SWEDISH INSTITUTE OF SPACE PHYSICS
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ROSETTA RPC-LAP
to Planetary Science Archive
Interface Control Document

RO-IRFU-LAP-EAICD

Issue 2.1.1

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Document History

Version	Date	Sections Changed	Notes
1.0	2003-08-19	New document	Initial draft
1.1	2005-08-04	All sections updated.	PDS Software and archive has matured
1.2	2005-11-24	Most sections updated.	Corrections in response to PSA team.
1.3	2006-01-27		Never issued.
1.4	2006-01-31	Minor corrections.	Corrections in response to PSA team.
1.5	2006-10-31	Numerous updates related to PDS review, mostly RID corrections.	PDS archive review.
1.6	2012-07-03	Almost all.	Complete update and revision of all text, taking RIDs from the Lutetia review into account. Geometry info added.
1.7	2012-10-10	Minor corrections.	Corrections in response to comments on previous version. Non-correspondence of filenames in EDITED and CALIBRATED described. More details on bias values and their calibration.
1.8	2012-01-30	2.2, 2.3, 2.5, 3.1.4	Editorial and typo correction in response to comments by PSA. All tables renumbered. Improved description of filenames in Section 3.1.4.
1.9	2013-08-13		Editorial changes in response to PSA review.
1.9.1	2015-02-23	1.9, 2.5, 4.3.1.5, 4.3.2.2-5	Updated contact names, addresses, a calibration detail (cubic fit), and renamed keywords, other minor edits.

1.9.2	2015-07-07	2.3, Table 2.3-1	Corrected the macro table graphics. Emphasized that the macro table is an example.
1.9.3	2015-09-01	0, 2.7, 4.1.4, 4.2.3, 5.3.2.4, Tables 3-1, 3-2	New specifications for geometry files.
1.10	2016-08-31	Most sections modified, in particular Sections 2 and 3 (new).	Changes in response to PSA & PDS review. Updates for new CALIBRATED data set format. Updated specification of geometry files, extended descriptions of in-flight data products and HK, added RPCLAP_CALIB_MEAS_EXCEPT.
1.10.1	2016-10-12	Section 3.7, 4.1.4, Table 8	Changes in response to PSA & PDS review. Added missing information on RPCLAP_CALIB_MEAS_EXCEPT. Product ID text as proper table. Mission-specific keywords cleaned up.
1.10.2	2016-12-14	Section 2.5, 3.1, 3.2.1	Described two additional offset calibrations and a related caveat. Moved tables within Section 3.1 to end of section.
1.10.3	2017-03-02	Section 2.5, 3.1	Calibration typo fixed (offsets between ADC16 and ADC20 data). Fixed broken internal references.
1.11	2017-08-24	Section 2.5, 2.6 (moved into 3.1.1), 3.1, 3.2.1, 3.3, 3.9, 5.3.1.5, 5.3.2.1.5	Rephrased language to not use “we” or “our” (all sections). Algorithm to select RPCLAP*yymmdd*_CALIB_MEAS corrected to mention RPCLAP_CALIB_MEAS_EXCEPT. Clarified calibration and updated new calibration procedures (8 kHz filter offsets, moving-average bug compensation, new ADC20 calib. factors). Removed unused ADC20 calib. factor PDS keywords. Added high/low-gain, truncated/non-

			truncated to summary of instrument settings. Added TSEQ coordinates to geometry files. Updated SPICE usage. Updated quality flags information.
1.11.1	2017-09-11	2.4, 2.5.1, 5.3.2, 2.5.5, 2.5.6.1, 3.2.1, 3.5, 4.4.3.2	Removed geometry files from EDITED. Moved geometry data product design. New algorithm and new supporting data product RPCLAP*yymmdd*_CALIB_COEFF for bias- and temperature-dependent current offset, replacing old data product RPCLAP_CALIB_MEAS_EXCEPT and all except one RPCLAP*yymmdd*_CALIB_MEAS. Updated P2 caveats.
1.11.2	2017-09-29	2.2, 2.5.7 (new), 2.5.8 (new), 3.1, 5.3.1.5	Added excluded LF samples, pseudocode to describe calibration, distinction coarse/fine sweeps, note on ADC20 average bug (last four bits).
1.11.3	2017-11-20	Changes in response to Review; 2.2, 2.5.1, 3.2.1, 4.1.4, Table 5-6, Fig. 2, Fig. 3 (prev.)	Transfer functions and time shift. Clarified product IDs and filenames with colors. Removed (old) Fig 3. Caveat for absence of way to detect saturation in CALIBRATED data.
1.12	2018-08-28	1.8, 2.4, 3, 3.1, 3.3.1, 4.1.4, 4.4.3.3, 4.4.3.5, 5.3.1.2, 5.3.1.5, 5.3.2, Table 5-6, Table 9	Updates due to reorganizing EDITED data products and adding saturation handling. Added references to list of mission phases. Quality flag "Low sample size" explained. Updated label file examples. Removed keyword ROSETTA:LAP_P*x*_INITIAL_SWEEP_SMPLS. Minor updates.
1.12.1	2018-08-29	3.5, 5.3.2.3, Table 7	Updated probe illumination angles, added geometry illumination columns.
1.12.2	2018-12-03	1.9, 3.4.1, 2.5.8, 3.5, 3.8 (new),	Probe illumination algorithm typo fixed. Described the use of fill values. Contact persons.

		..5.3.1.5, 5.3.2, Table 5	Clarification on bias setting by telecommand. Updated label examples. Added and clarified PDS label column names. Clarified four cleared bits dues to moving average.
2.0.0	2019-03-31	2.2 (figure 1 update and minor edits), 2.3.3 (new) 2.4 (D+) 2.6 (new) 3.1 (D+) 3.1.1 (new) 3.11 (removed) 3.2 (D+) 3.3.2 (D+) 3.3.3 (new) 3.4 (reorg.) 3.4.2.2 (new) 3.7 (D+) 4.1.2 (D+) 4.4.3.2 (D+) 5.3.1.5 (clarif.) 5.3.2.3 (new), Table 3 (new), Table 7 (new),	Added DERIVED-level data sets and did editorial changes throughout the document for release as version 2. Additions for DERIVED are noted by D+ in the section list in the column at left. Minor editorial changes (e.g. change of notation from P1 to LAP1) are not listed.
2.0.1	2019-04-04	Mainly 2.6, and Tables 7 and 8	Correction of errors in 2.0.0 due to file conversion (corrupted tables, lost text, incorrect cross-references, font issues, etc).
2.1.0	2019-06-27	2.4, 2.4.x (new), 3.2, 3.3.2, 3.5, 3.7, 4.4.3.2, 5.3.2.3.6 (new), Table 6 (new), Table 9 (new)	Changes in response to review, values, improved quality flag description, name change NPL→NED, added NEL data sets, reorged science data products, removed duplicate calibr. files info.
2.1.1	2019-07-15	2.4.1, 2.6.7, 3.3 (new), 3.5.2.3 (new) , 3.7 (new), 4.4.3.7 (new) 5.3.1.2, 5.3.2 (removed)	Changes in response to review. Added browse plots. Removed label file examples. X axis in Figure 1 corrected. Sections on timing and macro 0x515 added. Updated N_E_FIX_T_E description. Some listings and

			unnumbered tables converted to numbered tables.

CONTENTS

1 Introduction

1.1 Purpose and Scope

This document provides users of PSA/PDS data products from the Langmuir Probe instrument of the Rosetta Plasma Consortium (RPC-LAP) with a description of the data products and how they were generated. It is also the official interface between the LAP team and the archiving authority.

1.2 Archiving Authorities

1.2.1 Planetary Data System (PDS)

The Planetary Data System Standard is used as archiving standard by

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

1.2.2 ESA's Planetary Science Archive (PSA)

ESA implements an online science archive, the PSA,

- to support and ease data ingestion
- to offer additional services to the scientific user community and science operations teams as e.g.
  - search queries that allow searches across instruments, missions and scientific disciplines
  - several data delivery options such as:
    - direct download of data products, linked files and data sets
    - FTP download of data products, linked files and data sets

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

1.3 Contents

This document describes the data flow of the LAP instrument on the Rosetta mission from the s/c until the insertion into the PSA for ESA. It includes information on how data were processed, formatted, labeled and uniquely identified. The document discusses general naming schemes for data volumes, data sets, data and label files as well as fundamental features of the instrument. Standards used to generate the product are explained. The design of the data set structure and the data product is given, with some examples.

1.4 Intended Readership

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

1.5 Applicable Documents

AD1 Planetary Data System Standards Reference, February 27, 2009, Version 3.8, JPL D-7669, Part 2

AD2 ROSETTA Archive Generation, Validation and Transfer Plan, September 01, 2005, RO-EST-PL-5011

AD3 RO-RPC-UM, Rosetta Plasma Consortium: User´s Manual

AD4 RO-IGEP-TR-0016, RPC Archiving Guidelines

1.6 Reference Documents

RD1 RPC-LAP: The Rosetta Langmuir probe instrument. A. I. Eriksson, R. Boström, R. Gill, L. Åhlén, S.-E. Jansson, J.-E. Wahlslund, M. André, A. Mälkki, J. A. Holtet, B. Lybekk, A. Pedersen, L. G. Blomberg and the LAP team. *Space Science Reviews, 128*, 729-744, 2007. DOI:10.1007/s11214-006-9003-3.

RD2 RPC-LAP: The Langmuir probe instrument of the Rosetta plasma consortium. A. I. Eriksson, R. Gill, J.-E. Wahlund, M. André, A. Mälkki, B. Lybekk, A. Pedersen, J. A. Holtet, L. G. Blomberg and N. J. T. Edberg. In *Rosetta: ESA's Mission to the Origin of the Solar System*, editors R. Schulz, C. Alexander, H. Bönhardt and K.-H. Glassmeier. Springer, 2009.

RD3 RPC: The Rosetta Plasma Consortium. C. Carr, E. Cupido, C. G. Y. Lee, A. Balogh, T. Beek, J. L. Burch, C. N. Dunford, A. I. Eriksson, R. Gill, K. H. Glassmeier, R. Goldstein, D. Lagoutte, R. Lundin, K. Lundin, B. Lybekk, J. L. Michau, G. Musmann, H. Nilsson, C. Pollock, I. Richter and J. G. Trotignon. *Space Science Reviews, 128*, 629-647, 2007. DOI: 10.1007/s11214-006-9136-4.

RD4 RPC: The Rosetta Plasma Consortium. C. Carr, E. Cupido, C.G.Y. Lee, A. Balogh, T. Beek, J. L. Burch, C. N. Dunford, A. I. Eriksson, R. Gill, K.-H. Glassmeier, R. Goldstein, D. Lagoutte, R. Lundin, K. Lundin, B. Lybekk, J. L. Michau, G. Musmann, H. Nilsson, C. Pollock, I. Richter and J. G. Trotignon. In *Rosetta: ESA's Mission to the Origin of the Solar System*, editors R. Schulz, C. Alexander, H. Bönhardt and K.-H. Glassmeier. Springer, 2009.

RD5 RPC-MIP: The Mutual Impedance Probe of the Rosetta Plasma Consortium. J.-G. Trotignon, J.-L. Michau, D. Lagoutte, M. Chabassière, G. Chalumeau, F. Colin, P. M. E. Décréau, J. Geiswiller, P. Gille, R. Grard, T. Hachemi, M. Hamelin, A. Eriksson, H. Laakso, J.P. Lebreton, C. Mazelle, O. Randriamboarison, W. Schmidt, A. Smit, U. Telljohann and P. Zamora. *Space Science Reviews, 128*, 713-728, 2007. DOI: 10.1007/s11214-006-9005-1.

RD6 N.J.T. Edberg, A.I. Eriksson, U. Auster, S. Barabash, A.Bößwetter, C.M. Carr, S.W.H. Cowley, E. Cupido, M. Fränz, K.-H. Glassmeier, R. Goldstein, M. Lester, R. Lundin, R. Modolo, H. Nilsson, I. Richter, M. Samara, J.G. Trotignon, 'Simultaneous measurements of the Martian plasma environment by Rosetta and Mars Express', Planet. Space Sci., 57, 1085-1096, 2008. doi:10.1016/j.pss.2008.10.016

RD7 Odelstad et al, Evolution of the plasma environment of comet 67P from spacecraft potential measurements by the Rosetta Langmuir probe instrument, *Geophysical Research Letters, 42*, 10126-10134, 2015, doi:10.1002/2015GL066599

RD8 Odelstad et al., Measurements of the electrostatic potential of Rosetta at comet 67P, *Monthly Notices of the Royal Astronomical Society, 469*, S568-S581, 2017, doi:10.1093/mnras/stx2232

RD9 Johansson et al., Rosetta photoelectron emission and solar ultraviolet flux at comet 67P, *Monthly Notices of the Royal Astronomical Society, 469*, S626-S635, 2017, doi:10.1093/mnras/stx2369

RD10 Eriksson et al., Cold and warm electrons at comet 67P, *Astronomy and Astrophysics, 605,* A14, 2017, doi:10.1051/0004-6361/201630159

RD11 Engelhardt et al., Cold electrons at comet 67P/Churyumov-Gerasimenko, *Astronomy and Astrophysics, 616*, A51, 2018, doi:10.1051/0004-6361/201833251

RD12 Engelhardt et al., Plasma density structures at comet 67P/Churyumov-Gerasimenko, *Monthly Notices of the Royal Astronomical Society, 477*, 1296-1307, 2018, doi:10.1093/mnras/sty765

RD13 RPC User Guide, March 28, 2019, Version 2.0.

RD14 RPC-LAP Science Data User Guide, July 12, 2019, Version 1.1.

1.7 Relationships to Other Interfaces

This document is the top level document for LAP PDS-compliant PSA archiving.

1.8 Acronyms and Abbreviations

ADC	Analog-to-Digital Converter
ADC16	The 16-bit ADC. One on each probe.
ADC20	The 20-bit ADC. One on each probe.
AQP	Acquisition Period
bps	Bits per second
BM	Burst rate TM mode
DAC	Digital-to-Analog Converter
DDS	Data Disposition System
DVAL	Data Validation Tool (software)
E	Current bias (E-field measurement), mode of a LAP probe
EAICD	Experiment to Archive Interface Control Document
ESA	European Space Agency
ESOC	European Space Operations Centre
GSE	Ground Support Equipment
HGA	High-Gain Antenna
ICA	Ion Composition Analyzer (other RPC instrument)
HF	High Frequency sampling
HK	Housekeeping
IC	Imperial College, London
IES	Ion and Electron Sensor (other RPC instrument)
IRFU	Swedish Institute of Space Physics, Uppsala branch (Institutet för rymdfysik (IRF), Uppsala)
LAP	Langmuir Probe instrument
LAP1	LAP probe 1
LAP2	LAP probe 2
LDL	Long Debye Length (mode of the MIP instrument)
LF	Low Frequency sampling
LM	Low rate TM mode

MAG	Fluxgate magnetometer (other RPC instrument)
MIP	Mutual Impedance Probe (other RPC instrument)
N	Voltage bias (deNsity measurement), mode of a LAP probe
NM	Normal rate TM mode
OBT	On-board time, expressed as a second counter with true decimals (as opposed to s/c clock counts).
P1	LAP probe 1
P2	LAP probe 2
PDS	Planetary Data System
PIU	Plasma Interface Unit (RPC central unit)
PSA	Planetary Science Archive (ESA)
PSD	Power Spectral Density
PVV	PSA Volume Verifier
RPC	Rosetta Plasma Consortium
s/c	Spacecraft
SDL	Short Debye Length (normal mode of MIP instrument)
SSP	Surface Science Package (on the Philae lander)
TBD	To be defined
TBW	To be written
TM	Telemetry.
TM units	The units of the digital values sent to DACs (set bias), and received from ADCs (measurements).
Vps	Probe-to-spacecraft voltage

1.9 Contact Names and Addresses

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2 Overview of Instrument Design, Data Handling and Product Generation

2.1 RPC and LAP

RPC, the Rosetta Plasma Consortium, is a set of instruments on the Rosetta orbiter for investigation of plasma properties and electromagnetic fields. RPC is described in RD3 and RD4. The Langmuir probe (LAP) instrument is one of these instruments, and is referred to as RPC-LAP or LAP in the rest of this document.

2.2 The LAP Instrument

This section gives a very brief introduction to the LAP instrument, and is recommended reading for any user of any LAP data product. For more complete information, refer to the two published instrument descriptions, RD1 and RD2.

LAP uses two spherical sensors of 2.5 cm radius, mounted on 15 cm "stubs," which, in turn, are attached to the ends of the spacecraft booms by a "foot" (see picture on document cover page). Probe 1 is mounted on the "upper" spacecraft boom, also carrying the RPC-MIP antenna (RD5). This boom, which is 2.24 m in length from hinge to probe, is protruding from the spacecraft at an angle of 45° to the nominal comet direction (the *z* axis in Figure 1; see also Table 1). By pointing to the comet, probe 1 will get access to a plasma flow from the comet as undisturbed as possible by any spacecraft sheath or wakes, without interfering with the field of view of other instruments. Probe 2 is mounted on the "lower" boom, 1.62 m in length, which also carries the RPC-MAG sensors. The distance between the probes is 5.00 m, and the probe separation in the nominal comet direction (*z* axis) is 4.55 m.

	x (m)	*y* (m)	*z* (m)
Probe 1	−1.19	2.43	3.88
Hinge 1	−1.19	0.85	2.30
Probe 2	−2.48	0.78	−0.65
Hinge 2	−1.19	0.65	0.30

Table 1. Positions in the spacecraft coordinate system, indicated in Figure 1, for the LAP probes and for the hinges at the boom roots. [After AD3]

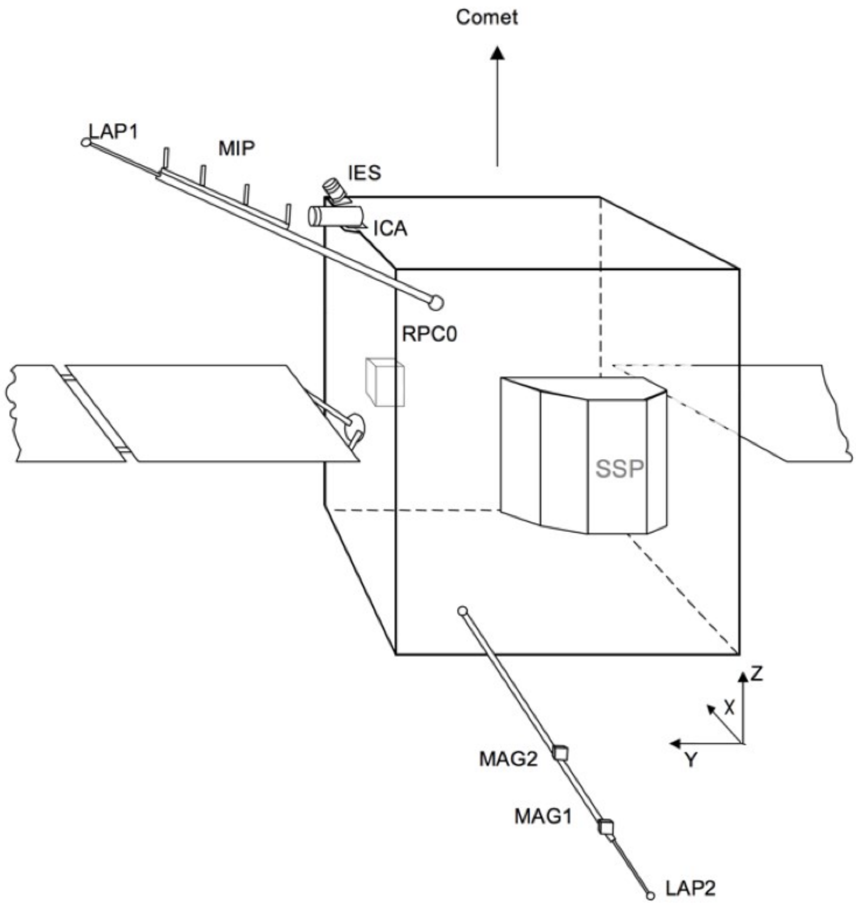

Figure 1. The mounting of the LAP sensors, LAP1 and LAP2, and other RPC units on the Rosetta spacecraft. RPC-0 is the common electronics box, also housing the LAP electronics boards. The direction of the s/c coordinate axes are indicated: the origin of the s/c coordinate system is at the center of the –Z surface (bottom surface in this sketch). SSP is the Philae lander, not part of RPC. [From RD13].

This document primarily uses the designations LAP1 and LAP2 for the two LAP probes. The short form P1 and P2 are used for e.g. label column names (Table 7 and Table 8), instrument-specific PDS keywords (Section 5.3.1.5); and some calibration data products (Section 3.9). Other schemes can also be found in the literature and documentation: RPC-3.1 and RPC-3.2, probe 1 and probe 1, sensor 1 and sensor 2, S1 and S2, and so forth. In addition we sometimes use the designation LAP3 or P3 to represent difference measurements, i.e. the LAP1 measurement minus the LAP2 measurement, but calculated in the instrument (in TM units).

The probes can be independently operated in any of two *bias modes*:

- A *bias voltage* can be applied to the probe, in which case the basic measured quantity is the current flowing from the probe to the plasma. In general, this current is denoted as Ip, with I1 and I2 referring to the specific currents from the two probes. This bias mode is denoted N (for deNsity mode) or (in the EDITED data set filenames).

- A *bias current* (including zero, corresponding to floating probes) can be applied to the probe. In this case, the basic quantity measured is the voltage of the probe with respect to the spacecraft, denoted Vps in general, with V1 and V2 denoting the specific signal from each probe. This bias mode is denoted E (for Electric field mode).

Probe LAP2 may also be used by the RPC-MIP instrument for use in its LDL (Long Debye-Length) mode [RD5]. In this case, LAP can only take data from LAP1. To indicate how the probes are operated, it is convenient to group the LAP1 and LAP2 bias modes together. For example, "NE" then indicates that LAP1 is in voltage bias mode (N) and LAP2 in current bias mode (E), while "E-" indicates that LAP1 is in current bias mode (E) and LAP2 is not used by LAP because it is being handed over to MIP for LDL operations.

In general, voltage bias is most useful in dense plasmas for determining the prime LAP science parameters of plasma density, electron temperature, plasma flow speed, and the density fluctuation spectrum, while the bias current is applied to get measurements of spacecraft potential and electric (wave) fields. In tenuous plasmas, the density is better obtained from the spacecraft potential. The limit between "dense" and "tenuous" is not absolute but set by the currents flowing to an object at zero potential with respect to the surrounding plasma: "dense" means that the random thermal electron current dominates, "tenuous" that the photoemission current dominates. Hence, the dense-tenuous density limit depends on the photoemission current, which is proportional to the solar UV flux. The limit density follows a $1/r^2$ relation with distance from the sun, and also varies with temporal solar UV intensity variations. In general, the limit varies between at a few hundred cm^{-3} at Earth orbit to a few tens cm^{-3} in the outer part of the Rosetta operational range of solar distances.

The bias applied on a probe can either be set to a constant value or, in the case of bias voltage, "swept", i.e. varied in steps over some range of voltage. LAP also has the possibility to apply a square-wave voltage of up to a few kHz to either probe and observe the resulting signal on the other probe.

Each probe has its own electronics, and can thus be operated independently of the other probe, regarding biasing as well as sampling. To each probe is attached two analog-to-digital converters (ADCs): one 20-bit ADC (ADC20), operating at 57.8 samples/s and denoted L or LF (for low frequency sampling), and one 16-bit ADC (ADC16), operating at 18 750 samples/s and denoted H or HF (for high frequency sampling).

Data are low-pass filtered by one of three different filters before sampling, cutting (3 dB damping point) at 20 Hz for L sampling and at either 4 kHz or 8 kHz for H sampling. The filter characteristics are shown in Figure 2, and are also available in the files containing the string FRQ in the CALIB directory, see Section 4.4.3.2. The filters were designed for high phase linearity in the pass band, resulting in the flat group delays displayed in Panels (c) and (d) of Figure 2.

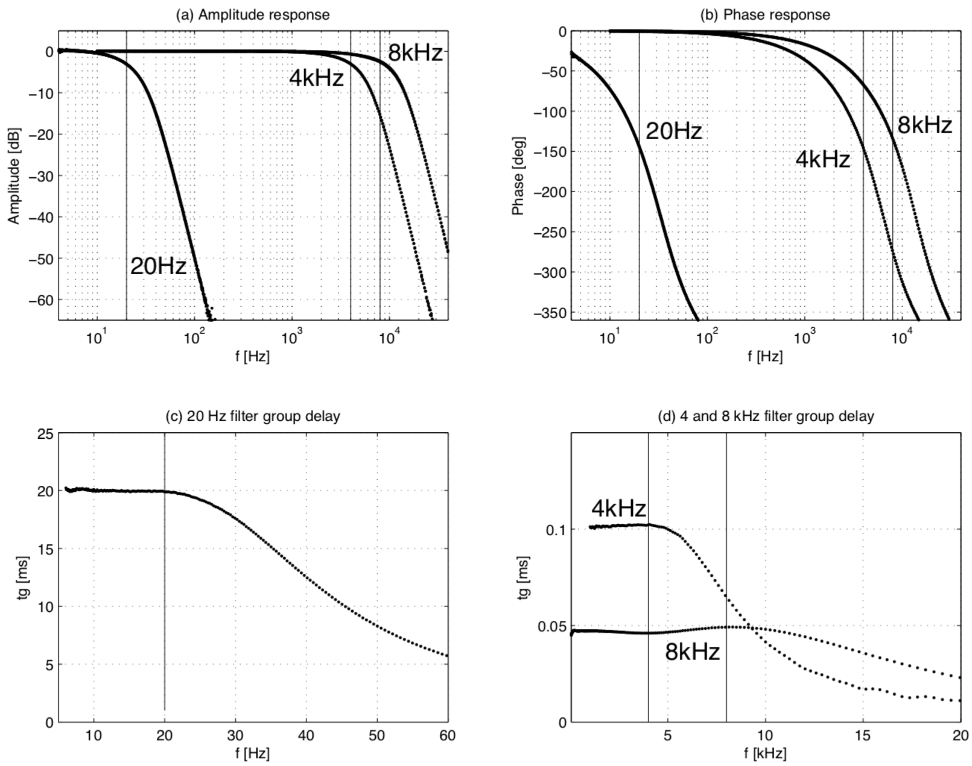

Figure 2. (a) Amplitude and (b) phase response of the LAP instrument, showing the roll-off of the three anti-aliasing filters, as measured in laboratory tests of the flight hardware. Data for LAP1 and LAP2 are plotted on top of each other but the probes are identical to the limit of the plot resolution and can therefore not be distinguished. (c) LAP2 group delay times for the 20 Hz, and (d) 4 kHz and 8 kHz filters, calculated from the LAP2 data in (b), showing the very low distortion in the pass bands. Vertical lines indicate nominal corner frequencies.

A variety of different measurements can be produced by this arrangement, producing different data types. The basic data types are listed below: however, it should be noted that the LAP flight s/w is very flexible, and functions can be defined for construction of other data types not listed here.

- *Fix-bias time series.* With the probes at constant bias (current or voltage), the time series, at some (almost) constant sampling frequency, from both or any of the probes, or derived time series like their difference or their average, can be transmitted.

- *Bias sweeps.* The bias voltage can be varied during a brief interval, known as a sweep. While the samples acquired still constitutes a time series, the basic assumption is that the plasma does not vary during the short sweep, and the sweep is treated as a set of instantaneous and simultaneous samples acquired at different bias. A sweep consists of at least one sequence of monotonously increasing or decreasing bias voltages, possibly followed by another sequence of monotonously decreasing or increasing (i.e. opposite direction) of bias voltages. Sweeps can be either "coarse" (low-resolution bias) or fine (high-resolution bias). See RD1, page 738.

Data can be transmitted to the PIU and further to the spacecraft systems at three different data rates or telemetry modes:

- *Low TM mode (LM):* 1.6 bps. Not used for regular science operations.
- *Normal TM mode (NM):* 62.5 bps. Most common mode for science operations.
- *Burst TM mode (BM):* 2253 bps. Used for shorter intervals when RPC TM allocation so allows.

2.3 LAP Operational Modes - Macros

This section describes the LAP operational mode concept. A general knowledge of these is necessary for at least users of LAP EDITED and CALIBRATED data sets, and could be of interest also to users of DERIVED data sets.

As described above, and in more detail in RD1 and RD2, the LAP probes can be used in different bias and sampling modes. Such settings are combined in instrument macros, which are command sequences stored in the LAP flash memory (RD1, RD2).

The basic time unit for LAP operations is the spacecraft data acquisition period (AQP) of 32 s. A macro specifies the LAP operations over an integer number of AQPs, with indefinite repetition. Each such repetition is sometimes referred to as a "macro cycle". When the instrument is commanded to run a certain macro, it thus repeats the sequence of instructions specified in the macro, excluding some initial set-up part, until commanded to stop or to change macro. A macro can therefore be said to define an operational mode of LAP.

A macro can contain any LAP command. In practice, macro instructions include the following:

- Bias settings for each probe
- Sweep setup
- Number of samples to acquire from each of the ADCs (beginning at the start of the AQP)
- Onboard data reduction: digital filtering, downsampling, and subtraction or addition of two signals.
- Possible idle wait for a number of AQPs (to keep telemetry within bounds)
- Telemetry mode (LM, NM, or BM)

Each macro is identified by a macro ID, which is stored in the data so that the instrument setup is always well known. A macro ID is fundamentally a sequence of three hexadecimal digits, e.g. 0x506, although digits outside the range 0-9 have rarely been used.

While a macro defines all LAP settings, it is possible to modify some such settings by telecommand while a macro is running. This has been used only for the probe bias settings, particularly for adjusting the bias current to a probe in voltage mode when its illumination changes. These manually set bias values are included in the data files.

The document **DOCUMENT/RO-IRFU-LAPMAC-***YYMMDD***-***phase***.PDF** contains a human-friendly summary of the types of measurements made by the various science macros used in the current mission phase. As new macros can be uploaded, the macros actually in use may be different for each phase of the mission. Table 2 shows an example of such a summary.

2.3.1 *Macro Blocks*

We define the term "macro block", or "command block", as the uninterrupted period of time when a given macro runs with the exception that macro blocks never run over midnight. Therefore, if the same macro runs continuously over midnight (once), it will still count as two separate macro blocks. A macro block is therefore a natural period of time for analyzing LAP science data products. All LAP data products cover at least one macro block of time per file, typically several hours.

2.3.2 *Example Macro Explained*

To understand the macro table, Table 2, take as an example macro 0x506, which can be run at Normal telemetry rate. From the table, one can see that when this macro is running, both LAP probes are in bias voltage mode (NN), with a constant bias of +10 V when not sweeping. One can also see that the data sampled by the instrument in this mode are:

- Both probe currents I1 and I2 are available continuously at a time resolution of about 2.2 s (0.45 samples/s). These signals are conveniently denoted as I1L and I2L, the L signifying that the low frequency ADCs (ADC20) are used. Had the probes been in current bias mode, the signals had been voltages denoted V1L and V2L. This continuous sampling is not exactly continuous: the sampling is always reset at the beginning of each AQP, and there may also be one or a few samples missing at the end of an AQP. Despite this, it covers almost all the entire AQP, and is available in every AQP, and hence is at least quasi-continuous. These data are produced by the two ADC20s at 57.8 samples/s, and are then downsampled by a factor of 128. This downsampling is always by some power of two, so for a macro where the table says continuous data at 0.9 samples/s, the exact number is 57.8/64 samples/s.

- Every 5th AQP (every 160 s = 5 * 32 s/AQP), 96 samples are taken simultaneously on both probes at full time resolution by the two ADC16s (18.750 kHz). These signals are denoted I1H and I2H, with H signifying high frequency, and are referred to as HF snapshots. In macros where the probes are in current bias mode, the HF signals are voltage samples denoted by V1H and V2H. In this particular macro, they cover 5.12 ms (96/18750 s), and can thus be used to study wave activity between 0.2 and 8 kHz (where the low-pass filter sets in, see Figure 2). In some macros (e.g. 0x700), digitally onboard-computed differences between the probes rather than individual signals are stored. In some other macros, the data are digitally filtered and downsampled (e.g. by a factor 8, to 2.34 kHz, in 0x416) onboard.
- Both probes bias voltages are swept between -12 and +12 V every 5th AQP (every 160 s, not the same AQPs as in which the HF snapshots are taken), in steps of 0.5 V. Sweeps are only available in bias voltage mode.

In the LAP EDITED and CALIBRATED data sets, one file is saved for each type of data, macro block and probe. This means that for every macro block where this particular macro runs, there are two data files containing I1L and I2L, two data files containing I1H and I2H, and two files containing I1S and I2S data. The number of EDITED and CALIBRATED files can thus differ for different macros.

LAP Macro Table

Date: 120828

Macro ID	0x104	0x212	0x503	0x504	0x505	0x506	0x600	0x604	0x700	0x701	0x702	0x703	0x704	0x705	0x706	0x803	0x804	0x807
Notes	Calibration	Use 0x506			Use 0x506		Use 0x506		Use 0x503	Use 0x503	Use 0x503			Use 0x503	Use 0x504		Use 0x807	
Purpose	Calibration	Swp, HF	Vs, HF	Vs, HF	N, HF, swp	N, HF, swps	Swp, HF	N, HF, swps	Vs, HF	Vs, HF	Vs, HF	LDL, Vs, HF	DL, Vs, wave	Vs, HF	Vs, HF	LDL, N, HF	LDL, N, HF	DL, N, HF, swp
TM rate	NM	NM	NM	BM	NM	NM	NM	BM	NM	NM	NM	NM	BM	NM	BM	NM	BM	BM
Bias mode	NN	NN	EE	EE	NN	NN	NN	NN	EE	EE	EE	E-	E-	EE	EE	N-	N-	N-
Fix bias P1	.	0 V	-8 nA	-8 nA	+10 V	+10 V	+20 V	+20 V	-17 nA	-17 nA	+1 nA	-30 nA	-29 nA	-29 nA	-29 nA	+10 V	+10 V	+10 V
Fix bias P2	.	0 V	+3 nA	+3 nA	+10 V	+10 V	+20 V	+20 V	-17 nA	+1 nA	-17 nA	MIP	MIP	+3 nA	+3 nA	MIP	MIP	MIP
Continuous data (ADC20)																		
Sampled data	.	.	V1, V2	V1, V2	I1, I2	I1, I2	.	I1, I2	V1, V2	V1, V2	V1, V2	V1	V1	V1, V2	V1, V2	I1	I1	I1
fsamp [Hz]	.	.	0.9	57.8	0.45	0.45	.	28.9	0.9	0.9	0.9	1.8	57.8	0.9	57.8	1.8	57.8	57.8
Wave snapshots (ADC16)																		
Sampled data	.	I1, I2	V1	V1, V2	I1, I2	I1, I2	I1, I2	I1, I2	V1-V2	V1-V2	V1-V2	V1	V1	V1-V2	V1-V2	I1	I1	I1
fsamp [Hz]	.	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750	18750
Samples	.	256	272	432	96	96	256	1840	160	160	160	160	2416	272	2624	160	2416	4080
Cadency [AQPs]	.	8	5	1	5	5	8	3	3	3	3	3	1	5	3	3	1	2
Cadency [s]	.	256	160	32	160	160	256	96	96	96	96	96	32	160	96	96	32	64
Sweeps (ADC16)																		
Probes	Open	P1, P2	.	.	P1, P2	P1, P2	P1, P2	P1, P2	.	.	.	.	.	.	.	.	.	P1
Cadency [AQPs]	8	8	.	.	5	5	8	3	.	.	.	.	.	.	.	.	.	2
Cadency [s]	256	256	.	.	160	160	256	96	.	.	.	.	.	.	.	.	.	64
Range [V]	[-30, +30]	[-30,+15]	.	.	[-18, +18]	[-12, +12]	[-30, +20]	[-30, +20]	.	.	.	.	.	.	.	.	.	[-30, +30]
Step [V]	0.25	1	.	.	0.75	0.5	0.25?	0.25	.	.	.	.	.	.	.	.	.	0.25
First upload			PC8	PC8	PC12	PC12			PC4	PC4	PC4	PC6	PC6	PC6	PC6	PC10	PC10	PC12

Field colour indicates use:
Green: prefered non-LDL science macros
Orange: prefered LDL science macros
Yellow: maintenance, diagnostics, etc
Grey: superseded science macros

Text colour indicatess telemetry mode:
Black: Normal Mode
Blue: Burst Mode

Table 2. Example LAP science macros. LAP science macros uploaded June 2010. Text color indicates normal mode (NM, black) or burst mode (BM, blue) data rate. Background color indicates operational status: Pale green and orange are useful science macros without or with LDL, yellow calibration macros, and grey older science macros. The file `DOCUMENT/RO-IRFU-LAPMAC-`*`YYMMDD`*`-`*`phase`*`.PDF` contains the table relevant for the current mission phase.

2.3.3 *Table of Combinations of Averaging and Downsampling Actually Used*

LAP LF data can be averaged and downsampled (from the original 57.8 Hz sampling frequency) onboard. Due to the nature of averaging and downsampling, not all combinations are useful. The exact combinations of averaging and downsampling actually used in any science macros throughout the entire mission have been summarized in Table 3. Most macros have one unique such combination, though two (0x710 and 0x910) toggles between two which therefore are indicated in the files containing the resulting data (EFL files in DERIVED data).

Averaging and downsampling configuration number indicated in the electric field component data product (column 4)	Number of samples averaged over	Downsampling rate
0	1	1
1	2	1
2	2	2
3	4	4
4	64	4
5	32	32
6	64	32
7	64	64
8	128	128
9	256	256

Table 3. Complete set of combinations of moving average and downsampling used throughout the entire mission. The average and downsampling columns in this table are equivalent to the PDS keywords LAP_P1P2_ADC20_MA_LENGTH and LAP_P1P2_ADC20_DOWNSAMPLE respectively (Section 5.3.1.5). Table is also used for interpreting the “averaging and downsampling configuration value” in the Electric field component data product, see Table **8**.

2.4 Overview of Data Sets

This section describes the general structure of the LAP data sets. It should be of interest to any user of these data sets.

Note: The regular user should only be interested in the DERIVED-level data sets, i.e. DERIV2 and NEL data sets (see sections below).

2.4.1 Division into Archiving Levels

In conformance to PDS standards, data are archived at different levels (archiving levels, processing levels) where higher-level data can be derived from lower-level data. The same information may thus, in some sense, be represented multiple times in multiple data sets. Not all data is represented at every archiving level, since e.g. some data are calibration measurements which cannot be used to calibrate itself, or data that is not deemed to be of good enough quality to calibrate (e.g. fine sweeps), or data that is corrupt (e.g. due to bad commanding). Every LAP data set contains data for exactly one of the three archiving levels below:

- EDITED (level 2, L2): Decommutated uncalibrated raw data in TM units.
- CALIBRATED (level 3, L3): Data corrected for instrumental offsets and converted to engineering units (V and A).
- DERIVED (level 5, L5): Final physical output parameters in physical units (V, cm^{-3}, eV etc.)

2.4.2 Division into Types of Data Sets

LAP data is archived using four different *types* of data sets, where each type of data set contains its own set of unique types of data products. The types of data sets are identified by the following strings:

- EDITED2 (EDITED-level)
- CALIB2 (CALIBRATED-level)
- DERIV2 (DERIVED-level)
- NEL (DERIVED-level)

These data set type strings are also used as description strings in DATA_SET_IDs which in turn are used to uniquely identify individual data sets (see Section 4.1.2) and which is where users are like to encounter them.

Therefore, in the context of LAP data and of reading this document, the terms EDITED-level and EDITED2, and CALIBRATED-level and CALIB2, respectively, are almost synonymous, whereas DERIVED-level and DERIV2 are not synonymous due to the existence of NEL data sets.

The reason for dividing the DERIVED data into DERIV2 and NEL is historical and should be unimportant to any user. The reason for the digit “2” in EDITED2 and CALIB2 is to distinguish them from some earlier, published but now superseded versions of LAP EDITED and CALIBRATED data sets which used an entirely different, and much less practical, system of data products. The digit “2” in DERIV2 is historical: to distinguish it from internal, unofficial versions of data sets never released to the public. The name NEL refers to the sole type of science data product contained in the NEL data sets (NE=electron/plasma density, L=LF).

2.4.3 Overview of Content of Different Types of Data Sets

The types of data found in the different LAP data sets in more detail:

- EDITED2 data sets:
  - EDITED-level science data – science data stream converted to human and PDS readable format, but still in TM units and with no calibrations or corrections applied. Every type of data is separately collected into a longer time series spanning a macro block (a continuous run of a given macro but still splitting at midnight). Data from onboard calibrations are included. The edited science data files are supplied mainly for long term archiving and reference purposes, and are not intended or suitable for regular scientific use.
  - Sweep descriptions – Information on step biases and time between steps valid for all sweeps on a given probe within a given macro block.
  - Block files – One table per day listing the macro blocks: macro number and their respective time coverages.
  - HK data – the HK data stream converted to human and PDS readable format, one file for each LAP HK packet. These data are supplied for long term archiving and reference purposes only, and are not intended or suitable for regular scientific use. The edited HK data files are only archived together with the edited science data files.
- CALIB2 data sets:
  - CALIBRATED-level science data - the science data stream converted to engineering units (volt and ampere), calibrated and corrected for known offsets and errors. Every type of data

is separately collected into a longer time series spanning a macro block (a continuous run of a given macro but still splitting at midnight). Data from pure calibration macros (in particular macro 0x104) are not included since they cannot be used to calibrate themselves. The calibrated data as such are of high quality, but there is no attempt for correction of e.g. attitude-dependent spacecraft-plasma interaction effects (wakes, photoemission, etc.), and scientific interpretation of the data requires great caution. These data products are very analogous to the EDITED2 data products.

  - Sweep descriptions – Information on step biases and time between steps valid for all sweeps on a given probe within a given macro block.
  - Block files – One table per day listing the macro blocks: macro number and their respective time coverages.
  - Geometry data files – one file per day containing position and attitude information at 32 s intervals throughout the day. The geometry files are archived with the calibrated science data files.

- DERIV2 data sets:
  - DERIVED-level science data - Science data converted to high-level products, e.g. plasma parameters.
    - Downsampled LF science data of currents and voltage at 32 s time resolution.
    - Power spectra (PSD) of HF currents and voltage.
    - High-level physical parameters derived from lower-level data:
      - Electric field
      - Spacecraft potential proxy
      - Plasma density
      - Electron temperature
      - Effective ion speed
      - Photosaturation current
  - Block files – One table per day listing the macro blocks: macro number and their respective time coverages.
  - Geometry data files – Identical to the counterparts in CALIBRATED data sets.
  - Browse plots (quicklooks) – One image per UTC day, containing plots that summarize the data for that day.

- NEL data sets: Additional DERIVED-level data set containing one additional type of science data product (NEL).
    - Plasma density (NEL)
    - Block files – One table per day listing the macro blocks: macro number and their respective time coverages.

Every type of data is collected into a longer time series spanning a macro block (a continuous run of a given macro but still splitting at midnight).

An even more detailed and hands-on description of how to use data products can be found in Section 3.2.

2.5 Calibration Process for CALIBRATED Data

This section is included for reference and should only be relevant for users interested in how to derive CALIBRATED data from EDITED data.

The measured EDITED data (current or voltage) are based on the direct output of the analog-to-digital converters (ADCs), and spans the range -32,768 to 32,767 (ADC16 data, and ADC20 data truncated to 16 bits) and -524,288 to 524,287 (non-truncated ADC20 data), with 0 representing approximately zero volt or ampere measured at a probe.

Saturation, i.e. the analog input to the ADCs being outside of the permitted range, is represented by the ADCs as the minimum digital value, both in the case of positive and negative saturation.

The probe current, both in the form of the bias current in E mode and the measured current in N mode, is by standard convention taken to be positive when flowing from the probe to the plasma. However, to follow the actual settings of the digital-to-analog converters, the bias current values have the opposite sign in the EDITED data set, so that -128 corresponds to a nominal bias current of +44 nA (with conventional sign choice) in the CALIBRATED data set, and +127 to -44 nA. Bias voltages range from -128 to 127 in EDITED, with the same sign as in CALIBRATED.

The data in the CALIBRATED data sets have been calibrated using the contents of the CALIB directory and files mentioned below are contained in that directory (see Section 4.4.3.2). Note that the CALIB directory also includes files with the instrument frequency response measured on ground (transfer functions; See Section 4.4.3.2) and that these are not used at present, but are included only for reference as vital instrument information.

The following sections describe the steps needed to produce CALIBRATED data from EDITED data.

2.5.1 *Frequency Response and Time Shift*

All analog signals run through analog low-pass filters before sampling as described in Section 2.2. The filters are designed for high phase linearity in the pass band, yielding frequency independent delays to the signals. To compensate for this delay, the timestamp of every calibrated ADC20 sample is decreased by 20 ms (see RD1, Figure 2 caption) in CALIBRATED and DERIVED data to ensure consistency with RPC-MAG (50 ms time resolution), which is the only other instrument on Rosetta with comparable time resolution. For ADC16 samples (4 and 8 kHz filters), *no adjustment* for the corresponding 0.1 and 0.05 ms group delays has been applied at any archive level.

2.5.2 *Obtaining Bias Voltages and Bias Currents.*

Bias voltages and bias currents are not routinely measured onboard. Their digital values are synthetically generated from knowledge of the commanded bias, after which they are converted to engineering units (volts and amperes) using the calibration tables contained in the files RPCLAP030101_CALIB_VBIAS.TAB and RPCLAP030101_CALIB_IBIAS.TAB, determined on ground. While there is no routine measurement of the biases onboard, it is possible to measure the current resulting from a given voltage bias applied over a 5.1 Mohm resistor (e.g. via macro 0x105) for occasional verification of the instrument integrity and consistency.

2.5.3 *Compensating for Jump in the ADC16 Output*

The measured ADC16 values are non-linear due to an unintended jump between -1 and 0 TM units. Therefore, 2.5 TM units is added to all non-negative ADC16 samples before further calibration, i.e. *before* multiplying with a calibration factor to obtain a value in ampere or volt. It is implicit elsewhere in this chapter that ADC16 TM data have first been modified this way in the calibration process. (EDITED data are not modified because of this.)

2.5.4 *Compensating for ADC20 Moving-average Bug in Flight s/w*

There is a flight s/w bug associated with moving average. The moving-average feature is only implemented for ADC20 data and this bug therefore only concerns such data. The bug consists of that the flight s/w mistakenly calculates moving averages $\underline{x}$ as

$$\underline{x} = \frac{(\sum_{i=1}^{N} x_i) + z}{N}, \text{ when } N \neq 1$$

where x_i are the real samples (in TM units), *z* is an unknown number (in TM units), and *N* is the originally intended (i.e. commanded) number of samples per average, as specified in the LAP-specific PDS label keyword

LAP_P1P2_ADC20_MA_LENGTH. Note that a value of $N = 1$ is equivalent to the moving average function being disabled, which means that the bug is not triggered. When the bug is triggered, we compensate for the bug by multiplying the data, in TM units, by $N/(N+1)$, decreasing its effect to some added random noise. It is implicit that this correction is made for on-board averaged ADC20 TM data elsewhere in this chapter

Note that this bug does not clash with the jump in ADC16 values, Section 2.5.3, since that concerns another ADC.

2.5.5 *Convert Measured Values in TM Units to Volt and Ampere*

Currents and voltages measured by the ADCs in TM units, but corrected for the effects in Sections 2.5.3 and 2.5.4, are converted to ampere and volt by multiplying them with the appropriate calibration factors.

For ADC16 data, the calibration factors C_{ADC16} are identical on LAP1 and LAP2 and were obtained from pre-flight ground tests. They are listed in Table 4.

ADC16 calibration factor, C_{ADC16}	***Value***
E-field	1.22072175E-3
Density mode, low gain	6.10360876E-9
Density mode, high gain	3.05180438E-10

Table 4. Calibration factors for ADC16 data (identical values for both probes).

For ADC20 data, the corresponding calibration factor values $C_{\mathrm{ADC20},i}$ can be obtained with

$$C_{ADC20,i} = C_{ADC16} * k_{trunc} * R_i$$

where k_{trunc} is 1 for truncated data and 16 for non-truncated data, R_i is a near-unity ADC ratio calibration value, and i = probe. The ADC ratio calibration values R_i are listed in Table 5 and were obtained in a one-time in-flight calibration on 2015-05-28 which compared the behavior of the ADC16s and ADC20s.

Probe	**ADC ratio calibration value, R_i**
LAP1	1.0030
LAP2	1.0046

Table 5. Near-unity ADC ratio calibration values needed to derive ADC20 calibration factors from ADC16 calibration factors.

2.5.6 *Adding and Subtracting Offsets*

In addition to the above, there are known offsets which, depending on bias and type of data, need to be added/subtracted from the measured currents and voltages produced above (in ampere or volt). These offsets are described below.

2.5.6.1 Temperature- and Bias-dependent Current Offsets (Density Mode)

Current measurements (i.e. only density mode) are sensitive to inevitable bias-dependent offsets due to small leakage currents in the instrument which add to the current before it is measured. These offsets also vary with time and temperature, and are therefore measured repeatedly. The following steps are taken to determine offsets and correct the data.

1) **Measuring bias-dependent current offsets:** The offsets were measured regularly during the mission by running macro 0x104 on the order of once per week. In this macro the probes are physically disconnected from the probes by opening a relay, thus disabling the bias current. The non-zero current that still arises is then measured (ADC16, 4 kHz filter) for every possible voltage-bias setting and for each probe, and originates from the instrument electronics themselves.
2) **Analyzing the measured offsets and producing tables of coefficients:** The LAP team has analyzed these measured offsets to produce tables of coefficients p_i, q_i, r_i, and s_i for each probe *i* (see below), as they change over time, but with a much higher time resolution (every 32 s) than that of the actually measurements of the offsets. These tables are stored in the **RPCLAP***YYMMDD*_**CALIB_COEFF** data products. To produce these tables of coefficients, the LAP team has analyzed how the measured offsets vary over time and how they correlate with instrument temperatures over time etc. Note that these tables themselves might be updated in future versions of data sets as the team's understanding of the behavior of these offsets improves. Only the tables of coefficients that have actually been used to produce a particular data set are included in that data set.
3) **Calculating and removing the offsets:** For any given sample, we use the timestamp of the first sample of that same data product in the same AQP. That timestamp is in turn used for looking up the relevant coefficients for the relevant probe(s) (two probes for LAP3 data, i.e. differential measurements). Coefficients are interpolated over time between the tabulated values. The offset value $I_{\text{offset},i}$ which is subtracted from each current sample is

$$I_{offset,i} = p_i \cdot \left(V_{bias,i} - s_i\right)^3 + q_i \cdot \left(V_{bias,i} - s_i\right) + r_i$$

where $V_{\text{bias},i}$ is probe voltage bias (in TM units), and i = probe. $I_{\text{offset},i}$ is expressed in ADC16 TM units, but including the correction for the ADC jump (Section 2.5.3) and are generally not integers. Thus, to subtract the offset from a sample in engineering units (A), one must multiply the above offset with the relevant ADC16 calibration factor (low/high gain), also for ADC20 data.

2.5.6.2 Offsets Between ADC16 Data and ADC20 Data

In theory, the ADC16 and ADC20 for a given probe convert the same *intermediate* analog signal, *internal* to the LAP electronic circuitry, to TM units. In practice, there is an offset between the two. To compensate for this, the following values are added to all ADC20 data:

Probe 1: -77.9601

Probe 2: -84.8991

Probe 1-Probe 2 (diff. measurements): -77.9601 + 84.8991 = 6.9390

The above values are expressed in ADC16 TM units and are thus multiplied with the relevant ADC16 calibration factors (select density/E-field mode, high/low gain as for the current sample; but *not* ADC20 factors) to convert them to engineering units (ampere, volt) before they are added to ADC20 data. The values were obtained in a one-time in-flight calibration on 2015-05-28.

2.5.6.3 Offsets Between 4 kHz and 8 kHz Filter Data (ADC16)

There are offsets between data measured using the 4 kHz filter and data measured using the 8 kHz filter. Therefore, this offset applies to both density mode and E field mode, but only to ADC16 data, since only the ADC16s are connected to the 4 and 8 kHz filters. To compensate for this we add the following to all 8 kHz-filter data (both measured currents and measured voltages):

Probe 1: 1.4

Probe 2: 25.35

Probe 1-Probe 2 (diff. measurements): 1.4-25.35 = -23.95

The above values are expressed in ADC16 TM units and one should thus multiply with the relevant ADC16 calibration factors (density/E field, high/low gain as for the sample) to produce the values in engineering units (ampere, volt).

2.5.7 Excluding LF Samples During Sweeps

LF samples which are taken during sweeps are in reality taken with the sweep bias, not the commanded fix-bias. The relevant sweep bias to match with such a LF sample is also ambiguous due to the ADC20 20 Hz low-pass filter. Therefore, LF samples that occur during, or just after, a sweep are kept in edited data sets but are eliminated from other data sets. HF samples cannot be taken during a sweep since they use the same ADC as sweeps (ADC16).

2.5.8 *Pseudocode Describing Calibration Process*

The pseudocode below summarizes most of the calibration already described in the previous sections for LAP1 and LAP2 data (not LAP3 data), but without actual numeric values.

```
%============================================================
% Definitions of terms
% --------------------
% TM units =          "Telemetry" units, digital values both
%                     returned from ADCs in telemetry (TM),
%                     and sent in telecommands (TC) to DACs.
%                     EDITED dataset contain data in TM
units.
% Engineering units = Decimal values representing values in
%                     ampere or volt. CALIBRATED data sets
%                     contain data in engineering units.
%
% Variable naming conventions
% ---------------------------
% adc    = ADC; Analogue-to-Digital Converter
% ci     = Calibration info, i.e. various calibration
%          constants, calibration tables, calibration
%          functions.
% meas   = Measured value, sample (as opposed to bias).
% ed     = Value to be used in EDITED-level data set
% cal    = Value to be used in CALIBRATED-level data set
% factor = Something that should be multiplied with a
%          measured value.
% offset = Something that should be SUBTRACTED from a
%          measured value.
%============================================================

%============================================================
% Derive truncation factor to compensate for ADC20 data being
% truncated from 20 bits to 16 bits.
%============================================================
if isAdc20 && isAdc20Truncated ; adc20TruncationFactor = 16;
else                             adc20TruncationFactor =  1;
end

%====================================================
% Derive factor to compensate for moving average bug
%====================================================
if isAdc20 && (LAP_P1P2_ADC20_MA_LENGTH ~= 1)
    adc20MovingAverageTmFactor = ...
        LAP_P1P2_ADC20_MA_LENGTH / (LAP_P1P2_ADC20_MA_LENGTH
+ 1);
else
    adc20MovingAverageTmFactor = 1;
end

%============================================================
```

```
% Set conversion factors
% ----------------------
% Multiplicative factors to convert
% measured TM units (not bias) --> engineering units, with or
% without considering various additional effects, and always
% without considering offsets.
%
% adc16Factor
%     Current ideal conversion factor for
%     ADC16 TM measurements --> engineering units.
% adc20Factor
%     Current ideal conversion factor for
%     ADC20 TM measurements --> engineering units.
% adcMeasFactor
%     (temporary variable) Conversion factor for the ADC that
%     is actually used for sampling, compensated for
%     small non-ideal differences between ADCs (ADC16 or
%     ADC20; no truncation factor, no moving average-bug
%     factor).
% combinedMeasFactor
%     Total current conversion factor for
%     TM --> enginering units, for ANY measured value,
%     compensating for various effects.
%==============================================================
if isDensity
    if usesHighGain
        adc16Factor = ci.LAP_CURRENT_CAL_16B_G1;
        adc20Factor = ci.LAP_CURRENT_CAL_16B_G1 / 16.0;
    else
        adc16Factor = ci.LAP_CURRENT_CAL_16B_G0_05;
        adc20Factor = ci.LAP_CURRENT_CAL_16B_G0_05 / 16.0;
    end
else
    adc16Factor = ci.LAP_VOLTAGE_CAL_16B;
    adc20Factor = ci.LAP_VOLTAGE_CAL_16B / 16.0;
end

% Compensate for
% (1) that the ADC20s are not exactly (only approximately)
% a factor 16 more sensitive than ADC16s, and
% (2) small differences between approximately identical ADCs.
if     probeNbr == 1; adcRatio = ci.ADC_RATIO_P1;
elseif probeNbr == 2; adcRatio = ci.ADC_RATIO_P2;
else   error('This code can only handle LAP1 & LAP2, not
LAP3.')
end
adc20Factor = adc20Factor * adcRatio;

if isAdc16 ; adcMeasFactor = adc16Factor;
else         adcMeasFactor = adc20Factor;
end
combinedMeasFactor = adcMeasFactor ...
    * adc20TruncationFactor ...
    * adc20MovingAverageTmFactor;
```

```
%==============================================================
% Set total measurement offset = Value to be SUBTRACTED from
% measured values, in engineering/calibrated units.
%==============================================================
calMeasOffset = 0;
if isDensity
    % Offset in measured current due to setting the bias
    % voltage (there is no analogue for E-field mode).
    %calMeasOffset = calMeasOffset ...
    %    + ci.bvdcoFunc(probeNbr, edVoltage) * adc16Factor;
    calMeasOffset = calMeasOffset ...
        + ci.bvdcoFunc(probeNbr, edVoltage, edObt(1)) *
adc16Factor;
end
if isAdc16 && usesFilter8kHz
    % Offset due to difference between the 4 kHz and 8 kHz
    % low-pass filters.
    calMeasOffset = calMeasOffset ...
        + (ci.KHZ8_Px_OFFSET_ADC16TM(probeNbr) *
adc16Factor);
end
if isAdc20
    % Offset due to difference between ADC16 and ADC20 data.
    calMeasOffset = calMeasOffset ...
        + ci.ADC20_Px_OFFSET_ADC16TM(probeNbr) * adc16Factor;
end

%==============================================================
% Modify edCurrent, edVoltage
% ---------------------------
% Compensate for an unintended jump in the ADC16
% analogue-to-digital conversion between -1 TM units and 0 TM
% units. Subtract offset for non-negative values. (The
% correction is defined as the subtraction of a negative
% number to be consistent with the sign convention for other
% calibration offsets.)
%==============================================================
if isAdc16
    if isDensity
        i = (edCurrent >= 0);
        edCurrent(i) = edCurrent(i) ...
            - ci.ADC16_NONNEGATIVE_OFFSET_ADC16TM;
    else
        i = (edVoltage >= 0);
        edVoltage(i) = edVoltage(i) ...
            - ci.ADC16_NONNEGATIVE_OFFSET_ADC16TM;
    end
end

%==============================================================
% Final conversion ~TM units-->engineering units
% ----------------------------------------------
% ci.biasVoltageCalibFunc, biasVoltageCalibFunc = Functions
% for looking up calibrated BIAS value in table.
%==============================================================
```

```
if isDensity
    calCurrent = edCurrent * combinedMeasFactor -
calMeasOffset;
    calVoltage = ci.biasVoltageCalibFunc(probeNbr,
edVoltage);
else
    calCurrent = ci.biasCurrentCalibFunc(probeNbr,
edCurrent);
    calVoltage = edVoltage * combinedMeasFactor -
calMeasOffset;
end

%=============================================================
% Adjust LF timestamps for group delay
% ------------------------------------
% OBT = Spacecraft clock as a number (not string), i.e. with
% true decimals, and no reset count. Approximate seconds.
%=============================================================
if isAdc20
    calObt = edObt - ci.ADC20_GROUP_DELAY_S;
    calUtc = obt2Utc(calObt, ci);
else
    calObt = edObt;
    calUtc = edUtc;
```

2.6 Calibration Process for DERIVED Data

The following sections describe the steps needed to derive the corresponding DERIVED data from CALIBRATED data. For each type of data the name of the corresponding quantity (column) is given, as well as a characteristic string included in the name of the data files containing the data discussed. In this notation, “PSD files” is to be understood as files including the string “PSD” in their name. For a complete description of the file names and all their contents, see Section 3.2.

2.6.1 Downsampled LF Science Data

Quantities:

P1_CURRENT and P1_CURRENT_STDDEV in I1D files

P2_CURRENT and P2_CURRENT_STDDEV in I2D files

P1_VOLTAGE and P1_VOLTAGE_STDDEV in V1D files

P2_VOLTAGE and P2_VOLTAGE_STDDEV in V2D files

The intent of these data is to provide a uniformly sampled data set of limited size covering all the mission, for survey and statistical purposes. They are provided in the same units (ampères and volts) as the CALIBRATED data from which they are derived, as it is difficult to provide a statistically homogeneous calibration to plasma density valid for all the mission. If the measured quantity is probe voltage these downsampled data are denoted V1D and V2D for the two probes and are (for proper illumination and bias current conditions) proxies for the negative of the s/c potential, V_{sc}, which in turn can be used to track density variations [RD7, RD8]. If the measured quantity is a current, the downsampled data I1D and I2D can be calibrated to plasma density [RD9, RD11], assuming constant V_{sc} and electron or ion energy.

For each macro block, the current and voltage science data in CALIBRATED is averaged to a 32 s time resolution, and the standard deviation is calculated. As either voltage or current, depending on LAP bias mode, is a set parameter, its standard deviation will be zero. The averaging window spans 32 s, starting at midnight every calendar UTC day. The timestamps are set to the midpoint of each averaging window (i.e. not the mid-point of the data). Thus, the first UTC timestamp of the first downsampled data point of a day, if valid science data is available, is always 00:00:16, the subsequent one is 00:00:48, and so on.

Saturated data points as well as data taken during a probe bias sweep, in which the bias voltage varies, are removed before averaging. The data records underlying the averages may thus not always be identical in time span. Data are still included in the rare case of a bias change during the interval, but the sample is then flagged as described in Section 3.4.2.

There is no quality value defined for these parameters, as they are based directly on raw data with no particular model performance.

2.6.2 *Power Spectra of HF Currents and Voltage*

Quantities:

PSD_I1H, PSD_I2H, PSD_V1H or PSD_V2H in PSD files.

This data product contains power spectra derived from the HF time series data products in the corresponding calibrated-level data sets.

Note that a data user could in principle derive his/her own power spectra from these. However, these data products are provided anyway in order to also make certain non-trivial corrections for known problems.

The HF waveform snapshot data mode was run at two different sampling rates during the mission, 18.75 kHz and 2.34 kHz. Due to disturbances during the RPCMIP SDL mode, the 18.75 kHz data is spliced into sections of 0.6 ms starting at 0.2 ms of each science data, with 0.2 ms gaps between each section. This was not possible for the 2.34 kHz data which were instead split into 64 ms long sections.

A linear fit is removed for each section, before the power spectral density (PSD) analysis is performed via Welch's method (using the pwelch.m MATLAB function), applied using a Hamming window of the same size as the number of data points in the section. Any sections (typically at the end of the snapshot data) that spanned less than 3 ms for the 18.75 kHz data or 24 ms for the 2.34 kHz data were ignored. The resulting power spectra are given in units of X^2/Hz, where X is ampères or volts depending on LAP bias mode. The normalization is such that integration over frequency gives the variance of the signal in that time interval.

When RPCMIP was in its LDL mode signal disturbances are also present in the HF data. As there was no globally identifiable period that could be identified and removed for all variants of RPCMIP 'LDL' modes, these data are instead flagged by a quality flag (Section 3.4.2).

Standard quality flags are given for these measurements (Section 3.4.2). As these are based on raw data, there is no quality value defined.

In addition to the power spectral density, the PSD files also contain the mean values of the current and voltage during each snapshot.

2.6.3 *Photoelectron Knee Potential*

Quantity: V_PH_KNEE in ASW files

An automated routine analyses every LAP1 voltage sweep (i.e. when the current is measured for a range of voltages) to find characteristic regions in the sweep. The spacecraft potential is estimated from a "knee" in the sweep from a sunlit probe arising from the fact that all photoelectrons escape a probe when it is negative with respect to its surroundings, but not at higher voltages. This knee (V_{ph}) therefore marks the point where the potential between the probe and the surrounding plasma is 0 V, and can be found by locating a local maximum in d^2I/dV^2 [RD10], where I and V are the current and bias voltage respectively. The algorithm does this by filtering/smoothing the data before fitting a Gaussian to peak in the second derivative. The filtering may reduce the accuracy and introduce artifacts in individual analyzed result, but provides a sufficiently stable estimate during the entire mission. This is especially important in tenuous plasmas where currents are close to the instrument resolution level, and during disturbances from other sources.

If the probe is not sunlit, the knee detected should instead be a smaller discontinuity in the sweep, where the absolute potential between a plasma at infinity and the probe is zero, i.e. where electron current goes from a retarding exponential to a linear relation. This value is not archived because of the relatively high noise, but is the basis for the region identification of the rest of the analysis pipeline.

With the sign convention we use, the photoelectron knee is a direct proxy for the spacecraft potential, V_{SC}, between the spacecraft and the plasma [RD8]. Corrections to V_{ph} for obtaining a better value of V_{SC} are studied in RD7 and RD8. To avoid confusion, no such corrections have been attempted on these data. It should be noted that the recommended proxy for the spacecraft potential is the U_SC quantity in the USC files, but as V_PH_KNEE is non-trivial to find from the data and may be of interest to some users it is included in the data set.

The quality value provided is a function of the range of the sweep, the bias step resolution and the signal strength of positive currents, as well as the spread of the fitted Gaussian and mapped to a value between 0 (worst) and 1 (best). Standard quality flags are provided for the sweep as a whole (Section 3.4.2). Each individual parameter, including this one, also has a quality value assigned.

2.6.4 Photosaturation Current, Method 1

Quantity: I_PHO_60M in PHO files

The photoelectron emission saturation current on the LAP probes is a parameter of interest on its own for assessing s/c plasma interaction issues, but also scientifically as it depends directly on the solar EUV flux reaching the s/c.

A statistical analysis of ion current of sweeps (i.e. the region of the sweep where the absolute potential of the probe is very negative, and any positive current contributions is assumed to be negligible) of a sunlit probe, has been found [RD9] to give a good estimate of the photosaturation current of LAP1. By comparing a linear least-squared-distance fit of the ion current slope and the ion current magnitude at some negative absolute potential for several subsequent sweeps, we can extrapolate (in a linear least-squared-distance fit) the current intersection for when the ion current contribution is zero. The current offset found is the estimated photosaturation current for that time period.

The ion current magnitude is taken close to V_b = -17 V in each sweep. The least number of sweeps used for each photosaturation estimate after outlier removal is 10. The photosaturation current is estimated hourly, starting at midnight each calendar day, and timestamped at the midpoint of each estimate, i.e. 00:30:00, 01:30:00, … etc. This data product is provided only for LAP1.

Standard quality flags are provided for the sweep as a whole (Section 3.4.2). Each individual parameter, including this one, also has a quality value assigned. The quality value is given as the exponential of the negative fractional error estimate of the slope of the least-square linear fit, thereby mapped to a value between 0 and 1.

2.6.5 *Photosaturation Current, Method 2*

Quantity: I_PH0_S in ASW files

Each sweep can also be used individually to estimate the photosaturation current during that time. A linear fit of the slope of the ion current and the slope and intersect of the electron current is performed and removed from the sweep at large negative and positive bias potentials. In a well-understood sweep of a simple Maxwellian electron current plasma, the remaining current should only be photoelectron current and secondary electron current from particle impact, of which the latter is assumed to be small. This estimate has been found to have a low signal-to-noise ratio [RD9], due to instrument constraints and analysis routine performance, but agrees on average with other estimates and can allow higher time resolution (minutes) than Method 1 (one hour). The data product is only provided for LAP1.

Standard quality flags are provided for the sweep as a whole (Section 3.4.2). Each individual parameter, including this one, also has a quality value assigned. The quality value given is the exponential of the error in determining the slope of the ion current multiplied 300, divided by Iph0, thus mapped to a value between 0.1 with most estimates below 0.7.

2.6.6 *Spacecraft Potential Proxy*

Quantity: U_SC in USC files

The spacecraft potential proxy alternates between using values from one of two methods, depending on what data is available. The floating potential V_{float} of the probes (Section 2.6.6.1) has been found to be a good proxy for the spacecraft potential, whenever the probes are sunlit [RD7, RD8]. An analogous measurement of the floating potential (that is, the voltage on the probe for which the current to it is zero) using the Langmuir Probe sweep, V_z (Section 2.6.6.2), can also be provided, and is defined more or less continuously throughout the mission.

The algorithm for selecting which value to put in the time series is to choose the topmost available alternative listed below:

(1) Downsampled floating potential measurement for an illuminated LAP1

(2) Downsampled floating potential measurement for an illuminated LAP2

(3) V_z for LAP1

(4) V_z for LAP1, but using a linearly extrapolated sweep

Which above value is actually chosen by the algorithm is stored with the data product.

Standard quality flags are applied (Section 3.4.2).

2.6.6.1 Method Using Floating Potential

When any of the probes are electronically disconnected from the bias circuitry, i.e. no current bias, the probe potential is left to float to its equilibrium potential, V_{float} .A good proxy for the spacecraft potential has been found to be -V_{float}, and this data product is produced whenever this data product is available after known disturbances filtered out. Known disturbances are saturation and a probe being in shadow. If both probes are available, the value is taken from the V1D files containing data from LAP1. If LAP1 goes into shadow, the value is taken from V2D.

For this method the quality value is defined as 1- the fractional standard deviation around the mean of the downsampled interval of measurements.

2.6.6.2 Method Using V_z

When LAP is not running a suitable macro for V_{float}, and in an effort to provide a reasonably consistent data set for the entire mission we provide instead the sweep-derived estimate of potential for which the net current to the probe is zero, V_z. For each sweep, the last and first bias step of negative and positive currents, are recorded and a linear least-squared-distance fit is performed on four points around this region to estimate at what potential the zero-intersection of current occurs, V_Z. If there are several zero-intersections detected in a sweep due to noise, or disturbances from other instruments, each zero-intersection is ranked based on the largest distance to the closest zero-intersection in the opposite direction and the least-square-distance fit is performed on the highest rank. If the largest distance is one (and tied), all zero-intersections are removed before a re-evaluation. If there are no zero-intersections and all currents are negative, the bias potential for which the current is extrapolated to zero from the four highest bias potential measurements is outputted. The quality value can have three values for these cases: 0.8 for a simple sweep with exactly one zero-intersections, 0.7 for an extrapolated bias potential, 0.4 for a sweep with several zero-intersections.

If there are several zero-intersections detected in a sweep due to noise, or disturbances from other instruments, each zero-intersection is ranked based on the longest distance to the closest subsequent zero-intersection in the opposite direction. If two points are ranked equally and low (each followed/preluded by another zero-intersection), all zero-intersection points are ignored and the sweep re-evaluated. If there at any point are no zero-intersection, and all the currents are negative, the current is extrapolated to zero from the last four bias potentials in the sweep. For the latter case, the quality value is 0.7. For several zero-intersections the quality value is 0.4, and otherwise 0.8.

2.6.7 *Plasma Density for Assumed Fixed Electron Temperature*

Quantity: N_E_FIX_T_E in ASW files

While usually giving good results in at intermediate densities (typically 10 -100 cm^{-3} for most of the Rosetta mission), this is not the preferred LAP density parameter as it can severely underestimate the plasma density when the spacecraft potential is highly negative, and also as it is not cross-calibrated with MIP. For most science needs, the cross-calibrated plasma density in the NED files (also known as the LAPMIP density, see below) or the high-time resolution MIPLAP density in the RPC-MIP data set should be the preferred choice.

The plasma (electron) density is calculated from a least-square linear fit of the slope of the LAP sweep at the electron saturation region, which is governed by the equation

$$\frac{dI}{dV} = A_p e^2 n_e \sqrt{\frac{1}{2\pi k_B T_e m_e}},$$

Where *I* and *V* are the measured current and bias voltage of the sweep (*I* and *V* are seen as functions of eachother), $A_p$is the surface area of the probe, e is the elementary charge, $n_e$is the electron number density, T_e is the electron temperature, m_e is the electron mass, and k_B is the Boltzmann constant.

For deriving n_e from d*I*/d*V* we use a fixed electron temperature T_e = 5 eV except when d*I*/d*V* > 70 nA/V, in which case we instead use 0.1 eV. These two values have been found to give values well comparing to densities from the MIP instrument. It was shown in [RD11] that 70 nA/V very well separates situations where the current to the probe are dominated by warm or cold electrons, but of course the limit is not entirely sharp so bad data points may occur particularly on the limits of regions dominated by cold electrons.

The relevant part of the sweep for finding d*I*/d*V* is selected as the highest 25% of sweep bias voltage values above the photoelectron knee potential algorithm result (V_PH_KNEE). If that is less than five measurement points, the top five measurements are analyzed. If there are less than two positive non-saturated current values, the estimate is discarded.

The quality value is given as the exponential of the negative fractional error estimate of the slope of the least-square linear fit, thereby mapped to a value between 0 and 1. Standard quality flags are applied (Section 3.4.2).

We do not provide any density estimate using the sweep-determined electron temperature (T_E in the ASW files) as that parameter is quite noisy. The user who wish to obtain such values can do so by scaling N_E_FIX_T_E by the square root of T_E.

2.6.8 *Plasma Density, Downsampled*

Quantity: N_ED in NED files

This is considered to be the best mission-wide *low time resolution* plasma density estimate. It is obtained using the spacecraft potential proxy U_SC, which is most consistent and has the best mission-wide coverage and cross-calibration with LAP and MIP density data.

The best *full time resolution* plasma density product is considered to be the MIP-LAP cross-calibrated density delivered with the MIP data set. In that product, the full time resolution (down to 16 ms) LAP probe current or probe voltage have been calibrated to plasma density using MIP values over short (20 minutes) time windows.

However, MIP data are not always available for calibration, either due to being turned off or the density being above or below their instrument range. In an effort to provide mission-wide plasma density estimate, we calibrate our spacecraft potential proxy data to MIP densities (after 2015-01-01 00:00:00) or LAP densities in a window over several days.

Before 2015, the scarcity of good concurrent MIP & LAP measurements, combined with the less pronounced spacecraft potential sheath effects on the LAP plasma density estimates (Section 2.6.7) motivated the use of the LAP sweep density estimates (N_E_FIX_T_E in the ASW files) for our calibration, and the source of the density calibration data set is labelled as per Section 3.9.

The algorithm for selecting which LAP data to use for the derivation is to choose the topmost available alternative listed below:

(1) Downsampled floating potential measurement for an illuminated LAP1

(2) Downsampled floating potential measurement for an illuminated LAP2

(3) V_Z for LAP1

(4) V_Z for LAP1, but using a linearly extrapolated sweep

Which above value is actually chosen by the algorithm is stored with the data product. V_Z is described in Section 2.6.6.2.

The calibration of U_SC to N_ED is derived by linear orthogonal least-squares fitting the log of the density to the spacecraft potential proxy USC window of three days which is iterated and stepped one day at a time over the entire mission. The calibration generates two fitting coefficients and a correlation coefficient. A quality value is taken to be the absolute value of the correlation coefficient (value from 0 to 1) and archived together with the coefficients in the file **CALIB/RPCLAP***YYMMDD***_CALIB_NED.TAB** as described in Section 3.9. For each measurement of U_SC, linearly interpolated coefficients (C1,C2) are computed from the two closest calibration coefficients, and then used to estimate the density using:

$$N\_ED = exp(C_1 \times V_n + C_2), \text{ where}$$

$$V_n = U\_SC + 5.5 \times exp\left(\frac{U\_SC}{8}\right)$$

As detailed in Section 2.6.6., the resolution of the data is between 32 and 160 seconds depending on LAP operational mode (macro).

Standard quality flags are applied (Section 3.4.2). The quality value is inherited from the spacecraft potential proxy (Section 2.6.6).

2.6.9 *Plasma Density, LF (NEL data sets)*

Quantity: N_EL in NEL files (NEL data sets).

For intervals where RPC-MIP does not provide cross-calibrated densities, but there is LAP LF data in ion current or floating potential mode, RPCLAP can sometimes linearly cross-calibrate these measurements into densities using a similar cross-calibration technique, but with fits over larger time-periods.

For floating potential data from a sunlit probe, the measurements are converted into densities using the exact same method as specified in Section **Error! Reference source not found.**. As in Section 2.6.6.1 if there is coinciding floating potential measurements from both probes, measurements from P1 is chosen, and otherwise merged.

For LF current data, Ip, where the probe is biased below -15 V from the spacecraft ground, the method and cross-calibration, is somewhat similar. The algorithm uses a time series of coefficients, each one derived from fits of data, typically over a three-hour period. This time series is stored in the calibration file **CALIB/RPCLAP***YYMMDD*_**CALIB_NEL_I_Pe.TAB** file, as described in Section 3.9. For each measurement, linearly interpolated coefficients (C1,C2) is estimated from the two closest calibration coefficients, and then used to estimate the N_EL density using:

$$N\_EL = \begin{cases} C_1 \times I_\mathrm{p} + C_2 & \text{if fully sunlit} \\ C_1 \times I_\mathrm{p} & \text{if LAP1 is in shadow} \end{cases}$$

Quality values are evaluated from the goodness of fit of the cross-calibration, and the signal strength above the photoemission current.

This method is not applied for ion current data from P2 after 2016-05-01 (UTC), nor before 2014-12-12 (UTC).

Note: This data product is only available in NEL data sets, see Section 2.4.2.

2.6.10 *Effective Ion Speed*

Quantity: V_ION_EFF_XCAL in ASW files

The ion current is taken from the region of the sweep where the absolute potential of the probe is very negative, and we can assume the electron collection. The region identification is done by taking the lowest 40% of sweep bias measurements below the photoelectron knee potential routine. If that is less than three measurement points, the algorithm outputs fill values. In this region the slope of the current is governed by equation

$$\frac{dI}{dV} = A_p e q_i \sqrt{(2/m_i E_i)}$$

. This is performed for every sweep on LAP1, if there is a simultaneous MIP density estimate.

Where I and V are the sweep current and bias voltage, A_p is the cross-sectional area of the probe, e is the elementary charge, n_i is the ion number density, m_i is the ion mass, q_i is the ion charge and E_i is the effective kinetic energy of the incoming ions, dependent on thermal and flow velocity. By performing a linear least-squared-distance fit of this region to get an estimate of the slope, and using the simultaneous RPCMIP electron density, assuming quasi-neutrality and an effective ion mass of 19 a.m.u., we can estimate the effective energy of the ion. Taking

$$E_i = 0.5\, m_i v_i^2,$$

we obtain an effective ion speed v_i. This is performed for every sweep on LAP1, if there is a simultaneous MIP density estimate.

If the identified linear slope fit does not increase more than the instrument resolution of 0.3 nA in the identified ion current region, or the uncertainty in the slope is above 100%, the least-square fit is reiterated over 50% more points in the ion current region. If this reiteration fails the same test, the estimate is discarded.

A quality value is calculated as the exponential of the negative sum of the fractional error estimate of the slope of the least-square linear fit and the fractional uncertainty in the MIP measurement, thereby mapped to a value between 0 and 1.

2.6.11 *Electron Temperature, Method 1*

Quantity: T_E in ASW files

The nomenclature of "Electron Temperature" (T_e) is to be understood as the characteristic energy of the Maxwellian distribution approximation of the electron gas. When the Langmuir probe absolute potential (V_p) between the probe and a plasma at infinity is below 0 V, the electron current I_e to the probe is governed by an exponential

$$I_e \propto exp\left(eV_p/k_B T_e\right)$$

where e is the elementary charge and k_B is Boltzmann's constant [RD9]. By identifying and removing other currents such as ion current and secondaries, we select a region of retarding electron current and perform a least-square linear fit to the logarithm of the current to identify T_e. If the probe is sunlit, the region of the retarding electron current fit is constrained to a region below V_{ph} where the photoelectron current can be assumed to behave only as an offset, and is removed by identifying this offset. The quality value is given as the exponential of the negative fractional error estimate of the slope of the least-square linear fit, thereby mapped to a value between 0 and 1.

2.6.12 Electron Temperature, Method 2

Quantity: T_E_XCAL in ASW files

From the same slope estimate as in Section 2.6.3 we can use the density of a simultaneous MIP measurement to instead solve for the electron temperature (see RD10). The method is useful primarily in the presence of a cold component in the electron gas, whose temperature cannot be obtained by method 1 above. The T_E_XCAL estimate is therefore calculated for which the slope (obtained as discussed in Section 2.6.7 above) is higher than 70 nA/V (see RD10) and for which there is a simultaneous MIP density estimate.

The two electron temperature estimates T_E and T_E_XCAL refer to different parts of the cometary electron energy distribution. In the common situation of co-existing cold and warm components they will be estimates of the characteristic energy of the warm and cold components, respectively.

A quality value is calculated as the exponential of the negative sum of the fractional error estimate of the slope of the least-square linear fit and the fractional uncertainty in the MIP measurement, thereby mapped to a value between 0 and 1.

2.6.13 Electric Field Component

Quantity: EFIELD_COMPONENT in EFL files

This data product represents the electric field component *E* in the direction from probe 1 to probe 2. It is calculated from simultaneous floating probe measurements V_{P2} and V_{P1} on two illuminated probes, and taking the difference divided by the distance *L*., i.e.

$$E = \frac{V_{P2} - V_{P1}}{L}$$

The DC component of this is not trusted, so a 32 second moving average value is subtracted from the data, which thus effectively cover the range from 0.03 Hz to 20 Hz (where the analog low-pass filter sets in). For macros 0x710 and 0x910, which saw some use in the last months of the mission including the final descent to the comet surface, one of the probes is recurrently placed in bias voltage mode for providing Langmuir probe sweeps. This gives a 32 or 64 second data gap to the electric field measurement, so instead of a moving average, the average value of the raw voltage difference over the 96 seconds of continuous data available between the gaps is subtracted

Only a small fraction of the mission was spent simultaneously making floating probe measurements on both probes. Therefore, this data product is only available for a small subset of the mission. More specifically, it is only available when running any of the macros 0x710, 0x801, 0x802, and 0x910.

3 Overview of Data Products

This section describes the organization of the LAP data products.

Note: The regular user should only be interested in the DERIVED-level data sets, i.e. DERIV2 and NEL data sets.

The descriptions of science data products (Section 3.2), caveats (Section 3.5), and documentation (Section 3.12) should also be of interest to any user of the archived LAP data.

The time interval covered by a particular data set can be found in the CATALOG/DATASET.CAT file. A list of mission phases can be found in CATALOG/ROSETTA_MSN.CAT.

3.1 Understanding EDITED and CALIBRATED Science Data Products

3.1.1 Instrument Settings

To understand and classify the types of EDITED and CALIBRATED LAP science data available one must consider that every LAP science data product is based on data acquired using a certain combination of instrument settings. For a single data product, many of these options can be set independently of each other, but not necessarily in all combinations, and not all permitted combinations are useful.

The list below summarizes the most important options which can be combined to produce different types of science data products. Each item lists mutually exclusive options where exactly one option under every item is always used for every single data product (recursively). "Data" here refers to the measured sample values in any one EDITED or CALIBRATED science data product. Multiple such data products can cover the same time interval.

- Data are always acquired from either
  - **LAP1**,
  - **LAP2**, or
  - "**LAP3**" = Digitally onboard-calculated value of LAP1 minus LAP2 (difference measurement). (Seldom used.)
- Data are always acquired in either
  - **Density mode** (bias voltage; measures current), or
  - **E-field mode** (bias current; measures voltage).
- Data are always acquired in either of two bias modes:
  - **Sweep bias** (using ADC16 for measurements), i.e. bias rapidly sweeping over voltages (never currents) within a short period of time. This is thus only applicable to density mode. Sweeps come in two forms:
    - **Coarse sweeps**
    - **Fine sweeps**, with a higher bias step resolution. (seldom used). These data are scientifically less useful and only available in EDITED.
  - **Fix bias**, i.e. where the bias is constant over a long period of time, and which is always acquired in one of the two forms below:
    - **LF**, i.e. low frequency sampling (using ADC20 for measurements) which for the most of the time are quasi-continuous, or
    - **HF**, i.e. short high-frequency snapshots (using ADC16 for measurements).

For a more advanced user, it may also be important to be aware of some more technical settings, e.g. for understanding the calibration. Similar to the list above, each item lists mutually exclusive options, where exactly one option under every item is always used (recursively). These options are generally not associated with any particular data products with the exception of ADC16/ADC20.

- **Data from a given probe** is always acquired through either of the two ADCs connected to that particular probe. The two ADCs are:
  - **ADC16** (16-bit samples acquired at 18750 samples/s), with a physical low-pass filter with a cutoff at either of the two options below:
    - **4 kHz**, or
    - **8 kHz**
  - **ADC20** (20-bit samples acquired at 57.8 samples/s), with a physical low-pass filter with a cutoff at 20 Hz. ADC20 samples in TM units are always either
    - **full 20-bit values**, or
    - **16-bit values**, truncated (onboard) from 20-bit values
- **ADC20** data (in TM; both probes together) is always either
  - **Full time resolution**, or
  - **Averaged over** (moving average). Note that downsampling (in TM) does not automatically reflect the averaging, although it is generally commanded to do so. See Table 3.
- **All density mode data** (measured currents) is acquired using either
  - **high-gain** setting (the great majority of data), or
  - **low-gain** setting

Filenames and product IDs can be used to determine the first of the two above sections of settings (probe, E-field/density, sweep/fix bias, HF/LF). See Section 4.1.4. The remaining, and more technical and obscure settings, can be determined from mission-specific PDS keywords found in the data product label files, see Section 5.3.1.5.

The exact science data products which are actually available within a macro block, and with which exact parameters, depends on the LAP macro (see Section 2.3).

3.1.2 How to Determine the Most Relevant Settings for Data Products

The macro which produced a particular data product can be derived from the value of the PDS keyword INSTRUMENT_MODE_ID in the data product label files, see Section 5.3.1.5 or, for most but not all data products, from the macro ID in the filename, see Section 4.1.4. The file **DOCUMENT/RO-IRFU-LAPMAC-***YYMMDD***-***phase***.PDF** contains a human reader-friendly table over what the science macros relevant for the current mission phase do.

- Whether a data product contains ADC16 or ADC20 data can be determined from filenames and product IDs.
- Whether density mode or E-field mode is used can be determined from filenames, product IDs, and from LAP-specific label keywords LAP_P1_BIAS_MODE and LAP_P2_BIAS_MODE.
- Whether low gain or high gain is used can be determined from the LAP-specific label keywords LAP_P1_STRATEGY_OR_RANGE and LAP_P2_STRATEGY_OR_RANGE.
- Whether or not ADC20 data has been truncated to 16 bits onboard the spacecraft can be determined from the LAP-specific label keywords ROSETTA:LAP_P1P2_ADC20_STATUS.

See Sections 4.1.4 for filenames and product ID. See Section 5.3.1.5 for the complete list of LAP-specific PDS keywords

3.2 Science Data Products

RPCLAP data sets contain the data products described in Table 6, Table 7, Table 8, and Table 9, all of them stored in table (.TAB) files and described in label (.LBL) files. Note that probe, data type etc. are specified in the data filenames and product IDs and that they are explained further in Section 4.1.2.

Note that we sort the data products by *type* of data set (Section 2.4.2).

Data Products Found in all Data Sets			
Data type	***Columns***		***Product ID***
	Nbr of columns	***Column data; NAME (PDS keyword value)***	
Block list	1	UTC start time; **START_TIME_UTC**	**LAP_***CCYYMMDD***_000000_BLKLIST**
	1	UTC stop time; **STOP_TIME_UTC**	
	1	Macro ID; **MACRO_ID**	

Table 6. Data products found in all data sets. Product ID in our data sets are equal to filenames without suffix. Black boldface characters are static, while red, italicized letters are variables. The complete filenaming and product ID convention as well as the meaning of red, italicized letters (variables) can be found in Section 4.1.4. Block lists show the sequence of commanded macros run on any particular UTC day and do not contain any measurements.

Analogous Science Data Products Found only in EDITED2 and CALIB2 Data Sets			
Data type	***Columns***		***Product ID***
	Nbr. of columns	***Column data; NAME (PDS keyword value)***	
Time series, fix bias on **one probe** (E-field & density mode; LF/HF)	1	UTC time; **TIME_UTC**	**LAP_***CCYYMMDD***_***hhmmss***_***iii***_***jek*** ("*e*" = probe = 1 or 2)
	1	OBT time; **TIME_OBT**	
	1	Current; bias or measured, ampere;	

		P*e*_CURRENT	
	1	Voltage; bias or measured, volt; **P*e*_VOLTAGE**	
	1	Quality flag (CALIB. only); **QUALITY_FLAG**	
Time series, fix bias **difference** measurements (two probes), **E-field** (HF)	1	UTC time; **TIME_UTC**	**LAP_*CCYYMMDD_hhmmss_iii*_V3H**
	1	OBT time; **TIME_OBT**	
	2	Current bias, LAP1 and LAP2, ampere; **P1_CURRENT** **P2_CURRENT**	
	1	Measured voltage difference, LAP1 minus LAP2, volt; **P1_P2_VOLTAGE**	
	1	Quality flag (CALIB. only); **QUALITY_FLAG**	
Time series, **difference** measurements (two probes), **density mode** (HF)	1	UTC time; **TIME_UTC**	**LAP_*CCYYMMDD_hhmmss_iii*_I3H**
	1	OBT time; **TIME_OBT**	
	1	Measured current difference, LAP1 minus LAP2, ampere; **P1_P2_CURRENT**	
	2	Voltage bias, LAP1 and LAP2, volt; **P1_VOLTAGE** **P2_VOLTAGE**	

	Only CALIB2 — 1	Quality flag; **QUALITY_FLAG**	
Sweep data	1	Start UTC time; **START_TIME_UTC**	**LAP_***CCYYMMDD_hhmmss_iii***_I***e***S** ("*e*" = probe = 1 or 2)
	1	Stop UTC time; **STOP_TIME_UTC**	
	1	Start OBT time; **START_TIME_OBT**	
	1	Stop OBT time; **STOP_TIME_OBT**	
	1	Quality flag (CALIB. only); **QUALITY_FLAG**	
	N (varies)	Measured currents for every step of a sweep; ampere **P***e***_SWEEP_CURRENT**	
Sweep description (step biases and time between steps)	1	Step time (seconds since beginning of sweep), second; **SWEEP_TIME**	**LAP_***CCYYMMDD_hhmmss_iii***_B***e***S** ("*e*" = probe = 1 or 2)
	1	Step bias, volt; **P***e***_VOLTAGE**	

Table 7. Science data products found only in EDITED2 and CALIB2 data sets. These data products are analogous and identical in format (sequence of columns) between the types of data sets (and archiving levels), with the exception of quality flags (columns), which are present in CALIB2, but not in EDITED2. Product ID in RPCLAP data sets are identical to filenames without suffix. Black boldface characters are static, while red, italicized letters are variables. The complete filenaming and product ID convention as well as the meaning of red, italicized letters (variables) can be found in Section 4.1.4. In analogy with filenames, the red letter "e" in the label column NAME (PDS keyword) refers to the probe number, i.e. "1" or "2". Combinations I3L and V3L (difference measurement, LF; density and E field mode respectively) are permitted by the instrument but have never been used and are therefore not represented. It is implicit that currents and voltages are in TM units for EDITED2, and units of ampere and volt for CALIB2.

Science Data Products Found only in DERIV2 Data Sets

Data type	***Columns***			***Product ID***
	Number of columns		***Column data; NAME (PDS keyword value)***	
Downsampled time series, 1 sample/32 s	1		UTC time; **TIME_UTC**	**LAP_***CCYYMMDD_hhmmss_iii_je***D** ("*e*" = probe = 1 or 2)
	1		OBT time; **TIME_OBT**	
	1		Current; bias or measured, ampere; **P*e*_CURRENT**	
	1		Current, standard deviation, ampere; **P*e*_CURRENT_STDDEV**	
	1		Voltage; bias or measured, volt; **P*e*_VOLTAGE**	
	1		Voltage standard deviation, volt; **P*e*_VOLTAGE_STDDEV**	
	1		Quality flag; **QUALITY_FLAG**	
Power spectral density (PSD) of HF snapshot	1		Start UTC time; **SPECTRA_START_TIME_UTC**	**LAP_***CCYYMMDD_hhmmss***_PSD_***je***H** ("*j*" = I or V; "*e*" = probe = 1 or 2)
	1		Stop UTC time; **SPECTRA_STOP_TIME_UTC**	
	1		Start OBT time; **SPECTRA_START_OBT**	
	1		Stop OBT time; **SPECTRA_STOP_TIME_OBT**	
	1		Quality flag; **QUALITY_FLAG**	
	Only for single probe LAP1 or	1	Current mean; bias or measured, ampere; **P*e*_CURRENT_MEAN**	

	LAP2 (not difference)	1	Voltage mean; bias or measured, volt; **P*e*_VOLTAGE_MEAN**	
	Only for difference measurement, density mode	1	Measured current mean difference, ampere **P1_P2_CURRENT_MEAN**	
		2	LAP1 & LAP2 voltage bias, volt; **P1_VOLTAGE_MEAN**, **P2_VOLTAGE_MEAN**	
	Only for difference measurement, E field mode	2	LAP1 current bias, ampere; **P1_CURRENT_MEAN**, **P2_CURRENT_MEAN**	
		1	Measured voltage mean difference, volt; **P1_P2_VOLTAGE_MEAN**	
	N (function of macro)		Power spectral density (PSD), nA^2/Hz or V^2/Hz; **PSD_*je*H**	
Power spectrum frequencies	N (function of macro)		Frequencies for the PSD of the current macro (always only one row), Hertz; **FREQUENCY_LIST**	**LAP_*CCYYMMDD*_*hhmmss*_FRQ_*je*H** ("*j*" = I or V; "*e*" = probe = 1, 2, or 3)
Photoemission saturation current, 1 sample/60 minutes	1		UTC time; **TIME_UTC**	**LAP_*CCYYMMDD*_000000_60M__PHO**
	1		OBT time; **TIME_OBT**	
	1		Photosaturation current, method 1; ampere; **I_PH0_60M**	
	1		Quality value; **I_PH0_60M_QUALITY_VALUE**	
	1		Quality flag; **QUALITY_FLAG**	
Spacecraft potential proxy	1		UTC time; **TIME_UTC**	**LAP_*CCYYMMDD*_*hhmmss*_*iii*_USC**
	1		OBT time; **TIME_OBT**	

	1	Spacecraft potential proxy (two alternating methods); volt; Either 1 sample/sweep, or 1 sample/32 s; **U_SC**	
	1	Quality value; **U_SC_QUALITY_VALUE**	
	1	Source of data (probe, floating potential or sweep) **DATA_SOURCE**	
	1	Quality flag; **QUALITY_FLAG**	
Analysed Sweep parameters (ASW)	1	UTC time; **TIME_UTC**	**LAP_***CCYYMMDD_hhmmss_iii***_ASW**
	1	OBT time; **TIME_OBT**	
	1	Plasma density; cm^{-3}; **N_E_FIX_T_E**	
	1	Quality value; **N_E_FIX_T_E_QUALITY_VALUE**	
	1	Photosaturation current derived from individual sweep; ampere; **I_PH0_S**	
	1	Quality value; **I_PH0_S_QUALITY_VALUE**	
	1	Effective ion speed; m/s; V_ION_EFF_XCAL	
	1	Quality value; **V_ION_EFF_XCAL_QUALITY_VALUE**	
	1	Electron temperature; eV; **T_E**	
	1	Quality value; **T_E_QUALITY_VALUE**	
	1	Electron temperature, method 2 (cross-calibrated); eV; **T_E_XCAL**	
	1	Quality value;	

		T_E_XCAL_QUALITY_VALUE	
	1	Photoelectron Knee Potential; Volt; **V_PH_KNEE**	
	1	Quality value; **V_PH_KNEE_QUALITY_VALUE**	
	1	Quality flag; **QUALITY_FLAG**	
Plasma density based on spacecraft potential proxy	1	UTC time; **UTC_TIME**	**LAP_***CCYYMMDD_hhmmss_iii***_NED**
	1	OBT time; **TIME_OBT**	
	1	Plasma density, cm^{-3}; **N_ED**	
	1	Quality value; **QUALITY_VALUE**	
	1	Source of underlying data. **DATA_SOURCE**	
	1	Quality flag; **QUALITY_FLAG**	
Electric field component	1	UTC time; **UTC_TIME**	**LAP_***CCYYMMDD_hhmmss_iii***_EFL**
	1	OBT time; **TIME_OBT**	
	1	Electric field. Positive value refers to electric field in the direction from LAP1 to LAP2; mV/m; **EFIELD_COMPONENT**	
	1	Averaging and downsampling configuration. See Table 3; **SAMPLING_CONFIG**	
	1	Quality flag; **QUALITY_FLAG**	

Table 8. Science data products found only in DERIV2 data sets. Product ID in our data sets are equal to filenames without suffix. Black boldface characters are static, while red, italicized letters are variables. The complete filenaming and product ID convention as well as the meaning of red, italicized letters (variables) can be found in Section 4.1.4. “Quality value” columns only apply

to the physical value in the preceding column. The "data source" columns in the spacecraft potential proxy and plasma density products are analogous and are described in Sections 2.6.6 and 2.6.8.

Science Data Products Found only in NEL Data Sets			
Data type	***Columns***		***Product ID***
	Nbr of columns	***Column data; NAME (PDS keyword value)***	
Plasma density	1	UTC time; **TIME_UTC**	**LAP_***CCYYMMDD_hhmmss_iii***_NEL**
	1	OBT time; **TIME_OBT**	
	1	Plasma density; **N_EL**	
Table 9. Science data products found only in NEL data sets. Product ID in our data sets are equal to filenames without suffix. Black boldface characters are static, while red, italicized letters are variables. The complete filenaming and product ID convention as well as the meaning of red, italicized letters (variables) can be found in Section 4.1.4.			

All data products, cover an entire macro block per file (see Section 2.3.1), except block lists, photosaturation current, HK and geometry which cover an entire UTC day per file.

The EDITED2 and CALIB2 sweep description data products are needed to obtain the bias and timestamp of individual samples in the sweep data product. The DERIV2 power spectrum frequencies data product is needed to interpret the power spectral density data product. Both the sweep description and power spectrum frequencies data products are given once per probe and macro block since they are identical for all sweeps on a given probe for a given macro. Block lists contain the macros that have been run during a given UTC day and when.

3.3 Timing and Frequency issues

All LAP data products ultimately derive from one or several data points sampled by one of the instrument ADCs. The time assigned to each data point is the time the sample was acquired by the ADC, which we for the data from the low frequency ADCs have corrected for the filter group delay (Section 2.5.1). We consider the data represented by a sample as an average over the time since the last sample, though the low pass filters actually extend this time period slightly. There thus is a finite "time width" of every LAP sample, usually discussed in terms of the cutoff frequencies of the low pass filters. The group delay correction adjusts the sample time to well represent the center of the sampling period. It may be noted that there is no correction for the group delay in data products based on the high frequency (4 or 8 kHz) low pass filtered signals which are sampled at 18.75 kHz. The reason for this is that as no other instrument onboard Rosetta has sampling frequencies comparable to this, there is little use in applying time shifts of 50 and 100 μs so we have preferred to change the data as little as possible.

Data are sometimes averaged and downsampled in the LAP instrument before transmission. The time assigned to a data product using such data is the average time of the individual samples included in the average.

The probe bias voltage sweeps consist of a number of samples acquired at constant rate over some time period. The I1S and I2S files (CALIB2 data sets) containing the currents sampled during a sweep include the start and stop time of the sweep, i.e. the time of the first and last samples acquired. The timing of a particular sample within a sweep can be determined by adding the sweep start time to the relative sampling time of individual samples given in the B1S and B2S files (CALIB2 data sets).

For data derived from a sweep, we provide one time stamp which is at the center of the time window during which the sweep was obtained. As different parameters are derived from different parts of the sweep they may be dominated by data from different time periods within the sweep (typically from a fraction of a second up to a few seconds). Users should be aware of this uncertainty when using the data.

Related to timing is also the question of frequency widths of the only spectral product provided, the PSD files (DERIV2 data sets). As these derive from a digital Fourier transform of the sampled waveform data, the width of the frequency bins is identical to the distance between frequencies.

3.4 Data Quality Indicators

3.4.1 PDS Keyword DATA_QUALITY_ID

The PDS standard contains a quality indicator in the form of the PDS keyword DATA_QUALITY_ID, describing the quality of a data product in its entirety (i.e. table file, in the case of RPCLAP data sets). The LAP team has made no effort to make use of this feature. The RPCLAP LBL files do contain this keywords but its value is always set to “1”.

3.4.2 Quality Flags

Some CALIBRATED and DERIVED data products contain columns with a quality flag. A quality flag is a (base 10) integer that is constructed in the two steps below:

1. Add together the constants associated with the relevant quality-related effects in Table 10. Note that these constants are chosen such that every digit represents up to three true/false values for the presence/absence of three specific separate quality-related effects.
2. Should the three quality-related effects be irrelevant for the given data product, then that digit is replaced by the digit “9”.

Example: suppose that one encounters the quality flag “109”. 109 = 100 + 9 means (1) that there is an ongoing wheel off-loading (+100), and (2) that the quality-related effects associated with +1 and +2 cannot occur even in principle for the kind of data that one is looking at.

Quality flag event description	***Additive constant***
Low quality sweep analysis model fit	+1
One of two meanings: (1) Low sample size; an average is based on fewer data points than nominal (due to filtering or otherwise) and applies to sweep steps and downsampled time series. (2) zero-padding; zeros replace lost samples for the purpose of calculating PSD.	+2
One of two meanings: (1) Sweep data product and data products based on sweeps: SAA rotation of more than 0.05° during sweep. (2) Downsampled time series data product: Bias change within the 32 s downsampling period.	+10
Probe in partial or full shadow	+20
Rosetta wheel off-loading (WOL) or Orbit-control-maneuver (OCM)	+100
One of two meanings:	+200

(1) For LAP1: LDL disturbance (LAP2 in LDL mode) (2) For LAP2: Contamination signature possibly present	
Saturation	+400

Table 10. Values added to the quality flag to signify different quality-related conditions.

Note that in both CALIBRATED and DERIVED data sets, saturation is signaled both (1) through the quality flag (when available), and (2) by having the measured value replaced by a fill value.

3.4.3 Quality Values

A quality value is a decimal value in the range 0 (worst) to 1 (best) that is associated with a specific quantity that is derived from other data, e.g. a sweep. The value represents goodness of fit, or how well the underlying model fits the data, and thus indirectly the quality of the quantity derived from the data. There is no absolute relation to error bars.

Note that every *quality value* column refers to one specific, derived variable (column), as opposed to *quality flags* which may refer to multiple variables (columns).

Quality values are only used for some DERIVED data products. The quality value for a given data product is described in the corresponding subsection of Section 2.6.

3.5 **Caveats When Interpreting Science Data**

This section lists technical details which are important for regular LAP data users to be aware of.

3.5.1 General

3.5.1.1 LAP Probe 2 Contamination After Hibernation

After hibernation, LAP probe 2 (LAP2) showed strong signs of contamination, to some extent visible all through the mission. Clear signs of this include that the current to LAP2 is always lower than to LAP1 at similar bias voltage, and sweeps in both directions (available from macro 0x204) showing hysteresis effects. To avoid problems, **avoid using probe 2 measurements at positive bias potential, whether in sweeps or at fixed bias**. Measurements of negative currents are usually good, due to the higher probe sheath resistance, and so are also voltage measurements with the probe floating, as no current then flows through the probe surface, but caution is recommended.

3.5.1.2 Strong and Intermittent Currents on LAP Probe 2 from May 2016

From May 2016 to end of mission, LAP probe 2 (LAP2) occasionally exhibits very strong and intermittent currents when at negative bias voltage. These are not yet well understood, and are therefore not considered to be reliable plasma measurements. No LAP2 current measurements from this period have been used for deriving the physical quantities in the DERIVED data set. There is no indication of any problem with LAP2 voltage measurements in floating mode.

3.5.1.3 Saturated Data and Limitations in Representing Them

Saturated data means that the pre-ADC signal is outside the range of the ADC. It can thus not be properly represented digitally and should not be used. Saturation on either the positive or negative side is represented by the ADCs as the maximum *negative* value that the corresponding ADC can output. Note however, that for data using onboard-averaging (only available for ADC20 data), saturated samples may have been combined with non-saturated samples, meaning that the resulting average, which was transmitted back to Earth, may be inaccurate and *without* there being a way to determine with absolute certainty from TM whether saturated samples influence the result.

- EDITED data: Saturation is (for non-onboard averaged data) represented as -32,768 in 16-bit data (ADC16 data, and truncated ADC20 data), and as -524,288 in 20-bit data (non-truncated ADC20 data). See Section 2.5.
- CALIBRATED data: Saturated samples are represented by using the fill value -1000 000 000. Saturation is also signaled in the quality flags (Section 3.4.2), since there may be multiple reasons for this value. Technically, these values have been found by searching for calibrated values outside a certain limited interval of values in order to catch more de facto saturated values. Therefore, they are a superset of the corresponding EDITED samples reported as saturated by the ADCs as described above.

3.5.1.4 Fix Bias Values are Reconstructed from Command Log

Fix bias values included in the files are not measured but reconstructed from the spacecraft command log and the known characteristics of the instrument. Due to finite time resolution and delays in the system, there can be a difference in the time of an indicated bias change and when its effect can be seen in the data of up to one second. In addition, in certain plasmas the time constant for charging a probe when in current bias mode (E field mode) can be so long that there is a further delay before the bias has settled. Users should thus take care when interpreting data close to a bias setting. This only applies to measurements at fixed bias; the bias voltage in sweeps is synced to the measurements internally by LAP and so has correct timing. See also Section 2.5.

3.5.1.5 Interference from MIP Instrument

There is obvious interference from the MIP instrument when using its LDL mode, e.g. when running macros 0x801 or 0x807. This affects mainly the data sampled at kHz frequencies at fixed bias and in sweeps. Outliers are removed from sweep data to compensate for this. For the fix bias snapshots at 18.75 kHz sampling frequency, this mostly affects the first samples in a record, but can in longer records sometimes be seen also further into the record. In sweeps from e.g. macro 0x807, MIP interference can be detected as spikes where one or two samples deviate from their neighbors. Some MIP interference may occur also outside of LDL operations, as might of course interference from other sources. LDL mode (on/off) is determined by the macro running and is therefore the same during every run of any particular macro. Therefore the LDL mode can be detected through the macro number and the macro table in the DOCUMENT directory. The column MIPLAP (not LDLMODE) in HK (Table 13).

3.5.1.6 Transfer Functions are not Used for Calibration

The transfer functions are not used for calibration, besides for adjusting ADC20 data timestamps for group delay. The transfer functions are however provided for reference, see Section 2.5.

3.5.1.7 Bias-Dependent Current Offsets May be Updated

The time series of coefficients used to derive bias-dependent current offsets has been derived from the LAP team's manual analysis of in-flight calibration measurements, instrument temperatures etc. These tables could therefore be updated in future versions of data sets, though as of March 2019 this is not considered to be likely. See Section 2.5.6.1.

3.5.1.8 20-bit Data with Moving Average Only Have 16 Bits of Information

Due to a flight s/w bug, the four least significant bits in what should be 20-bit data *which uses moving average* are random. To avoid confusing this noise with real information, these bits have therefore been set to zero. Note that these bits have also been set to zero in EDITED data, and not just in the calibration process.

3.5.2 Fix-Bias Measurements

3.5.2.1 When to Use Probe-to-Spacecraft Potential as a Proxy for Density

For particular studies, a user may be interested in using the U_SC or some other s/c potential data product as an electron density proxy with own calibrations different from the N_ED and N_EL products we provide in the data set, for example by comparison to ICA or IES density moments in the solar wind. The paper by Edberg et al (RD6) is one example. However, because the perturbations from the solar panels, the wake formed behind the s/c and solar panels in the solar wind, and the photoelectron cloud around the spacecraft are all sensitive to the probe location, **s/c potential proxies should be used for deriving electron density only during intervals of constant pointing**. Perturbations from wake and photoemission have been studied by Sjogren (report available at http://www.space.irfu.se/exjobb/2009_alex_sjogren/).

3.5.2.2 Alternating Downsampling in Macros 0x710 and 0x910

All macros s**pecify that fix-bias measurements run with a constant combination of downsampling and moving average length, except macros 0x710 and 0x910 wh**ich alternate between two configurations. Due to having just one label file per fix bias table file, and each fix bias table file covering an entire macro block, the PDS label keywords LAP_P1P2_ADC20_DOWNSAMPLE and LAP_P1P2_ADC20_MA_LENGTH, which normally contain these settings, can not be made to reflect these alternating configurations. To avoid confusion, these keywords have therefore been removed from the affected label files. See Sections 2.3.3 and 5.3.1.5.

The downsampling rate at any specific moment can be obtained from these data products by looking at the frequency of timestamps. The corresponding downsampling rate can in turn be assumed to be equal to the moving average length *for these specific macros*.

- Macro 0x710: Fix-bias data alternates between
  - LAP_P1P2_ADC20_MA_LENGTH = "0x0100"
    LAP_P1P2_ADC20_DOWNSAMPLE = "0x0100"

  and
  - LAP_P1P2_ADC20_MA_LENGTH = "0x0004"
    LAP_P1P2_ADC20_DOWNSAMPLE = "0x0004"
- Macro 0x910: Fix-bias data alternates between
  - LAP_P1P2_ADC20_MA_LENGTH = "0x0100"
    LAP_P1P2_ADC20_DOWNSAMPLE = "0x0100"

  and
  - LAP_P1P2_ADC20_MA_LENGTH = "0x0004"
    LAP_P1P2_ADC20_DOWNSAMPLE = "0x0004"

Macro 0x710 was only run for parts of the time interval 2016-08-04 to 2016-09-30 (inclusive; UTC). Macro 0x910 was only run on parts of 2016-07-15 and 2016-07-27 (UTC).

3.5.2.3 Alternating Bias in Macro 0x515

Macro 0x515 is unique in that the bias voltage on one of the probes (LAP2) alternated between two different values, with a repeated cycle of staying at negative bias for 128 s and then at positive bias for 32 s. The macro was uploaded in October 2014 and saw some use into December 2014, when it was overwritten by 0x525 which has only one fix bias value for each probe.

The bias values reported for each sample in the I2L and I2H files are correct, showing the actual bias voltage applied at a given instant. However, as the 32 s averaging window used for producing I2D (DERIV2 data sets; a downsampled version of I2L, see Section 2.6.1) is not in sync with the AQP (also of 32s duration), the I2D files for Macro 0x515 include a lot of data where both measured current and set bias are averaged over a bias voltage change. Every such data point is correctly flagged in the files and can thus easily be removed by the user.

3.5.3 Sweep Measurements

3.5.3.1 Probe Bias Sweeps are Sensitive to Spacecraft Pointing

Probe bias sweeps are sensitive to the spacecraft pointing for the same reasons that fix-bias time measurements are. However, for all sweeps obtained prior to the comet phase, except some acquired in Earth's plasmasphere, the ion contribution to the data is so low that the photoemission saturation current can be obtained at all angles for which the probe is sunlit. Note however that the probe may be partially shadowed by its supporting rod (the stub), and that surface inhomogeneities may cause the photoemission to vary also with the pointing.

3.5.3.2 Sweeps Before September 2014

For all sweeps obtained before coming close to the nucleus in September 2014, and for some parts also later on, the dominating contributions to the probe current are probe photoemission (at negative bias voltage) and collection of photoelectrons emitted by the spacecraft and solar panels (at positive bias voltage). Hence, probe sweep data can be interpreted in terms of local plasma parameters only in the Earth's plasmasphere. The main reasons for occasionally running such sweeps in other environments, e.g. the solar wind and the Earth's magnetosphere, are to gather data for investigation of spacecraft-plasma-probe interactions and to monitor probe photoemission.

3.6 **Geometry Data Products**

The geometry data are all produced using the SPICE toolkit with kernels for Rosetta provided and updated by ESA. These data include the most important parameters for understanding the LAP measurements and are provided once every 32 seconds (once per AQP). The position is provided in target-centered solar orbital coordinates (TSO), and target-centered solar equatorial coordinates (TSEQ). At 67P, Mars and Earth, TSO is identical to cometocentric solar orbital (CSO), Mars-centric orbital (MSO) and geocentric solar ecliptic (GSE) coordinates, respectively. Similarly, at 67P, TSEQ is identical to cometocentric solar equatorial coordinates (CSEQ).

In TSO:

- X_TSO points towards the sun.
- Z_TSO is along the normal of the target (67P, Mars, Earth) orbit around the sun (the angular momentum vector).
- Y_TSO completes the right hand triad (X,Y,Z).

In TSEQ:

- X_TSEQ points towards the sun (identical to X_TSO).
- Z_TSEQ is the Sun’s axis of rotation, projected onto the plane perpendicular to X_TSEQ.
- Y_TSEQ completes the right hand triad (X,Y,Z).

The latitude and longitude are given in target-centered geographic coordinates, rotating with the target. For Rosetta at 67P, this is the Cheops system.

The solar zenith angle (SZA), commonly also known as the s/c phase angle, is the angle sun-target-Rosetta (0 deg. at the subsolar point, 90 deg. at the terminator).

The solar aspect and elevation angles are provided for describing the positions of the LAP probes w.r.t. the solar direction, and thereby regulates their illumination which is important to know since this controls the probes’ emission of photoelectrons. To intuitively and visually understand these angles, consider the spacecraft coordinate system in Figure 1. The solar panels are nominally held perpendicular to the direction of the sun, meaning it stays in the s/c XZ plane. The illumination of the probes thus depends on one angle alone, which is taken to be the angle from the s/c Z axis to the solar direction, counted as increasing from zero when the sun moves from +Z towards +X in the s/c frame. This defines the solar aspect angle (SAA). It is complemented by the solar elevation angle (SEA), which nominally is zero but attains positive (negative) values if the sun moves out of the s/c XZ plane toward the s/c +Y (-Y) axis. For the nominal case of SEA = 0, the probe illumination is given by SAA as:

SAA < 20 deg.	Both probes sunlit.
20 deg. < SAA < 81.2 deg.	LAP1 sunlit; LAP2 in shadow behind s/c body.
81.2 deg. < SAA < 82.2 deg.	LAP1 sunlit; LAP2 partially shadowed by s/c body.
82.2 deg. < SAA < 110.5 deg.	LAP1 sunlit; LAP2 possibly in shadow behind the high-gain antenna (HGA) depending on how the HGA is turned (see text below).
110.5 deg. < SAA < 131.2 deg.	Both probes sunlit.

131.2 deg. < SAA < 132.2 deg.	LAP1 partially shadowed by solar array; LAP2 sunlit.
132.2 deg. < SAA < 178.2 deg.	LAP1 in shadow behind solar array; LAP2 sunlit.
178.2 deg. < SAA < 179.2 deg.	LAP1 partially shadowed by solar array; LAP2 sunlit
179.2 < SAA	Both probes sunlit

The shading of LAP2 by the HGA is evaluated by modelling the HGA as a thin circular disk oriented as described by the relevant SPICE kernels, looking for possible intersection of the line-of-sight from the probe center to the sun with this disk. The probe shading is given in the geometry files as a numerical value for each probe according to Table 11.

Value	***Description***
0	Fully shaded
0.2	Partially shaded (by s/c body or solar array)
0.4	Only LAP2. Undetermined LAP2 HGA shading, either because the line-of-sight HGA intersection search failed to converge, or because the result indicated partial probe shading by the HGA, which is deemed to fall within the uncertainty of the method.
1	Fully illuminated
9.9	|SEA| > 1 deg., for which the SAA intervals described above (outside table) may not give accurate probe illumination.

Table 11. Values used to represent probe illumination for a single probe.

The target aspect and elevation angles (TAA and TEA) are similar except for referring to the target body instead of the sun. They are useful mainly at the comet in the case of TEA = 0 (i.e. the nucleus in the s/c XZ plane), as similar TAA intervals as for SAA above will indicate if the probes are exposed to or in the wake of a nominal radial outward plasma flow from the nucleus (corresponding to the sunlit and shadowed cases for SAA). This is information is very much more approximate than the rather exact solar illumination and should be used only as a rough indication, because of the often non-radial plasma flow as well as by the fact that there is no guarantee the solar array normal will be along the flow direction (for example, in the common case of Rosetta in terminator orbit, a radial flow from the nucleus is perpendicular to the solar direction).

Column	***Name (PDS keyword)***	***Description***
1	TIME_UTC	UTC time
2	OBT_TIME	OBT time
3	X_TSO	Target-centric solar orbital coordinates (TSO) [km]
4	Y_TSO	
5	Z_TSO	
6	X_TSEQ	

7	Y_TSEQ	Target-centric solar equatorial coordinates (TSEQ) [km]
8	Z_TSEQ	
9	LATITUDE	Spacecraft latitude in target coordinates [deg.]
10	LONGITUDE	Spacecraft longitude in target coordinates [deg.]
11	SZA	Solar zenith angle (SZA) [deg.], a.k.a. phase angle the angle between the spacecraft and the Sun as seen from the target
12	SAA	Solar aspect angle (SAA) [deg.], longitude of the Sun in the spacecraft coordinate system, counted positive from +Z toward +X
13	TAA	Target aspect angle (TAA) [deg.], longitude of the target in the spacecraft coordinate system, counted positive from +Z toward +X
14	SEA	Solar elevation angle (SEA) [deg.], latitude of the Sun in the spacecraft coordinate system, counted positive above the XZ plane toward +Y
15	TEA	Target elevation angle (TEA) [deg.], latitude of the target in the spacecraft coordinate system, counted positive above the XZ plane toward +Y
16	ILLUMINATION_P1	Whether LAP1 is illuminated or not. See Table **11**.
17	ILLUMINATION_P2	Whether LAP2 is illuminated or not. See Table **11**.

Table 12. The content (columns) of geometry files.

3.7 Browse Products (Quicklooks)

The RPC-LAP browse plots, only present in DERIV2 data sets, consist of one image file per UTC day. Each such image file contains multiple plots, summarizing multiple RPC-LAP data products for that day. Note that although the browse plots are only available in DERIV2 data sets, they describe RPC-LAP data found in both DERIV2 and CALIB2 data sets.

Consult the RPC-LAP Science Data User Guide [RD14] for an explanation of the actual content of the browse plots themselves.

3.8 Housekeeping Data Products

The HK parameters, only present in EDITED data sets, should not be of interest to normal science users since they do not provide any information not already present in the description of the macro. They are listed and described above for completeness. They are used for monitoring instrument operation and have no scientific interest on their own.

Column	***Name (PDS keyword)***	***Description and values***
1	UTC_TIME	Generation time of HK packet (UT).
2	OBT_TIME	Generation time of HK packet (s/c clock counter, but with true decimals)
3	PMAC	Currently programming macro (nonzero only during upload of instrument macros)
4	EMAC	Currently executing macro (indicates number within bank of last started macro)
5	WATCHD	Watchdog status (usually ENABLED, DISABLED only when uploading new macros)
6	PROMEN	PROM and flash memory status (usually DISABLED, ENABLED only at boot time and when uploading new macros)
7	OSC	Using oscillator (using oscillator 0 or 1)
8	LDLMODE	LDL mode and phase (this refers to an old LDL implementation not used in main mission, therefore always NONE)
9	TEMP	Temperature sensor status (usually DISABLED, ENABLED only when booting up)
10	CDRIV2	Range LAP2 bias (+-32 or +-1.3 V; usually +-32)
11	CDRIV1	Range LAP1 bias (+-32 or +-1.3 V; usually +-32)
12	E2D216	ADC 16 LAP2 mode (E-FIELD or DENSITY)
13	E1D116	ADC 16 LAP1 mode (E-FIELD or DENSITY)
14	E2D120	ADC 20 LAP2 mode (E-FIELD or DENSITY)
15	E1D120	ADC 20 LAP1 mode (E-FIELD or DENSITY)
16	CNTRE2	LAP2 feedback (E-FIELD or DENSITY)
17	CNTRE1	LAP1 feedback (E-FIELD or DENSITY)
18	MIPLAP	Instrument using probe 2 (LAP or MIP)
19	BTSTRP	Internal bootstrap status (usually ENABLED, rarely DISABLED)
20	F2122	LAP2 connected to: RX=analog input (usual), TX=transmitter (very rare)
21	F22ED	LAP2 bias mode (DENSITY or E-FIELD)
22	F22EDDEDC	LAP2 density range or E-field strategy (for DENSITY, G1.0 or G.05 gives high or the rarely used low gain; for E-FIELD, BIAS or FLOAT specifies if a bias current is applied or the probe is floating)

Column	*Name (PDS keyword)*	*Description and values*
23	F1121	LAP1 connected to: RX=analog input (usual), TX=transmitter (very rare)
24	F11ED	LAP1 bias mode (DENSITY or E-FIELD)
25	F11EDDEDC	LAP1 density range or E-field strategy (for DENSITY, G1.0 or G.05 gives high or the rarely used low gain; for E-FIELD, BIAS or FLOAT specifies if a bias current is applied or the probe is floating)
26	CALIBRATIONA	Flash checksum at reboot, then most significant byte of macro identifier.
27	CALIBRATIONB	Flash checksum at reboot, then least significant byte of macro identifier.
28	TMP12	Uncalibrated temperature, valid if TEMP is ENABLED and LAP2 in E-FIELD.
29	SWVERSION	Software version (15 in main mission).

Table 13. LAP HK parameters.

3.9 Instrument Calibration Data Products

Ground calibration data as well as in-flight calibrations are used and included in the data sets. The following calibration products are included in the CALIB directory of the LAP data sets:

In flight	*Product ID*
Coefficients used to derive current offsets as a function of probe, bias voltage, and time (density mode).	**RPCLAP***YYMMDD***_CALIB_COEFF**
Time series of coefficients used to derive the NED and NEL plasma density data products. Each data product separately covers the entire comet phase. The date in the filename refers to the version. Files specific to LAP1 and LAP2 have suffixes of _P1 and P_2, respectively	**RPCLAP***YYMMDD***_CALIB_NED** **RPCLAP***YYMMDD***_CALIB_NEL_I_P1** **RPCLAP***YYMMDD***_CALIB_NEL_I_P2** **RPCLAP***YYMMDD***_CALIB_NED_V**

On ground (pre-flight)	*Product ID*
Current biases and measured laboratory values.	**RPCLAP***YYMMDD***_CALIB_IBIAS**

Voltage biases and measured laboratory values.	**RPCLAP***YYMMDD***_CALIB_VBIAS**
Fine bias voltage settings and measured laboratory values.	**RPCLAP***YYMMDD***_CALIB_FINE**
Transfer function probe 1, Density mode	**RPCLAP***YYMMDD***_CALIB_FRQ_D_P1**
Transfer function probe 2, Density mode	**RPCLAP***YYMMDD***_CALIB_FRQ_D_P2**
Transfer function probe 1, E-field mode	**RPCLAP***YYMMDD***_CALIB_FRQ_E_P1**
Transfer function probe 2, E-field mode	**RPCLAP***YYMMDD***_CALIB_FRQ_E_P2**
Voltage bias-dependent current offsets in TM units, both probes. Effectively a single ground measurement of what **RPCLAP***YYMMDD***_CALIB_COEFF** represents in flight, albeit on a different format.	**RPCLAP***030101***_CALIB_MEAS**

As mentioned in Section 2.5, the transfer functions are currently not used in the production of calibrated or edited data sets, but are provided for reference. All other products are used in producing the calibrated data sets. *YYMMDD* is the date on which the corresponding calibration was made unless stated otherwise.

3.10 Special Values, Fill Values

A subset of columns in the data products use a specific fill value to represent missing data. Various columns in the science data files use a fill value of -1 000 000 000, whereas as the geometry illumination columns use a fill value of 9.9. The fill values are chosen such that they unlikely to be mistaken for real values when plotting them.

Exactly which columns use fill values is authoritatively defined through the use of the PDS keyword MISSING_CONSTANT and its associated value which is separately defined (or not defined) for every single column in the label files. The keyword DESCRIPTION, associated with such a column, should also contain some comments on the use and exact meaning of the fill value. If the keyword MISSING_CONSTANT is not defined for a column, then that column only contains valid values.

3.11 Software

There is no software included with the data set.

3.12 Documentation

Relevant documentation is archived in the **DOCUMENT/** directory of each data set. See detailed description in Section 4.4.3.5.

3.13 Ancillary Data Usage

All geometry files, as well as all conversions between spacecraft clock and UTC throughout the data sets, have been made using SPICE and SPICE kernels provided by the ESA SPICE Service.

4 Data Set Format and Content

This section should be of interest as a reference to any user directly accessing the LAP data set.

4.1 Format and Conventions

4.1.1 Deliveries and Data Set Volume Format

The LAP team use conventions defined as in the RO-EST-PL-5011_2_Rosetta_Archive_GVT_Plan, and conventions defined by the RPC team. For instance, the data directory naming conventions as in Section 4.1.3 are RPC consistent. One data set corresponds to one volume.

4.1.2 Data Set ID (DATA_SET_ID) Formation

Example:

RO-C-RPCLAP-3-ESC2-description-V1.0

RO	= INSTRUMENT_HOST_ID
C	= TARGET_ID
RPCLAP	= INSTRUMENT_ID
3	= Data processing level (DPL) number
ESC2	= Mission phase abbreviation

Edited data = 2, Calibrated data = 3, Derived data = 5.

Within each data set TARGET_NAME and TARGET_TYPE are used to identify the current target.

“description” is the type of LAP data set, i.e. EDITED2, CALIB2, DERIV2, or NEL (see Section 2.4.1).

4.1.3 Data Directory Naming Convention

Science data files are stored in one directory per day, organized as shown in Figure 3.

```
DATA_SET_ROOT
|
________________________________...
|         |              |
DATA      DOCUMENT       ...
|
________________________________
|            |                |
EDITED       CALIBRATED       DERIVED
|
___________________________________...
|         |         |         |
2004      2005      2006      ....
|
_________________________________...
|       |       |       |       |
JAN     FEB     MAR     APR     ...
|
_________________________________...
|       |       |       |       |
D01     D02     D03     D04     ...
```

Figure 3. Data directory structure.

4.1.4 *Filenaming and Product ID (PRODUCT_ID) Convention*

The LAP convention for files in the DATA/ (science data), CALIB/ (calibration data), and BROWSE/ (browse plots) subdirectories is that filenames are identical to the corresponding product ID (PRODUCT_ID) plus the relevant filename suffix. This document thus only explicitly states the filenaming convention in the DATA/ subdirectory. Filenames for the CALIB/ and BROWSE/ subdirectory are stated in Sections 4.4.3.2 and 4.4.3.7.

For science data files, the filename contains some information on the type of data which should make it possible to often avoid having to parse the corresponding PDS label file to distinguish between different types of data.

(EDITED2, CALIB2) Science data and sweep descriptions	**LAP**_*CCYYMMDD*_*hhmmss*_*xxx*_*jek*.*ext* See Table 7.
(DERIV2, NEL) Science data	**LAP**_*CCYYMMDD*_*hhmmss*_*xxx*_*xxx*.*ext*
(All data sets) Block list	**LAP**_*CCYYMMDD*_**000000_BLKLIST**.*ext*
(EDITED2) Housekeeping	**LAP**_*CCYYMMDD*_**000000_HK**.*ext*
(CALIB2, DERIV2) Geometry	**LAP**_*CCYYMMDD*_**000000_GEOM**.*ext*

In the above product IDs, black, boldface characters are static, and red italicized characters are variables which are described in Table 14.

Code	Meaning	Values
CCYYMMDD	Date (century, year, month,day)	
hhmmss	Time of day (hour, minute, second)	
e	Sensor (probe)	1 = Probe 1 2 = Probe 2 3 = Derived from both probe 1 and 2.
iii	Macro number.	Three hexadecimal digits.
j	Type of data.	I = Measured current V = Measured voltage B = Sweep description
k	Type of measurement.	L = LF (fix bias; ADC20) H = HF (fix bias; ADC16) S = Sweep (always ADC16)
x	N/A	Any (single) character
.ext	File extension	.LBL = PDS label file .TAB = Text file with data

Table 14. The meaning of the variables (red, italicized) in the descriptions of filenames and product IDs.

4.2 Standards Used in Data Product Generation

4.2.1 PDS Standards

LAP data sets comply with PDS version 3, and should follow version 3.6 of the PDS standard reference.

4.2.2 Time Standards

Time references in the LAP PDS data set are UTC and spacecraft clock. UTC time is displayed in the PDS CCYY-MM-DDThh:mm:ss.sss format. Conversion from spacecraft clock to UTC is done using SPICE and SPICE kernels provided by the ESA SPICE Service.

4.2.3 Reference Systems

The geometry files provide spacecraft positions in the target-centered solar orbital coordinate system. For Rosetta at comet 67P, the data sets use the Cheops system. The spacecraft pointing is described using angles which are defined using the Sun, the target, and the s/c coordinate axes, which are briefly described in Figure **1**.

4.3 **Data Validation**

All data is checked with PSA's software tools DVAL-NG and DatasetValidator before delivery.

4.3.1 EDITED

Data are automatically scanned for internal consistency when processed into edited format.

4.3.2 CALIBRATED

Data are visually scanned for noting obvious problems. Comparative investigations may be undertaken. Particularly noteworthy features are documented in the DATASET.CAT file in the CATALOG directory of each data set.

4.3.3 DERIVED

Two data products are cross-calibrated with other RPC instruments. The Level 5 plasma density in the NED files (in DERIV2 data sets) is generated by cross-calibration with RPC-MIP densities when these are available. The spacecraft potential in the USC files has been compared to ICA data on a general level though not for every case [RD7, RD8]. Other data have been visually scanned in daily plots for capturing obvious problems, and data from such cases removed.

4.4 **Content**

4.4.1 Volume Set

According to Section 19.4 in AD1.

4.4.2 Data Set Name (DATA_SET_NAME) Formation

The data set naming convention follows principles similar to those for the DATA_SET_ID, Section 4.1.2.

DATA_SET_NAME="ROSETTA-ORBITER <TARGET> RPCLAP <LEVELNUM> <MPHASE> <LEVELWORD> V<X>"

The variable fields here are:

<TARGET>	=	Target name, e.g. LUTETIA.
<LEVELNUM>	=	Data processing level number (e.g. 2 for EDITED).
<MPHASE>	=	Mission phase abbreviation, example AST1.
<LEVELWORD>	=	Free character string, which RPCLAP sets to EDITED2, CALIB2, DERIV2 depending on processing level.
<X>	=	Data set version number, e.g. 2.0.

One data set will be used for each processing level and mission phase. The data set name fits in the full length thus 60 characters.

4.4.3 Directories

4.4.3.1 Root Directory

Contents:

AAREADME.TXT
BROWSE/ (Only DERIV2 data sets)
CALIB/
CATALOG/
DATA/
DOCUMENT/
INDEX/
VOLDESC.CAT

See Section 5.1 for more detail.

4.4.3.2 Calibration Directory

The directory CALIB/ contains calibration files, described in Section 3.9.

Filename	Description
CALINFO.TXT	Information on directory contents
RPCLAP030101_CALIB_FINE.LBL RPCLAP030101_CALIB_FINE.TAB	
RPCLAP030101_CALIB_FRQ_D_P1.LBL RPCLAP030101_CALIB_FRQ_D_P1.TXT	
RPCLAP030101_CALIB_FRQ_D_P2.LBL RPCLAP030101_CALIB_FRQ_D_P2.TXT	
RPCLAP030101_CALIB_FRQ_E_P1.LBL RPCLAP030101_CALIB_FRQ_E_P1.TXT	
RPCLAP030101_CALIB_FRQ_E_P2.LBL RPCLAP030101_CALIB_FRQ_E_P2.TXT	
RPCLAP030101_CALIB_IBIAS.LBL RPCLAP030101_CALIB_IBIAS.TAB	
RPCLAP030101_CALIB_MEAS.LBL RPCLAP030101_CALIB_MEAS.TAB	
RPCLAP030101_CALIB_VBIAS.LBL RPCLAP030101_CALIB_VBIAS.TAB	
RPCLAP*YYMMDD*_CALIB_COEFF.LBL RPCLAP*YYMMDD*_CALIB_COEFF.TAB	
RPCLAP*YYMMDD*_CALIB_NED.LBL RPCLAP*YYMMDD*_CALIB_NED.TAB RPCLAP*YYMMDD*_CALIB_NEL_I_P1.LBL RPCLAP*YYMMDD*_CALIB_NEL_I_P1.TAB RPCLAP*YYMMDD*_CALIB_NEL_I_P2.LBL RPCLAP*YYMMDD*_CALIB_NEL_I_P2.TAB RPCLAP*YYMMDD*_CALIB_NEL_V.LBL RPCLAP*YYMMDD*_CALIB_NEL_V.TAB	

Table 15. Content of the CALIB/ directory. Not all files are present in all data sets. File content not described here is described in Section 3.9.

4.4.3.3 Catalog Directory

Filename	Description

CATINFO.TXT	This file contains a list of all catalog files located in the **CATALOG/** directory, with brief descriptions (as this table).
DATASET.CAT	Description of the data in the present Data set, including caveats and the time interval covered by the data set.
ROSETTA_INSTHOST.CAT	ROSETTA spacecraft information. File provided by ESA.
ROSETTA_MSN.CAT	ROSETTA Mission information, including mission phase schedule. File provided by ESA.
RPCLAP_INST.CAT	LAP instrument description.
RPCLAP_PERS.CAT	LAP key people with contact details.
RPCLAP_REF.CAT	Catalog of relevant publications. File provided by ESA.
RPCLAP_SOFTWARE.CAT	Software catalog file (only containing the information that there is no s/w).

Table 16. Content of the CATALOG/ directory.

4.4.3.4 Index Directory

Filename	Description
BROWSE_INDEX.LBL **BROWSE_INDEX.TAB**	Index of browse plots. (Only DERIV2 data sets.)
INDXINFO.TXT	Description of directory.
INDEX.LBL **INDEX.TAB**	Index of science data products. (Only DERIV2 data sets.)

Table 17. Content of the INDEX/ directory.

This directory contains the data set's index files. The IND* files are generated using the ESA/PSA software PVV.

4.4.3.5 Document Directory

This directory contains relevant LAP documentation as described below.

The FLIGHT REPORTS subdirectory contains LAP operations reports from the relevant mission phase (and may contain reports for other mission phases as well). These reports summarize the commanding, data taking, anomalies and outcomes of each operation. Note that one mission phase may include several operations, documented in separate reports (for example, EAR2 includes not only the operations around the 2nd Earth swing-by, but also a payload checkout activity).

Filename	Description
DOCINFO.TXT	Describes directory contents
ERIKSSON2007A.LBL **ERIKSSON2007A.PDF**	Instrument description, label file and document as PDF: A. I. Eriksson, R. Boström, R. Gill, L. Åhlén, S.-E. Jansson, J.-E. Wahlund, M. André, A. Mälkki, J. A. Holtet, B. Lybekk, A. Pedersen, L. G. Blomberg and the LAP team, RPC-LAP: The Rosetta Langmuir probe instrument, *Space Sci. Rev.*, 128, 729-744, 2007, doi:10.1007/s11214-006-9003-3
ERIKSSON2008A.LBL **ERIKSSON2008A.PDF**	Instrument description, label file and document as PDF: A. I. Eriksson, R. Gill, J.-E. Wahlund, M. André, A. Mälkki, B. Lybekk, A. Pedersen, J. A. Holtet, L. G. Blomberg and N. J. T. Edberg, RPC-LAP: The Langmuir probe instrument of the Rosetta Plasma Consortium, in *Rosetta: ESA's mission to the origin of the solar system*, eds. R. Schulz, C. Alexander, H. Boehnhardt and K.-H. Glassmeier, pp. 435-447, Springer, 2009, ISBN: 978-0-387-77517-3.
RO-IRFU-LAP-EAICD.LBL **RO-IRFU-LAP-EAICD.PDF**	EAICD (this document) as PDF, with label file
RO-IRFU-LAP-UG.LBL **RO-IRFU-LAP-UG.PDF**	RPCLAP Science Data User Guide, with label file
RPC_USER_GUIDE.LBL **RPC_USER_GUIDE.PDF**	RPC User Guide, with label file
RO-IRFU-LAP-XCAL.LBL **RO-IRFU-LAP-XCAL.PDF**	RPC-LAP Cross-calibration Report, with label file
RO-IRFU-LAPMAC-*YYMMDD-phase*.LBL **RO-IRFU-LAPMAC-*YYMMDD-phase*.PDF**	Description of the LAP macros referred to by INSTRUMENT_MODE_ID, in PDF format, with label file. This replaces the outdated LAPMPF document present in previous releases. The date *YYMMDD* is a version identifier. *phase* is the mission phase name abbreviation.

Table 18. Content of the DOCUMENT/ directory.

4.4.3.6 Data Directory

See Section 4.1.3 for overall structure, Sections 4.1.4 and 3.2 for data products in the data directory.

4.4.3.7 Browse Directory

The Browse directory is only available in DERIV2 data sets and contains files

Filename	Description
BROWINFO.TXT	Describes content of directory.
LAP_*CCYYMMDD***_BROWSE.LBL** **LAP_***CCYYMMDD***_BROWSE.PNG** (many)	Browse plot(s) with corresponding label file(s). *CCYYMMDD* represents the century, year, month and date for the UTC day for which the file applies.

Table 19. Content of BROWSE/ directory.

5 Detailed Interface Specifications

5.1 Structure and Organization Overview

The contents of the directories in a data set are discussed in Section 4. The general organization of the data set can be seen from the following example for the data set of CALIBRATED data from the Lutetia flyby:

```
DATASET_ROOT
   |-CALIB
   |-CATALOG
   |-DATA
   |---CALIBRATED
   |-----2010
   |-------JUL
   |---------D07
   |---------D08
   |---------D09
   |---------D10
   |---------D11
   |---------D12
   |---------D13
   |-DOCUMENT
   |---FLIGHT_REPORTS
   |-INDEX
```

For the contents of these directories, please see Section 4.4.

5.2 Data Sets, Definition and Content

Please see Sections 2.2 and 2.3.

5.3 Data Product Design

5.3.1 General Issues

5.3.1.1 File Characteristics of Data Elements

Data are stored in ASCII files with the filename extension ".TAB". The internal format is comma-separated values/columns. The associated label file, describing the data file in detail (column names, instrument settings etc), has the same base filename but with the extension ".LBL" instead.

5.3.1.2 Data Object Pointers Identification Data Elements

The only pointers used in the label files are ^TABLE from the *.LBL file to the *.TAB file, ^ARCHIVE_CONTENT_DESC to the LAP EAICD (this document), ^RPC_SCIENCE_USAGE_DESC to the RPC User Guide, and ^RPCLAP_SCIENCE_USAGE_DESC to the RPCLAP Science Data User Guide [RD14].

5.3.1.3 Instrument and Detector Descriptive Data Elements

Please see Sections 2.2 and 2.3.

5.3.1.4 Data Object Definition

All data are stored in *.TAB files. Their structure is defined in the OBJECT Table definition within the *.LBL files. Each data definition block has a DESCRIPTION which explains the meaning of the assigned data column exactly.

5.3.1.5 Instrument Specific PDS Keywords

The LAP data sets use some LAP-specific keywords in the label files. Most or all of these should not be relevant for the regular science user. Most of them regard internal instrument settings and are mostly present for completeness: see the instrument descriptions in the DOCUMENT directory for understanding their meaning.

Examples of format in label files:

```
ROSETTA:LAP_TM_RATE = "BURST"
ROSETTA:LAP_P1_SWEEP_START_BIAS = "0x00c0"
```

The instrument-specific keywords used are tabulated in Table **20**.

The LAP team has also defined a set of instrument modes using the already existing keyword INSTRUMENT_MODE_ID and

INSTRUMENT_MODE_DESC. Instrument modes are identified by the onboard macro producing the data (Section 2.3). The macro ID (MCID) is a hexadecimal number 0x0100 to 0x0A07 where the last digit cannot be higher than 7. The middle digit represents the version number of the macro, starting from 0.

Rosetta LAP-specific label keywords	***Valid values separated by colon***	***Maximum character string length***	***Description***
LAP_BOOTSTRAP	ON:OFF	3	Bootstrapping on or off
LAP_CURRENT_CAL_16B_G0_05	*Ascii real string*	14	Convert TM to [A] ADC16's gain 0.05
LAP_CURRENT_CAL_16B_G1	*Ascii real string*	14	Convert TM to [A] ADC16's gain 1
LAP_FEEDBACK_P1, LAP_FEEDBACK_P2	DENSITY:E-FIELD	7	E-Field or Density feedback relay probe 1 or 2
LAP_IBIAS1, LAP_IBIAS2	*Hex word string*	*6*	Fix current bias sensor 1 or 2
LAP_P1_ADC16, LAP_P2_ADC16	DENSITY:E-FIELD	7	ADC16 probe 1 or 2 E-Field or Density mode
LAP_P1_ADC16_DIG_FILT_CUTOFF, LAP_P2_ADC16_DIG_FILT_CUTOFF	4688 Hz:2344 Hz:1172 Hz:586 Hz	7	Digital filter used on probe 1 or 2
LAP_P1_ADC16_DIG_FILT_STATUS, LAP_P2_ADC16_DIG_FILT_STATUS	DISABLED:ENABLED	8	Digital filter on or off on probe 1 or 2
LAP_P1_ADC16_DOWNSAMPLE, LAP_P2_ADC16_DOWNSAMPLE	*Hex word string*	*6*	Data sensor 1 or 2 downsampled *n* times
LAP_P1_ADC16_FILTER, LAP_P2_ADC16_FILTER	4 KHZ:8 KHZ	5	Analog filter used
LAP_P1_ADC20, LAP_P2_ADC20	DENSITY:E-FIELD	7	ADC20 probe 1 or 2, E-Field or Density mode
LAP_P1_BIAS_MODE, LAP_P2_BIAS_MODE	E-FIELD:DENSITY	7	Probe 1 or 2 bias mode
LAP_P1_DENSITY_FIX_DURATION,	*Hex word string*	*6*	Duration in samples of fix density bias data sensor 1 or 2

LAP_P2_DENSITY_FIX_DURATION			
LAP_P1_EFIELD_FIX_DURATION, LAP_P2_EFIELD_FIX_DURATION	*Hex word string*	*6*	Duration in samples of fix E-field bias data sensor 1 or 2
LAP_P1_FINE_SWEEP_OFFSET, LAP_P2_FINE_SWEEP_OFFSET	*Hex word string*	*6*	Probe 1 or 2 fine sweep bias offset
LAP_P1_RANGE_DENS_BIAS, LAP_P2_RANGE_DENS_BIAS	+5:+32	3	Density bias range probe 1 or 2
LAP_P1_RX_OR_TX, LAP_P2_RX_OR_TX	ANALOG INPUT:TRANSMITTER	12	Connected to transmitter or not
LAP_P1_STRATEGY_OR_RANGE, LAP_P2_STRATEGY_OR_RANGE	BIAS:FLOAT:GAIN 0.05:GAIN 1	9	E-Field strategy or density gain probe 1 or 2
LAP_P1_SWEEP_FORMAT, LAP_P2_SWEEP_FORMAT	UP:DOWN:DOWN UP:UP DOWN	7	Sweeping direction on probe 1 and 2 respectively
LAP_P1_SWEEP_PLATEAU_DURATION, LAP_P2_SWEEP_PLATEAU_DURATION	*Hex word string*	*6*	Samples on a plateau on probe 1 and 2 respectively
LAP_P1_SWEEP_RESOLUTION, LAP_P2_SWEEP_RESOLUTION	COARSE:FINE	6	Sweeping resolution on probe 1 and 2 respectively
LAP_P1_SWEEP_START_BIAS, LAP_P2_SWEEP_START_BIAS	*Hex word string*	*6*	Sweep start bias on probe 1 and 2 respectively
LAP_P1_SWEEP_STEP_HEIGHT, LAP_P2_SWEEP_STEP_HEIGHT	*Hex word string*	*6*	Height of a bias step on probe 1 and 2 respectively
LAP_P1_SWEEP_STEPS, LAP_P2_SWEEP_STEPS	*Hex word string*	*6*	Number of bias steps in sweep on probe 1 and 2 respectively

LAP_P1P2_ADC20_DOWNSAMPLE	*Hex word string*	*6*	Downsampling *n* times on ADC20 data sensor 1 and 2
LAP_P1P2_ADC20_MA_LENGTH	*Hex word string*	*6*	Length of moving average (MA) used.
LAP_P1P2_ADC20_STATUS	EMPTY:P2T:P1T:P1T & P2T:P2F:P1T P2F:P1F:P1F P2T:P1F & P2F	9	Status: P1 = Sensor 1 P2 = Sensor 2 T = Truncated to 16 bit F = Full 20 bit
LAP_SWEEPING_P1, LAP_SWEEPING_P2	NO:YES	3	A sweep or time series
LAP_TM_RATE	NONE:MINIMUM:NORMAL:BURST	7	Telemetry rate
LAP_TRANSMITTER_AMPLITUDE	LTRO1:MTRO2:HTRO3:LTR1:MTR2:HTR3	5	Amplitude of transmitter signal full description. Not used up to now.
LAP_TRANSMITTER_FREQUENCY	*Hex word string*	*6*	Frequency of transmitter square wave in Hz. Not used up to now.
LAP_TRANSMITTER_STATUS	DISABLED:ENABLED	8	Transmitter on or off
LAP_VBIAS1, LAP_VBIAS2	*Hex word string*	*6*	Fix voltage bias sensor 1 or 2
LAP_VOLTAGE_CAL_16B	*Ascii real string*	14	Convert TM to [V] ADC16s

Table 20. LAP instrument-specific keywords. The table is sorted in alphabetical order of the first keyword in every cell of the left-most column. “Hex word” means values from `0x0000` to `0xffff`, though they are stored as character strings. All values are `DATA_TYPE = CHARACTER` and are enclosed in quotes in the label file. The valid string values are separated by a colon (“:”) in, and thus the colon is not part of the values themselves. Also note that the maximum character string length does not include counting quotes, null terminators, line feeds or carriage returns.

It is implicit that all keywords should be prefixed by the string “ROSETTA:”.