, 3 = FULL SCIENCE mode.
15	PREV_MOD	ASCII_NonNegative_Integer	Previous Mode 0 to 2 = Standby mode, 3 = FULL SCIENCE mode.
16	MODE_TRAN_CAUSE	ASCII_NonNegative_Integer	Mode transition: 0 = Commanded, 1 = Autonomous due to end of mode,

			2 = Autonomous due to error, 3 = No mode transition
17	SYNC	ASCII_NonNegative_Integer	Sync: 0 = SERENA Ext. Time SYNC'ed (SpaceWire), 1 = SERENA int. Time SYNC'ed
18	DATAT	ASCII_NonNegative_Integer	Datation: 0 = SERENA External Time Datation, 1 = SERENA Internal Time Datation
19	ERR_LAST	ASCII_NonNegative_Integer	Last Error. Standard Failure ID: 0 = Illegal APID (PAC error) 1 = Incomplete or invalid length Packet (failed to receive whole packet within time out period) 2 = Incorrect checksum. 3 = Illegal packet type 4 = Illegal packet subtype 7 = Command cannot be executed at this time (incorrect status of application to allow command execution).
20	CRIT_ERR_LAST	ASCII_NonNegative_Integer	Last Critical Error in short coding format. 0 = None, 2 = Anomaly, 3 = Anomaly – Ground Action; 4 = Anomaly – On board action
21	ERR_FIFO_EF	ASCII_NonNegative_Integer	Reporting error FIFO empty flag: 1 = Error, 0 = No Error
22	ERR_FIFO_OVF	ASCII_NonNegative_Integer	Reporting error FIFO overflow flag: 1 = Error, 0 = No Error
23	RST_TYP	ASCII_NonNegative_Integer	0 = System reset (default), 1 = Commanded, 2 = CPU error reset, 3 = Watch Dog reset, 4 = RAM Double Error Detected
24	RES_SCU	ASCII_NonNegative_Integer	RESERVED SCU Proc. Flags System @ Bit 0 (LSB) ELENA @ Bit 1 MIPA @ Bit 2 PICAM @ Bit 3 STROFIO @ Bit 4
25	ERR_CNT	ASCII_NonNegative_Integer	Error counter
26	LST_TC_TYP_ACC	ASCII_NonNegative_Integer	Last accepted TC type
27	LST_TC_STYP_ACC	ASCII_NonNegative_Integer	Last accepted TC sub-type
28	LST_TC_TYP_EXE	ASCII_NonNegative_Integer	Last executed TC type
29	LST_TC_STYP_EXE	ASCII_NonNegative_Integer	Last executed TC sub-type
30	TC_CNT	ASCII_NonNegative_Integer	Total Received TC counter
31	LST_TC_TYP_REJ	ASCII_NonNegative_Integer	Last rejected TC type.
32	LST_TC_STYP_REJ	ASCII_NonNegative_Integer	Last rejected TC sub-type
33	LST_TC_TYP_FEX	ASCII_NonNegative_Integer	Last execution failed TC type
34	LST_TC_STYP_FEX	ASCII_NonNegative_Integer	Last execution failed TC sub-type
35	SURV_PRM_CKS	ASCII_NonNegative_Integer	Survival PROM S/W Checksum
36	SURV_PRM_SW_VER	ASCII_NonNegative_Integer	Survival PROM S/W Version
37	RAM_SEC_COR	ASCII_NonNegative_Integer	RAM Single Error Corrections counter
38	EEPRM_SW_VER	ASCII_NonNegative_Integer	EEPROM S/W Version
39	EEPRM_SEC_COR	ASCII_NonNegative_Integer	EEPROM Single Error Corrections counter
40	EEPRM_CKS	ASCII_NonNegative_Integer	EEPROM S/W Checksum
41	EEPRM_DED_HI	ASCII_NonNegative_Integer	HI Address of the last DED in EEPROM

42	EEPRM_DED_LOW	ASCII_NonNegative_Integer	LOW Address of the last DED in EEPROM
43	RAM_FAI_HI	ASCII_NonNegative_Integer	RAM boot fail check first HI address
44	RAM_FAI_LOW	ASCII_NonNegative_Integer	RAM boot fail check first LOW address
45	RAM_NUM_FAI	ASCII_NonNegative_Integer	RAM boot fail check number of wrong locations
46	SCU_CUR	ASCII_Real	SCU Current [A]
47	ELE_CUR	ASCII_Real	ELENA current [A]
48	STR_CUR	ASCII_Real	STROFIO current [A]
49	PCM_CUR	ASCII_Real	PICAM current [A]
50	SCU_VCC	ASCII_Real	SCU Vcc +5V [V]
51	SCU_TMP	ASCII_Real	SCU Temperature [DegC]
52	MP_CUR	ASCII_Real	MIPA Current [A]
53	ELE_VCC	ASCII_Real	ELENA Vcc +3.3V [V]
54	PLANET_SUN_X	ASCII_Real	X coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
55	PLANET_SUN_Y	ASCII_Real	Y coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
56	PLANET_SUN_Z	ASCII_Real	Z coordinate of Earth-Sun, Venus-Sun or Mercury-Sun vector in the HEE reference frame. Equals to -1 during cruise.
57	PLANET_SUN_DIST	ASCII_Real	Distance Earth-Sun, Venus-Sun or Mercury-Sun. Equals to -1 during cruise.
58	PLANET_TAA	ASCII_Real	True anomaly angle of Earth, Venus or Mercury on its orbit around the Sun. Equals to -1 during cruise.
59	MPO_SUN_X	ASCII_Real	X coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
60	MPO_SUN_Y	ASCII_Real	Y coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
61	MPO_SUN_Z	ASCII_Real	Z coordinate of the MPO-Sun vector in the "MPO Spacecraft" frame.
62	MPO_SUN_DIST	ASCII_Real	MPO heliocentric distance.
63	MPO_PLANET_X	ASCII_Real	X coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
64	MPO_PLANET_Y	ASCII_Real	Y coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
65	MPO_PLANET_Z	ASCII_Real	Z coordinate of MPO-Earth, MPO-Venus or MPO-Mercury vector in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
66	MPO_PLANET_VX	ASCII_Real	Velocity in the X direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
67	MPO_PLANET_VY	ASCII_Real	Velocity in the Y direction with respect to Earth, Venus or Mercury

			in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
68	MPO_PLANET_VZ	ASCII_Real	Velocity in the Z direction with respect to Earth, Venus or Mercury in the "MPO Spacecraft" reference frame. Equals to -1 during cruise.
69	MPO_PLANET_DIST	ASCII_Real	Distance MPO-Earth, MPO-Venus or MPO-Mercury. Equals to -1 during cruise.
70	ANGLE_MPO_PLANET_Z_PLUS	ASCII_Real	Angle between MPO-Planet vector and +Z of "MPO Spacecraft" (off-nadir pointing). Equals to -1 during cruise.
71	SUB_MPO_LON	ASCII_Real	Longitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
72	SUB_MPO_LAT	ASCII_Real	Latitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
73	SUB_MPO_ALT	ASCII_Real	Altitude of sub-MPO point in Planet-fixed frame (Earth, Venus or Mercury). Equals to -1 during cruise.
74	MPO_LOC_SOL_TIME	ASCII_Real	Local solar time of MPO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
75	ANGLE_MPO_PLANET_SUN	ASCII_Real	Angle between MPO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
76	MPO_POS_PSORF_X	ASCII_Real	X coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
77	MPO_POS_PSORF_Y	ASCII_Real	Y coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
78	MPO_POS_PSORF_Z	ASCII_Real	Z coordinate of MPO in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
79	MPO_LON_PSORF	ASCII_Real	Longitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
80	MPO_LAT_PSORF	ASCII_Real	Latitude of MPO's position in PSO reference frame (GSE, VSO or MSO). Equals to -1 during cruise.
81	MPO_POS_PSMRF_X	ASCII_Real	X coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
82	MPO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
83	MPO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MPO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
84	MPO_LON_PSMRF	ASCII_Real	Longitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.

85	MPO_LAT_PSMRF	ASCII_Real	Latitude of MPO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
86	MMO_PLANET_DIST	ASCII_Real	Distance MMO-Earth, MMO-Venus or MMO-Mercury. Equals to -1 during cruise.
87	MMO_LOC_SOL_TIME	ASCII_Real	Local solar time of MMO's position at Earth, Venus or Mercury. Equals to -1 during cruise.
88	ANGLE_MMO_PLANET_SUN	ASCII_Real	Angle between MMO-Planet and Sun-Planet vectors. Equals to -1 during cruise.
89	MMO_POS_PSMRF_X	ASCII_Real	X coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
90	MMO_POS_PSMRF_Y	ASCII_Real	Y coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
91	MMO_POS_PSMRF_Z	ASCII_Real	Z coordinate of MMO in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
92	MMO_LON_PSMRF	ASCII_Real	Longitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
93	MMO_LAT_PSMRF	ASCII_Real	Latitude of MMO's position in PSM reference frame (GSM, VSO or MSM). Equals to -1 during cruise.
94	MPO_MMO_DIST	ASCII_Real	MPO-MMO distance.
95	ANGLE_MPO_PLANET_MMO	ASCII_Real	Angle between MPO-Planet and MMO-Planet vectors. Equals to -1 during cruise.

Table A-37 – *SCU Calibrated housekeeping data products fields description*

B. Detailed Description of the SERENA Datasets

B.1 ELENA Dataset Description

Operation times	Number of Data Products (Raw-Par-Cal-Der)	Note
2018-12-12T16:43:52 2018-12-12T18:57:57	S – (1-0-1-0) HK – (1-0-1-0)	NECP
2018-12-14T08:35:59 2018-12-14T17:04:59	S – (2-0-2-0) R – (1-1-1-0) SO-16 – (1-0-0-0) HK – (1-0-1-0)	NECP
2018-12-15T14:34:26 2018-12-15T17:54:16	S – (1-0-1-0) HK – (1-0-1-0)	Extension of NECP
2019-07-22T12:25:25 2019-07-26T17:06:42	S – (7-0-7-0) R – (4-4-4-0) SO-16 – (1-0-0-0) HK – (5-0-5-0)	Delta commissioning operations
2019-11-26T10:01:54 2019-11-26T10:35:54	HK – (1-0-1-0)	Cruise instrument checkout
2020-03-03T16:31:57 2020-03-03T16:58:23	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2020-06-19T17:53:07 2020-06-19T20:14:51	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2020-09-03T17:31:30 2020-09-10T16:48:07	S – (8-0-8-0) R – (9-9-9-0) HK – (6-0-6-0)	Cruise instrument checkout
2020-12-03T09:13:17 2020-12-03T14:41:58	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2020-12-08T09:07:20 2020-12-08T16:10:35	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2020-12-10T09:47:20 2020-12-10T15:30:57	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2020-12-17T15:45:36 2020-12-17T17:44:59	R – (1-1-1-0) HK – (1-0-1-0)	Cruise instrument checkout
2021-06-10T09:04:09 2021-06-10T16:50:39	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2021-06-17T09:12:56 2021-06-17T15:08:35	S – (1-0-1-0) R – (1-1-1-0) HK – (1-0-1-0)	Cruise instrument checkout
2021-11-04T13:21:30 2021-11-05T16:35:12	S – (6-0-6-0) R – (7-7-7-0)	SERENA suite and onboard software update test

	HK – (2-0-2-0)	
2021-11-11T08:29:56 2021-11-11T14:39:16	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2021-11-22T13:12:30 2021-11-22T21:25:21	S – (6-0-6-0) R – (6-6-6-0) HK – (1-0-1-0)	Cruise instrument checkout
2022-03-17T15:31:54 2022-03-17T17:31:45	HK – (1-0-1-0)	ELENA dedicated test
2022-06-09T14:17:35 2022-06-09T18:08:01	S – (2-0-2-0) R – (2-2-2-0) HK – (1-0-1-0)	SERENA suite and onboard software update test
2022-07-28T14:38:20 2022-07-28T17:54:06	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2022-10-06T12:56:20 2022-10-06T17:19:29	S – (4-0-4-0) R – (4-4-4-0) HK – (1-0-1-0)	ELENA dedicated test
2022-11-10T07:13:15 2022-11-10T12:10:36	S – (12-0-12-0) R – (12-12-12-0) HK – (1-0-1-0)	ELENA dedicated test
2023-03-15T13:17:15 2023-03-15T19:19:31	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2023-05-22T06:44:15 2023-05-22T07:22:41	S – (1-0-1-0) HK – (1-0-1-0)	Cruise instrument checkout
2023-07-12T14:06:35 2023-07-12T17:54:01	S – (1-0-1-0) HK – (1-0-1-0)	ELENA dedicated test
2023-10-06T12:33:55 2023-10-06T20:34:25	S – (4-0-4-0) R – (4-4-4-0) HK – (1-0-1-0)	ELENA dedicated test
2023-11-07T10:00:55 2023-11-10T13:01:41	S – (10-0-10-0) R – (10-10-10-0) HK – (5-0-5-0)	ELENA dedicated test
2024-04-11T13:08:50 2024-04-12T10:40:03	S – (7-0-7-0) R – (7-7-7-0) HK – (2-0-2-0)	SERENA suite and onboard software update test

Table B-1 – *Overview of the ELENA data products since launch*

B.2 STROFIO Dataset Description

Operation times	**Number of Data Products (per level)**	**Note**
2018-12-12T10:04:58	Basic rates – 3	NECP

2018-12-14T19:00:09	LQ TOF – 3 HQ TOF – 3 Re-LQ TOF – 3 Re-HQ TOF – 3 HK – 3	
2018-12-15T12:38:34 2018-12-15T18:17:34	Basic rates – 1 LQ TOF – 1 HQ TOF – 1 Re-LQ TOF – 1 Re-HQ TOF – 1 HK – 1	Extension of NECP
2019-03-25T18:10:19 2019-03-27T02:25:09	Basic rates – 3 LQ TOF – 3 HQ TOF – 3 Re-LQ TOF – 3 Re-HQ TOF – 3 HK – 3	STROFIO dedicated test
2019-03-29T15:07:01 2019-04-01T09:34:40	HK – 4	STROFIO dedicated test
2019-04-05T16:47:55 2019-04-06T02:24:09	Basic rates – 2 LQ TOF – 2 HQ TOF – 2 Re-LQ TOF – 2 Re-HQ TOF – 2 HK – 2	STROFIO dedicated test
2019-07-22T13:36:29 2019-07-28T08:14:28	Basic rates – 7 LQ TOF – 7 HQ TOF – 7 Re-LQ TOF – 7 Re-HQ TOF – 7 HK – 7	Delta commissioning operations
2019-11-20T08:16:20 2019-11-25T09:04:39	HK – 6	STROFIO dedicated test
2019-11-27T12:03:15 2019-11-27T22:26:00	Basic rates – 1 LQ TOF – 1 HQ TOF – 1 Re-LQ TOF – 1 Re-HQ TOF – 1 HK – 1	STROFIO dedicated test
2019-12-05T20:03:15 2019-12-13T11:41:50	Basic rates – 9 LQ TOF – 9 HQ TOF – 9 Re-LQ TOF – 9	STROFIO dedicated test

	Re-HQ TOF – 9 HK – 9	
2020-04-09T08:45:38 2020-04-11T13:35:58	Basic rates – 3 LQ TOF – 3 HQ TOF – 3 Re-LQ TOF – 3 Re-HQ TOF – 3 HK – 3	Earth flyby
2020-04-28T17:03:02 2020-05-08T12:30:19	Basic rates – 10 LQ TOF – 10 HQ TOF – 10 Re-LQ TOF – 10 Re-HQ TOF – 10 HK – 11	STROFIO dedicated test
2020-07-17T08:47:57 2020-07-21T07:45:39	Basic rates – 5 LQ TOF – 5 HQ TOF – 5 Re-LQ TOF – 5 Re-HQ TOF – 5 HK – 5	STROFIO dedicated test
2020-08-13T08:47:57 2020-08-15T10:52:49	Basic rates – 3 LQ TOF – 3 HQ TOF – 3 Re-LQ TOF – 3 Re-HQ TOF – 3 HK – 3	STROFIO dedicated test
2020-09-03T16:23:55 2020-09-09T10:23:36	Basic rates – 5 LQ TOF – 5 HQ TOF – 5 Re-LQ TOF – 5 Re-HQ TOF – 5 HK – 5	Cruise instrument checkout
2021-04-23T00:53:57 2021-05-01T03:15:31	Basic rates – 8 LQ TOF – 8 HQ TOF – 8 Re-LQ TOF – 8 Re-HQ TOF – 8 HK – 8	STROFIO dedicated test
2021-06-30T10:59:02 2021-06-30T12:23:02	HK – 1	STROFIO dedicated test
2021-07-23T07:09:57 2021-07-24T11:16:12	Basic rates – 2 LQ TOF – 2 HQ TOF – 2	STROFIO dedicated test

	Re-LQ TOF – 2 Re-HQ TOF – 2 HK – 2	
2021-07-28T08:48:57 2021-07-29T05:47:21	Basic rates – 2 LQ TOF – 1 HQ TOF – 1 Re-LQ TOF – 1 Re-HQ TOF – 1 HK – 2	STROFIO dedicated test
2021-08-19T11:04:02 2021-08-19T17:55:40	Basic rates – 1 HK – 1	STROFIO dedicated test
2021-08-26T00:02:57 2021-08-31T17:39:38	Basic rates – 6 HK – 6	STROFIO dedicated test
2021-09-09T07:43:57 2021-09-15T05:06:19	Basic rates – 7 HK – 7	STROFIO dedicated test
2021-11-04T10:30:01 2021-11-05T16:52:39	Basic rates – 2 LQ TOF – 2 HQ TOF – 2 Re-LQ TOF – 2 Re-HQ TOF – 2 HK – 2	SERENA suite and onboard software update test
2021-11-22T13:11:58 2021-11-22T21:42:34	Basic rates – 1 LQ TOF – 1 HQ TOF – 1 Re-LQ TOF – 1 Re-HQ TOF – 1 HK – 1	Cruise instrument checkout
2022-03-04T11:03:15 2022-03-10T13:45:59	Basic rates – 7 LQ TOF – 7 HQ TOF – 7 Re-LQ TOF – 7 Re-HQ TOF – 7 HK – 7	STROFIO dedicated test
2022-03-18T10:08:15 2022-03-24T13:35:39	Basic rates – 8 LQ TOF – 8 HQ TOF – 8 Re-LQ TOF – 8 Re-HQ TOF – 8 HK – 8	STROFIO dedicated test
2022-04-01T03:43:15 2022-04-07T13:02:49	Basic rates – 8 LQ TOF – 8 HQ TOF – 8	STROFIO dedicated test

	Re-LQ TOF – 8 Re-HQ TOF – 8 HK – 8	
2022-06-09T14:15:06 2022-06-09T18:24:54	Basic rates – 1 LQ TOF – 1 HQ TOF – 1 Re-LQ TOF – 1 Re-HQ TOF – 1 HK – 1	SERENA suite and onboard software update test
2022-08-04T11:08:15 2022-08-05T08:09:53	Basic rates – 2 LQ TOF – 2 HQ TOF – 2 Re-LQ TOF – 2 Re-HQ TOF – 2 HK – 2	STROFIO dedicated test
2022-09-16T00:54:45 2022-09-19T18:45:49	Basic rates – 4 LQ TOF – 4 HQ TOF – 4 Re-LQ TOF – 4 Re-HQ TOF – 4 HK – 4	STROFIO dedicated test
2022-09-30T00:03:27 2022-10-03T23:31:19	Basic rates – 4 LQ TOF – 4 HQ TOF – 4 Re-LQ TOF – 4 Re-HQ TOF – 4 HK – 4	STROFIO dedicated test
2022-11-03T00:03:45 2022-11-08T20:44:30	Basic rates – 6 LQ TOF – 1 HQ TOF – 1 Re-LQ TOF – 1 Re-HQ TOF – 1 HK – 6	STROFIO dedicated test
2023-02-18T00:03:45 2023-02-22T23:29:30	Basic rates – 5 LQ TOF – 1 HQ TOF – 1 Re-LQ TOF – 1 Re-HQ TOF – 1 HK – 5	STROFIO dedicated test
2023-05-22T04:46:34 2023-05-25T17:56:06	Basic rates – 4 LQ TOF – 2 HQ TOF – 2 Re-LQ TOF – 2	Cruise instrument checkout

	Re-HQ TOF – 2 HK – 4	
2023-05-30T12:36:46 2023-06-01T17:40:16	Basic rates – 3 LQ TOF – 3 HQ TOF – 3 Re-LQ TOF – 3 Re-HQ TOF – 3 HK – 3	STROFIO dedicated test
2023-07-13T00:03:27 2023-07-17T23:41:06	Basic rates – 4 LQ TOF – 1 HQ TOF – 1 Re-LQ TOF – 1 Re-HQ TOF – 1 HK – 4	STROFIO dedicated test
2023-09:30T00:03:26 2023-10-04T22:21:27	Basic rates – 5 LQ TOF – 1 HQ TOF – 1 Re-LQ TOF – 1 Re-HQ TOF – 1 HK – 5	STROFIO dedicated test
2023-10:16T00:03:45 2023-10-20T19:45:20	Basic rates – 5 LQ TOF – 5 HQ TOF – 5 Re-LQ TOF – 5 Re-HQ TOF – 5 HK – 5	STROFIO dedicated test
2023-11-07T09:48:27 2023-11-10T15:25:05	Basic rates – 4 LQ TOF – 4 HQ TOF – 4 Re-LQ TOF – 4 Re-HQ TOF – 4 HK – 4	STROFIO dedicated test
2023-11-16T00:03:27 2023-11-21T13:45:55	Basic rates – 6 LQ TOF – 4 HQ TOF – 4 Re-LQ TOF – 4 Re-HQ TOF – 4 HK – 6	STROFIO dedicated test
2024-04-11T13:07:11 2024-04-12T16:23:59	Basic rates – 2 LQ TOF – 2 HQ TOF – 2 Re-LQ TOF – 2 Re-HQ TOF – 2	SERENA suite and onboard software update test

	HK – 2	

Table B-2 – *Overview of STROFIO operations since launch*

B.3 MIPA Dataset Description

MIPA operation times	nE, nD, nM, nT	Signal	HV on	Note
2018-12-13T09:18:22.777Z - 2018-12-13T10:05:25.772Z	96-24- 32-1	Test pulse	No	Low voltage Commissioning
2018-12-15T14:46:33.782Z - 2018-12-15T17:07:32.771Z	96-24-32-1	Test pulse	No	Low voltage Commissioning
2019-07-22T10:56:50.597Z - 2019-07-22T18:00:45.591Z	96-24-32-1	0	600	First limited high voltage No high energy signal
2019-07-26T09:04:03.584Z - 2019-07-26T13:15:22.584Z	96-24-32-1	Natural background	3600	First full high voltage
2019-07-26T14:37:17.591Z - 2019-07-26T17:12:03.587Z	96-24-32-6	Natural background	3600	
2019-11-26T10:44:59.477Z - 2019-11-26T11:22:55.481Z	96-24-32-1	0	900	No high energy signal
2020-04-09T21:39:50.395Z - 2020-04-09T23:57:11.404Z	96-24-32-1	Signal	3600	ESB first part
2020-04-09T23:59:26.393Z - 2020-04-10T22:39:15.396Z	96-24-32-6	Signal	3600	ESB second part
2020-06-25T14:09:47.333Z - 2020-06-25T16:32:59.327Z	32-24-2-1; 32-24-2-4	Natural background	3600	VSB rehearsal
2020-06-25T17:24:47.331Z - 2020-06-25T19:48:01.331Z	32-24-2-1; 32-24-2-4	Natural background	3600	VSB rehearsal
2020-09-03T16:11:21 – 2020-09-03T18:40:57	HK only			SERENA software update MIPA HV table update Log/lin compression bug fixed
2020-09-04T14:10:26.314Z - 2020-09-04T17:07:12.306Z	96-24-32-1	Natural background	3600	
2020-09-07T15:57:35.308Z - 2020-09-07T20:11:59.313Z	32-24-2-1; 32-6-128-4	Signal	3600	
2020-09-08T00:12:39.314Z - 2020-09-08T17:47:12.316Z	96-24-32-1	Natural background	3600	
2020-09-08T17:47:35.307Z - 2020-09-08T22:01:53.310Z	32-6-128-4	Natural background	3600	
2020-09-08T17:47:35.307Z - 2020-09-08T22:01:53.310Z	32-24-2-4	Natural background	3600	

2020-09-08T22:02:14.308Z - 2020-09-08T23:58:22.308Z	32-6-128-4	Noise	3600	
2020-09-08T23:59:47.308Z - 2020-09-09T02:01:35.314Z	32-6-128-4	Natural background	3600	
2020-09-09T02:02:58.313Z - 2020-09-09T10:12:22.311Z	96-24-32-1	Natural background	3600	
2020-09-30T13:36:26.316Z - 2020-09-30T14:16:10.320Z	96-24-32-1	Natural background	3600	
2020-10-15T00:26:20.316Z - 2020-10-15T10:04:26.322Z	32-24-2-4	Signal	3600	VSB no. 2
2020-10-15T11:26:28.316Z - 2020-10-15T23:57:24.307Z	32-24-2-4	Natural background	3600	VSB no. 2
2020-10-16T05:23:19.308Z - 2020-10-16T22:10:06.314Z	32-24-2-4	Natural background	3600	VSB no. 2
2020-10-16T23:59:10.314Z - 2020-10-17T15:41:16.308Z	32-24-2-4	Natural background	3600	VSB no. 2
2020-10-17T16:55:13.308Z - 2020-10-17T23:57:41.310Z	32-24-2-4	Natural background	3600	VSB no. 2
2020-10-17T23:59:03.314Z - 2020-10-18T03:49:29.317Z	32-24-2-4	Natural background	3600	VSB no. 2
2021-06-16T09:04:23.168Z - 2021-06-16T14:22:37.165Z	32-24-2-1	Natural background	3600	
2021-06-17T09:02:54.171Z - 2021-06-17T14:52:45.163Z	96-24-32-1	Natural background	3600	
2021-07-05T22:52:53.156Z -2021-07-08T16:37:44.148Z	Multiple settings	Natural background	3600	
2021-07-08T16:37:44.148Z - 2021-07-23T04:37:44.230Z	32-24-2-4	Natural background	3600	
2021-08-09T03:46:16.224Z - 2021-08-10T19:48:55.228Z	32-24-2-4; 32-24-2-1	Signal	3600	VSB no. 2
2021-08-16T07:02:53.226Z - 2021-08-18T15:11:35.219Z	96-24-32-1; 32-24-2-1	Natural background	3600	
2021-09-19T15:52:53.225Z - 2021-09-21T20:12:38.225Z	96-24-32-1; 32-24-2-1; 32-24-8-1	Natural background	3600	
2021-09-24T16:47:03.216Z - 2021-09-24T21:33:12.227Z	96-24-32-1	n/a	0	Binning tests
2021-10-01T07:29:04.234Z - 2021-10-02T07:29:57.235Z	96-24-32-6; 32-24-8-1	Signal	3600	MSB no. 1
2021-10-06T08:29:27.240Z - 2021-10-08T23:55:32.237Z	32-24-2-1; 32-24-8-1	Natural background	3600	
2021-11-05T08:30:53.303Z - 2021-11-05T16:36:47.304Z	96-24-32-1; 32-24-2-1; 32-6-128-1	Natural background	3600	

2021-11-22T13:04:32.310Z - 2021-11-22T21:29:28.302Z	96-24-32-1; 32-24-2-1; 32-6-128-1	Natural background	3600	
2021-11-24T09:04:33.295Z - 2021-11-24T14:56:10.304Z	32-24-8-1	Natural background	3600	
2022-03-11T04:04:27.398Z - 2022-03-13T20:22:36.402Z	16-48-8-1	Natural background	3600	
2022-03-27T00:14:27.418Z - 2022-03-29T21:02:30.412Z	16-48-8-1	Natural background	3600	
2022-04-28T00:04:27.428Z - 2022-04-30T23:32:31.423Z	16-48-8-1	Natural background	3600	
2022-05-17T15:40:50.424Z - 2022-05-17T16:55:07.427Z	16-48-8-1	Natural background	3600	
2022-06-09T16:02:51.434Z - 2022-06-09T18:10:44.445Z	48-48-32-1	Natural background	3600	
2022-06-22T09:49:14.458Z - 2022-06-25T09:47:18.467Z	16-48-8-1	Signal	3600	MSB no. 2
2022-11-07T06:32:28.679Z - 2022-11-07T12:26:10.669Z	16-48-8-1	Natural background	3600	
2023-05-22T05:02:33.783Z - 2023-05-22T12:28:30.780Z	48-48-1-1; 32-24-2-1; 16-1-8-1	Natural background	3600	Single pixel test for mode 11 (High time resolution, 400 ms/E-spectrum)
2023-05-30T12:28:41.789Z - 2023-06-01T17:26:47.787Z	16-48-2-1	n/a	0	
2023-06-17T23:59:43.806Z - 2023-06-21T15:37:08.816Z	16-1-8-1	Signal	3600	MSB no. 3 (High time resolution, 400 ms/E-spectrum)
2023-10-07T00:04:41.907Z - 2023-10-11T07:12:43.908Z	16-48-8-1	Natural background	3600	
2023-11-10T10:03:40.967Z - 2023-11-10T15:37:33.969Z	48-48-1-1; 32-24-2-1; 16-48-8-1	Natural background	3600	CO #10, tested table switching and fixed deflection in mode 11
2024-04-12T09:34:28.055Z - 2024-04-12T16:10:42.066Z	16-48-2-1; 16-12-128-4; 48-48-32-1	Natural background	3600	CO #11
2024-09-04T18:45:42.255Z - 2024-09-05T02:41:18.257Z	48-48-8-1; 48-12-128-4; 48-12-64-1; 32-24-2-1	Signal	3600	MSB4, tested new mode with 48 energy/angle bins, tested other new modes

2025-01-07T21:58:16.500Z - 2025-01-08T14:01:31.505Z	48-48-8-1	Signal	3600	MSB6
2025-04-10T13:02:59.660Z - 2025-04-10T14:51:55.662Z	16-28-2-1	n/a	0	CO#13, testing deadtime settings
2025-10-14T13:54:27.894Z - 2025-10-14T16:51:53.908Z	48-48-8-1; 48-12-64-1; 16-28-2-1	Natural background	3600, 0	CO #14, testing deadtime settings

Table B-3 – *MIPA observation periods since launch*

B.4 PICAM Dataset Description

Operation times	Mode	Note
2018-12-12T08:59:31 2018-12-12T09:17:13	N/A	NECP
2018-12-15T08:29:51 2018-12-15T18:05:49	7 (TOF)	Extension of NECP
2019-07-22T09:57:49 2019-07-26T17:17:43	1 (IMG) 6 (IMG) 7 (TOF) 8 (TOF) 14 (TOF)	Delta commissioning operations
2019-11-26T08:15:09 2019-11-26T09:40:36	N/A	Cruise instrument checkout
2020-04-09T21:29:32 2020-04-10T22:31:45	4 (IMG) 6 (IMG) 8 (TOF)	Earth flyby
2020-06-25T15:30:09 2020-06-25T16:55:36	N/A	Cruise instrument checkout
2020-09-03T13:04:54 2020-09-03T18:41:26	7 (TOF) 11 (TOF)	PICAM onboard software update test
2020-09-04T12:14:30 2020-09-04T17:12:01	4 (IMG) 7 (TOF)	PICAM onboard software update test
2020-09-07T15:49:09 2020-09-09T10:16:58	1 (IMG) 8 (TOF) 11 (TOF) 13 (TOF)	PICAM onboard software update test
2020-10-15T00:17:41 2020-10-16T04:08:49	1 (IMG) 4 (IMG) 7 (TOF)	Venus flyby #1
2020-12-17T09:30:09 2020-12-17T17:52:27	7 (TOF) 8 (TOF)	Cruise instrument checkout

	13 (TOF)	
2021-05-07T08:03:09 2021-05-07T08:20:28	N/A	PICAM onboard software update test
2021-06-16T10:20:09 2021-06-16T11:47:18	N/A	Cruise instrument checkout
2021-06-17T09:13:09 2021-06-17T14:55:38	7 (TOF) 8 (TOF) 11 (TOF)	Cruise instrument checkout
2021-07-02T10:08:09 2021-07-02T14:33:00	7 (TOF)	Cruise science observations
2021-07-05T19:02:09 2021-07-05T22:39:48	2 (IMG) 3 (IMG) 5 (IMG) 9 (TOF) 10 (TOF)	Cruise science observations
2021-07-06T00:24:09 2021-07-06T08:05:49	N/A	PICAM onboard software update test
2021-07-16T10:08:09 2021-07-16T14:33:00	4 (IMG) 7 (TOF)	PICAM onboard software update test
2021-07-21T07:55:09 2021-07-21T21:29:14	4 (IMG) 7 (TOF)	PICAM onboard software update test
2021-08-09T03:47:03 2021-08-10T19:52:55	4 (IMG) 7 (TOF)	Venus flyby #2
2021-09-08T15:47:09 2021-09-08T16:13:31	7 (TOF)	Cruise science observations
2021-09-19T15:55:09 2021-09-21T22:31:26	4 (IMG) 15 (TOF)	Cruise science observations
2021-10-01T07:29:51 2021-10-02T07:33:49	4 (IMG) 11 (TOF)	Mercury flyby #1
2021-10-06T00:02:14 2021-10-06T13:31:26	4 (IMG) 8 (TOF) 11 (TOF) 12 (TOF) 13 (TOF) 14 (TOF) 15 (TOF)	Cruise science observations
2021-10-07T00:05:09 2021-10-08T22:36:05	4 (IMG) 7 (TOF)	Cruise science observations

2021-11-04T12:19:09 2021-11-04T14:31:17	7 (TOF) 11 (TOF)	SERENA suite and onboard software update test
2021-11-05T08:36:09 2021-11-05T16:41:35	1 (IMG) 7 (TOF) 8 (TOF) 11 (TOF) 13 (TOF)	SERENA suite and onboard software update test
2021-11-22T13:08:09 2021-11-22T21:27:08	1 (IMG) 8 (TOF) 11 (TOF) 13 (TOF)	Cruise instrument checkout
2021-11-24T10:20:09 2021-11-24T11:47:16	N/A	Cruise instrument checkout
2022-03-11T04:05:09 2022-03-13T20:25:23	4 (IMG) 7 (TOF)	Cruise science observations
2022-03-27T00:15:09 2022-03-29T21:05:13	4 (IMG) 7 (TOF)	Cruise science observations
2022-04-28T00:05:09 2022-04-30T23:35:13	4 (IMG) 7 (TOF)	Cruise science observations
2022-05-17T12:20:09 2022-05-17T13:48:16	4 (IMG) 7 (TOF)	Cruise science observations
2022-06-09T13:36:19 2022-06-09T18:14:15	7 (TOF) 13 (TOF)	SERENA suite and onboard software update test
2022-06-22T09:49:41 2022-06-25T09:50:10	1 (IMG) 4 (IMG)	Mercury flyby #2
2022-09-07T00:02:14 2022-09-07T15:06:07	4 (IMG)	Cruise science observations
2022-09-21T00:02:14 2022-09-21T15:06:07	4 (IMG)	Cruise science observations
2022-10-07T00:02:51 2022-10-19T20:06:07	4 (IMG)	Cruise science observations
2022-10-25T07:02:14 2022-10-27T13:22:00	4 (IMG)	Cruise science observations
2022-10-31T04:02:14	4 (IMG)	Cruise science observations

2022-10-31T20:06:39		
2022-11-07T07:50:09 2022-11-07T09:18:17	4 (IMG) 7 (TOF)	Cruise instrument checkout
2023-01-29T01:30:14 2023-02-12T23:31:40	1 (IMG) 4 (IMG)	Cruise science observations
2023-05-22T06:20:09 2023-05-22T07:45:17	4 (IMG) 7 (TOF)	Cruise instrument checkout
2023-05-30T12:32:09 2023-06-01T17:29:32	4 (IMG) 11 (TOF)	Cruise science observations
2023-06-17T23:54:44 2023-06-21T15:40:05	1 (IMG) 4 (IMG)	Mercury flyby #3
2023-07-31T13:50:25 2023-07-31T18:27:52	1 (IMG) 4 (IMG) 7 (TOF)	Cruise science observations
2023-10-05T00:02:10 2023-10-05T11:02:08	4 (IMG)	Cruise science observations
2023-10-07T00:05:18 2023-10-12T23:58:55	4 (IMG) 7 (TOF)	Cruise science observations
2023-11-10T11:20:08 2023-11-10T12:41:28	4 (IMG) 7 (TOF)	Cruise instrument checkout
2023-12-08T00:02:08 2023-12-22T23:31:39	4 (IMG) 7 (TOF)	Cruise science observations
2024-04-11T13:001:09 2024-04-12T16:07:08	1 (IMG) 4 (IMG) 7 (TOF) 8 (TOF) 11 (TOF) 13 (TOF)	SERENA suite and onboard software update test
2024-08-08T12:02:39 2024-08-08T14:04:14	7 (TOF)	PICAM dedicated test
2024-09-02T22:18:58 2024-09-06T21:35:54	1 (IMG) 7 (TOF) 8 (TOF) 11 (TOF) 0 (TOF)	Mercury flyby #4
2025-01-06T06:35:02 2025-01-10T04:50:27	4 (IMG) 7 (TOF)	Mercury flyby #6

	13 (TOF) 0 (TOF)	
2025-04-10T10:12:25 2025-04-10T12:26:07	4 (IMG) 13 (TOF) 0 (TOF)	Cruise instrument checkout
2025-07-15T13:20:26 2025-07-15T14:07:13	1 (IMG) 7 (TOF)	PICAM onboard LUT update test
2025-10-14T10:12:13 2025-10-14T13:36:12	1 (IMG) 7 (TOF)	Cruise instrument checkout

Table B-4 – *Overview of the PICAM observations since launch*

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