ROSETTA-RPC-IES
PLANETARY SCIENCE ARCHIVE
INTERFACE CONTROL DOCUMENT

APRIL 2017

SwRI® Project 14568

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Contract JPL 1345493

Prepared by

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Document No. 10991-IES-EAICD-03

Contract JPL -1345493

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REVISION NOTICE

Initial Issue: September 2005.

Revision 1: Updated for version 2 archive products. August 2007

Revision 2: Updated in response to comet phase archive review. May 2016.

Revision 3: Updates after finalizing L2 and L3 data product updates. April 2017.

1. INTRODUCTION

1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to (Science) Archive Interface Control Document) is to provide users of the RPC-IES instrument data with detailed description of the products and descriptions of how they were generated, including data sources and destinations. It is the official interface between the instrument team and the archiving authority.

1.2 Archiving Authorities

The Planetary Data System Standard is used as archiving standard by

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

1.2.1 ESA's Planetary Science Archive (PSA)

ESA implements an online science archive, the PSA,

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

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

1.3 Contents

This document describes the data flow of the IES instrument on the Rosetta mission from the spacecraft until the insertion into the PSA for ESA. It includes information on how data were processed, formatted, labeled and uniquely identified. The document discusses general naming schemes for data volumes, data sets, data and label files. Standards used to generate the product are explained.

The design of the data set structure and the data product is given. An example data product is given in section 4.3 Data Product Design.

1.4 Intended Readership

This document's intended readership includes staff of the archiving authorities and potential users of the RPC-IES data.

1.5 Applicable Documents

Planetary Data System Data Archive Preparation Guide April 1, 2010, Version 1.4, JPL D31224

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

Rosetta Archive Generation, Validation and Transfer Plan, January 2006, RO-EST-PL-5011

Rosetta Plasma Consortium Users' Manual, V 2.18, October 2011, RO-RPC-UM

Ion and Electron Sensor (IES) Flight Software Requirements Document, November 14, 2000, Rev. 0 Change 0, SWRI, Document No. 8182-FSRD-01

H.D.R. Evans, P. Bühler, W. Hajdas, E.J. Daly, P. Nieminen, A. Mohammadzadeh, Results from the ESA SREM monitors and comparison with existing radiation belt models, Advances in Space Research 42, 1527 (2008)

1.6 Relationships to Other Interfaces

N/A

1.7 Acronyms and Abbreviations

CCSDS	Consultative Committee for Space Data Systems
DDS	Data Distribution System
ESA	European Space Agency, Electrostatic Analyzer
ESOC	European Space Operations Centre
FOV	Field of View
HGA	High Gain Antenna
HGRTN	Heliocentric Radial-Tangential-Normal
IES	Ion and Electron Sensor
IESGS	IES Ground System
MCP	Microchannel Plate
NAIF	Navigation and Ancillary Information Facility
PDS	Planetary Data System
PSA	Planetary Science Archive
RDDS	Rosetta Data Distribution System
RPC	Rosetta Plasma Consortium
SPICE	NAIF information system
SREM	Standard Radiation Environment Monitor

1.8 Contact Names and Addresses

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2. OVERVIEW OF INSTRUMENT DESIGN, DATA HANDLING PROCESS AND PRODUCT GENERATION

2.1 Instrument Design

The IES for Rosetta is an electrostatic analyzer (ESA), featuring electrostatic angular deflection to obtain a field of view of 90º x 360º. The instrument objective is to obtain ion and electron distribution functions over the energy range from 4.32 eV/e up to 17.67 keV/e. The angular resolution for electrons is 5º x 22.5º (16 polar-angle sectors, referred to as elevation sectors henceforth and 16 azimuthal sectors). For ions, the angular resolution is 5º x 45º (16 elevation and 8 azimuthal sectors) with additional segmentation to 5º x 5º in the 45º azimuthal sector most likely to contain the solar wind (giving a total of 16 azimuthal sectors for ions). The back-to-back top hat geometry of the IES electrostatic analyzer allows it to analyze both electrons and positive ions with a single entrance aperture. The IES top hat analyzers have toroidal geometry with a smaller radius of curvature in the deflection plane than in the orthogonal plane. This toroidal feature results in a flat deflection plate geometry at the poles of the analyzers and has the advantage that the focal point is located outside the analyzers rather than within them, as is the case with spherical top hat analyzers. Particles within a narrow 8% energy pass band will pass through the analyzers and be focused onto the electron and ion microchannel plates (MCPs), which produce charge pulses on 16 discrete anodes, which define the azimuth acceptance angles. In addition, the IES entrance aperture contains electrostatic deflection electrodes, which expand its elevation angle field of view to ±45º. With the typical top hat polar-angle field of view of 360º, the IES acquires a total solid angle of 2.8 pi steradians.

Operation of IES is controlled by its on-board software in conjunction with sets of (selectable) look up tables. A table in one set determines the sequence of voltages applied to the electrostatic analyzer, thereby selecting the energy/charge of electrons and ions entering the sensor. Likewise, a table in another set determines the sequence of voltages applied to the deflector plates, thereby defining the acceptance angle of the particles. In the typical operating mode, for each ESA voltage chosen the deflector is stepped over its range, the ESA voltage is stepped to its next value, and so on. A complete 2 voltage sequence thus determines a complete measurement cycle. Yet another set of tables control the summing of adjacent angle/energy bins enabling reduction of data volume to fit within the data volume allocated to the instrument. Several versions of the tables are stored in the instrument so different operating modes can be easily chosen. In addition, new tables can be uplinked if desired.

During a measurement cycle the instrument obtains a full measurement of ion and electron flux with 16 azimuthal bins, 16 elevation bins and 128 energy bins, for a total of 65536 values (2x16x16x128) per measurement and then sums the adjacent bins for telemetry as determined by the operating mode

2.2 Scientific Objectives

IES measurements support goals to carry out investigations of (1) the solar wind interaction with the nucleus of comet 67P/Churyumov–Gerasimenko (CG), (2) the processes that govern the composition and structure of the cometary atmosphere, and (3) the interaction between the solar wind and the cometary atmosphere.

2.3 Data Handling Process

All RPC data packets were transmitted together during downlinks. RPC data were retrieved from the DDS at ESOC to a central RPC data server at Imperial College in London and then copied by IESGS at Southwest Research Institute. Please see section 2.4.5 for an overview of IESGS and section 1.8 for contact information.

2.4 Data Products

2.4.1 Pre-Flight Data Products

None. Raw calibration data are generated for internal use, but there are no current plans to submit these data to the PSA.

2.4.2 In-Flight Data Products

To ensure that the IES goals can be achieved, data will be archived as:

- Edited raw data (CODMAC level 2) – the science data in raw counts converted to human and PDS readable format.
- Calibrated data (CODMAC level 3) – the edited raw data with calibration factors included and converted to differential energy flux. Each flux data file has an associated file containing the uncertainties in flux data. Also included are corresponding files listing background counts subtracted from Level 2 data during conversion to Level 3.

These data may be used for cross-instrument calibrations, and both stand-alone and cross-instrument scientific analysis.

Table 1: Spacecraft Science Data Products in IES Data Sets

Product	Data Set Type	Maximum (MB / Day)	Mission Total, estimated
ELC	Level 2 (Counts)	67	190,650
	Level 3 (Differential Energy Flux)	67	
	Level 3 (Flux Uncertainty)	67	
	Level 3 (L2 Background Counts)	4	
ION	Level 2 (Counts)	33	97,760
	Level 3 (Differential Energy Flux)	33	
	Level 3 (Flux Uncertainty)	33	
	Level 3 (L2 Background Counts)	5	

2.4.2.1 Transition Cycles

In Level 2 products, cycles with Mode IDs that have four non-zero characters may appear. These infrequently appearing cycles are called transition cycles and are not listed explicitly in mode tables. A transition cycle mode is constructed in-flight when IES switches from a longer duration mode to a shorter mode. It is identified by a four character mode ID. It has the duration of the preceding longer cycle and collapse properties of the following shorter cycle.

In Level 3 products, these transition cycles do not appear. To reduce complexity during generation of the leve3 3 products and subsequent analysis by the users, the transition cycles are not processed and appear as gaps in data.

2.4.2.2 Flyback

Cycling of ESA voltages is completed using 128 steps (0 to 127) which include 4 steps (124 to 127) during 'flyback' (FB), the transition from the highest voltage of 1667 V (step 123) to 0 V (step 127). The actual transition time does not require all 4 steps, just one step. So science data readings during the first step of the flyback, 124 (FB1) should be considered unreliable to measure the background counts. Steps 125 (FB2) and 126 (FB3) may be considered as 0V for background measurements if not combined with other steps. The IES team has not used these flyback steps to determine background counts. In level three products these energy steps are not included.

2.4.3 Software

We do not intend to deliver any software.

2.4.4 Calibration Software

We do not intend to deliver any calibration software. A document describing the generation of the Level 3 differential energy flux data from the Level 2 counts data, FLUX_ANALYSIS.PDF is included in the DOCUMENTS directory in the Level 3 volume.

2.4.5 Pipeline Processing Software

The pipeline processing software is the IES Ground System (IESGS). IESGS extracts IES CCSDS packets from the RPC collective data files stored on the RPC central data server at Imperial College. These packets are used to build Level 2 ion and electron data products and the associated label files. The data products are grouped by date and written out to PDS compliant archive data files. One data file is created for each day. IESGS also generates Level 3 data products and the associated files from the Level 2 files. IES science products, archive and label files, and limited spectrograms are available to team scientists on the IESGS website.

2.4.6 Documentation

The document directory contains documentation that is considered to be either necessary or useful for users to understand the archive data set. These documents are not necessarily appropriate for inclusion in the PDS catalog. Documents may be included in multiple forms (ASCII, PDF, MS Word, HTML with image file pointers, etc.).

There is a separate directory for each archived document. Each directory includes the document in plain text (ASCII) and in another format (i.e. .DOC or .PDF). There is also a single label file that describes all the different formats of the included documents.

2.4.7 Derived and other Data Products

There are no plans to submit derived data products.

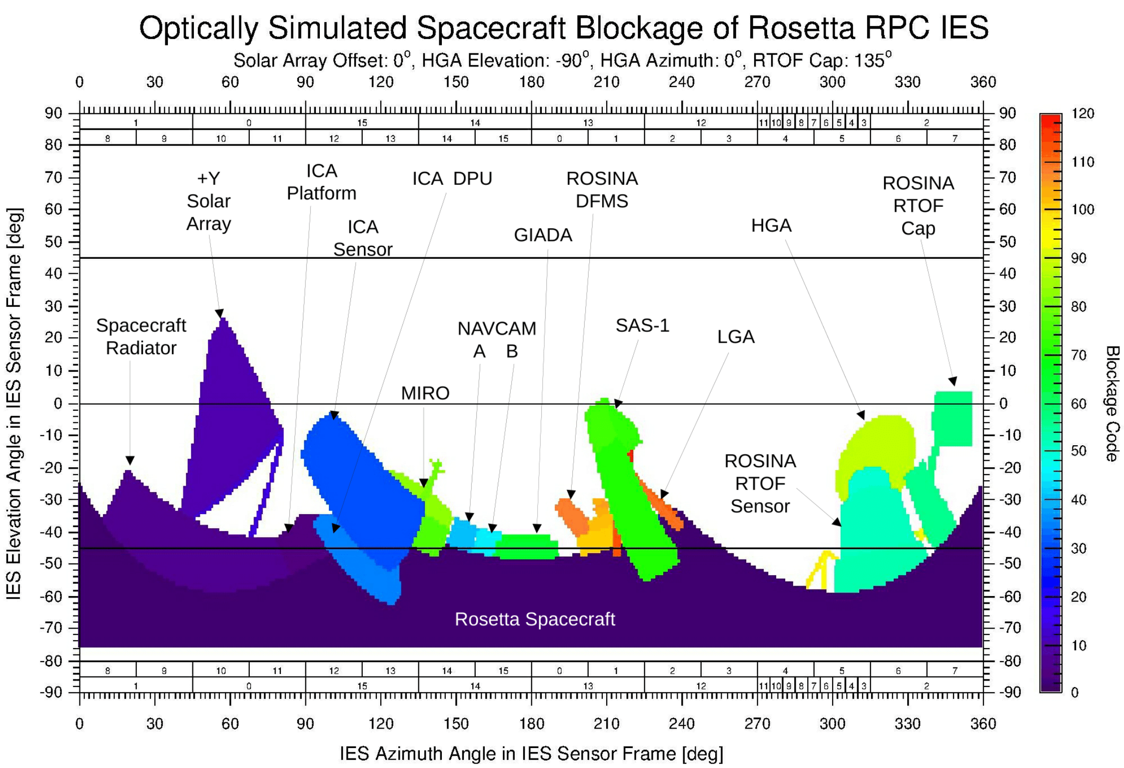
2.4.8 Ancillary Data Usage

Some ancillary data such as the position and velocity of the spacecraft at the start of the day are included in the label file for each day. Rosetta SPICE kernels and toolkits provided by the NAIF (Navigation and Ancillary Information Facility) may be used to generate higher fidelity position and pointing information.

2.5 Data Caveats

2.5.1 Blockage of Some Elevation Angle Bins

Several S/C structures and parts of other instruments block the IES FOV in portions of the most negative elevation angles. See the accompanying figure for an example. In particular, note that the positions of the solar arrays and the HGA in the IES FOV vary throughout the mission.



2.5.2 Geometric Factor

The documented IES geometric factor was obtained by combining results of ray tracing, flight calibration, and laboratory measurements.

2.5.3 Individual Anode (Azimuth) Characteristics

When counts from adjacent anodes are summed on board because of telemetry limitations, those anodes are given identical averaged values (sum/number of anodes).

2.5.3.1 Ions

Anodes 13 and 14 are often noisy so caution is recommended when using data from them.

The so-called "fine anodes" (3 - 11) are combined on board in most operating modes because of telemetry limitations. In those cases each of these 9 anodes are given identical values (the sum/9).

The data from individual fine anodes, when provided, suffer from crosstalk between these anodes as well as the two coarse anodes adjacent to the fine anodes.

A high noise rate is seen in anode 12 when the sun is incident between anodes 2 and 3. The suspected cause for this is a light leak. It is also seen in anode 13 when counts in 12 and 13 are combined.

2.5.3.2 Electrons

Occasionally the electron data exhibit a signal at several narrow energy ranges between 200-2000 eV, appearing as short dashes in spectrograms, as a result of interference from a neighboring instrument (ICA). The occurrences are indicated in the flag column.

Anode 11 became noisy shortly after launch and since 16 September 2007 data from that anode have not been downloaded. In 2014, anode 12 started exhibiting similar behavior and was removed from the data stream on 29 April 2015. In operating modes where data from two or more anodes are combined, if counts from anodes 11 or 12 were included prior to their removal and summed with other anodes, those anodes will include the noise.

2.5.4 Other caveats

Other caveats are included in the data files in the form of quality flags, with descriptions in the label files.

3. ARCHIVE FORMAT AND CONTENT

3.1 Format and Conventions

3.1.1 Deliveries and Archive Volume Format

The IES team submits the archive volumes to PSA electronically. After successful checks, reviews and ay updates, PSA transmits identical archives to PDS. PSA and PDS will be responsible for creating the physical volumes used for deep archiving.

3.1.2 Data Set ID Formation

RO-E/M/A/C/CAL/X/SS/D-RPCIES-x-phase-Vn.m

where:

RO	= INSTRUMENT_HOST_ID
E/M/A/C/CAL/X/SS/D	= TARGET_ID (Earth/Mars/Asteroid/Comet/Calibration/Checkout/Solar System/Dust)

RPCIES	= INSTRUMENT_ID
x	= {2,3,5} CODMAC data processing level numbers.
phase	= Mission phase abbreviation (GRND, LEOP, CVP, CR1, EAR1, etc)
n.m	= Version number

Within each data set TARGET_NAME and TARGET_TYPE are used to identify the current target. (Thus they will not stay the same within one data set, but data set id will.)

3.1.3 Data Directory Naming Convention

We use a year/month/day directory hierarchy. The directory structure is covered in more detail in section 3.4.3.

```
       DATA_SET_ROOT
             |
   +----+---+-------+---. . .
   |    |           |
 DATA DOCUMENT   CATALOG. . .
   |
 YYYY
  |  |
  MM MM
  |  |
  DD DD
```

3.1.4 File Naming Convention

For Level 2 data there are two IES data files generated per mode per day. For Level 3 data, six files are generated per day.:

```
Level 2 FILENAME:    RPCIESYYYYDDD_nnn_VV.EXT
Level 3 FILENAME:    RPCIESYYYYDDD_L3nnn_zzz_VV.EXT

where:

YYYY = Year
DDD  = Day of Year
nnn  = ELC (electron) or ION (ion)
zzz  = FLUX (flux), FXUN (uncertainty), or L2BG (background)
VV   = Archive product version
EXT  = LBL or TAB
```

3.2 Standards Used in Data Product Generation

3.2.1 PDS Standards

IES complies to PDS version 3, and we use version 3.6 of the PDS standard reference.

3.2.2 Time Standards

Time(UTC) in LBL files: yyyy-doyThh:mm:ss.sss
Time(UTC) in TAB files: yyyy-doyThh:mm:ss.sss
Spacecraft Clock (OBT) in LBL files: "1/nnnnnnnnnn"
Spacecraft Clock (OBT) in TAB files: nnnnnnnnnn

3.2.3 Reference Systems

IES field of view definitions, anode and elevation sizes, their orientations with respect to the spacecraft and frame definitions are described in the SPICE kernels defined and provided by NAIF. At the time of writing of this document, the filenames for the latest versions of these instrument kernel and frame kernel files were ROS_RPC_V17.TI and ROS_V25.TF respectively.

These kernels can be loaded and used to determine the position and attitude of the spacecraft, orientation of the IES instrument, look directions of anodes and elevations in any coordinate system at any given time. The reference frame internal to the instrument is called ROS_RPC_IES. This can be used as a reference when converting pointing information to and from other reference frames such as the Rosetta spacecraft, comet-centric or helio-centric frames.

Data Validation

Data will be scanned for internal consistency when decommutating to edited raw format. Before archiving, data are used internally by RPC scientists. All scientific analysis involving IES data are done using archive-formatted data products. To actually have the data used by scientists before delivery to archive is considered the best way of revealing problems and validating data, and this is the approach taken by IES.

After submission a peer review by PSA, PDS and the Rosetta archive team assesses the data set and documentation for compliance and scientific usability. Peer reviews are typically done for the initial submission and all subsequent format changes. Routine deliveries are merely checked for conformance to the standards put forth in this document.

3.3 Content

3.3.1 Volume Set

The IES archive are submitted electronically in volumes consistent with mission phases as defined by the Rosetta archiving team in consulation with PSA and PDS.

3.3.2 Data Set

Our naming convention for the data set follows the same principles as the DATA_SET_ID thus.

```
DATA_SET_NAME="ROSETTA-ORBITER E/M/A/C/CAL/X/SS/D RPCIES d PHASE
Vm.n"

where:

ROSETTA-ORBITER        = INSTRUMENT_HOST_NAME
E/M/A/C/CAL/X/SS/D     = TARGET_NAME (EARTH MARS ASTEROID COMET
                         CALIBRATION CHECKOUT SOLAR SYSTEM DUST)

RPCIES                 = INSTRUMENT_ID
d                      = CODMAC data processing level numbers 2,3
 or 5.
PHASE                  = Mission phase abbreviation (GRND, LEOP,
 CVP, CR1, EAR1, etc)
Vm.n                   = Version number
```

One data set is generated for each processing level for each phase. Multiple targets may be used for each data set and within each data set TARGET_ID will be used to identify the current target.

3.3.3 Directories

3.3.3.1 Root Directory

Table 2: Root Directory Contents

File Name	File Contents
AAREADME.TXT	This file completely describes the Volume organization and contents
VOLDESC.CAT	A description of the contents of this Volume in a PDS format readable by both humans and computers
CATALOG/	Catalog directory
DOCUMENT/	Document directory
INDEX/	Index directory
DATA/	Data directory
BROWSE/	Browse directory
CALIB/	Calibration data directory

3.3.3.2 Catalog Directory

Table 3: Catalog Directory Contents

File Name	File Contents
CATINFO.TXT	A description of the contents of this directory
DATASET.CAT	PDS Data Set catalog description of all the IES data files
INSTHOST.CAT	PDS instrument host (spacecraft) catalog description of the Rosetta orbiter spacecraft
INST.CAT	PDS instrument catalog description of the IES instrument
MISSION.CAT	PDS mission catalog description of the Rosetta mission
PERSON.CAT	PDS personnel catalog description of IES Team members and other persons involved with generation of IES Data Products
REF.CAT	IES-related references mentioned in other *.CAT files
SOFTWARE.CAT	Software catalog file

3.3.3.3 Index Directory

This directory contains the index files generated by the ESA S/W PVV.

3.3.3.4 Browse Directory and Browse Files

Spectrograms or other browse products may be introduced at a later date.

3.3.3.5 Document Directory

Table 4: Document Directory Contents	
File Name	**File Contents**
DOCINFO.TXT	A description of the contents of this directory and all subdirectories.
IES_EAICD/	Directory containing the IES EAICD document
IES_EAICD/IES_EAICD.DOC	The IES Experiment-Archive Interface Control Document as a MS Word doc
IES_EAICD/IES_EAICD.TXT	The IES Experiment-Archive Interface Control Document in plain text
IES_EAICD/IES_EAICD.LBL	A PDF detached label that describes IES_EAICD.HTM, IES_EAICD.ASC, and IES_EAICD.PDF

3.3.3.6 Data Directory

The data directory contains .TAB files that have the archive data in fixed width, comma separated columns corresponding to PDS table objects. Accompanying each .TAB file will be a label file (.LBL) containing metadata about the archive.

4. DETAILED INTERFACE SPECIFICATIONS

4.1 Structure and Organization Overview

See section 3.1.3 for general overview.

Now as defined in section 3.1.3 we have the following structure for the DATA directory.

```
          DATA_SET_ROOT
                |
   +----+---+-------+---. . .
   |    |           |
  DATA
   |
  YYYY
  |  |
  MM MM
  |  |
  DD DD
```

4.2 Data Sets, Definition and Content

IES data are archived in PDS table objects. Each line represents a set of electron or ion counts for the azimuth bin groups at a given time, energy, and elevation. The following columns will be first in each archive file:

Spacecraft Event Time (UTC)	This field contains the UTC time at the spacecraft at the beginning of the sample integration. This field has been generated from the spacecraft clock counter using the SPICE toolkit and appropriate leap seconds and spacecraft clock kernels. Time is provided in the standard PDS DOY format (i.e. 2005-125T00:00:00.215). All records from a single integration are assigned the same time. The amount of accumulation time is governed by the science mode. Details can be found in DOCUMENT/IES_MODES.PDF. A complete integration cycle requires the instrument to sweep through 16 elevation steps (or angles) for each of the 128 energy steps. Each elevation step takes 1/16th of an energy step to complete. During each accumulation interval, counts are acquired simultaneously from each of the 16 azimuths (or anodes).
Mode	Instrument mode, which determines the values used for the energy and elevation steps.
Energy Start Step	To fit within the data rate allocated to the instrument, counts acquired at discrete adjacent energy steps are summed together and telemetered. The number of energy steps that are summed together depends on the instrument mode. The ENERGY_START_STEP number corresponds to the lowest step number of that range.
Energy Stop Step	To fit within the data rate allocated to the instrument, counts

	acquired at discrete adjacent energy steps are summed together and telemetered. The number of energy steps that are summed together depends on the instrument mode. The ENERGY_STOP_STEP number corresponds to the highest step number of that range.
Angle Start Step	To fit within the data rate allocated to the instrument, counts acquired at discrete adjacent elevation steps (or angles) are summed together and telemetered. The number of elevation steps that are summed together depends on the instrument mode. The ANGLE_START_STEP number corresponds to the lowest step number of that range.
Angle Stop Step	To fit within the data rate allocated to the instrument, counts acquired at discrete adjacent elevation steps (or angles) are summed together and telemetered. The number of elevation steps that are summed together depends on the instrument mode. The ANGLE_STOP_STEP number corresponds to the highest step number of that range.

Following these columns is a series of azimuth columns. The value represents the number of electrons or ions observed in the azimuth bin (commonly referred to as “counts”) at the given time, energy, and elevation. These values are transmitted in groups of azimuth bins, which we expand by dividing the value by the number of azimuth bins in the group.

4.3 Data Product Design

4.3.1 Data Product Uncalibrated Design

Example of edited raw data detached label file (e.g. RPCIES20116274_ELC_V2.LBL):

```
PDS_VERSION_ID              = PDS3
DATA_SET_ID                 = "RO-C-RPCIES-2-ESC4-V1.0"
DATA_SET_NAME               = "
    ROSETTA-ORBITER 67P/CHURYUMOV-GERASIMENKO (1969 R1) RPCIES 2 ESC4
V1.0"
STANDARD_DATA_PRODUCT_ID    = "ELECTRON"
PRODUCT_ID                  = "RPCIES2016001_ELC_V2"
PRODUCT_TYPE                = "EDR"
PROCESSING_LEVEL_ID         = "2"
PRODUCT_CREATION_TIME       = 2017-02-08T14:56:09.825
PRODUCT_VERSION_ID          = "1.0"
LABEL_REVISION_NOTE         = "RELEASE VERSION 1.0"
INSTRUMENT_MODE_ID          = "N/A"
```

```
INSTRUMENT_MODE_DESC          = "N/A"
ROSETTA:PIPELINE_VERSION_ID   = "3.7"

RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 387
FILE_RECORDS                  = 169849
MD5_CHECKSUM                  = "ede133efc7f917df41e431d7563836d5"

START_TIME                    = 2016-01-01T00:03:08.891
STOP_TIME                     = 2016-01-01T23:56:44.919
SPACECRAFT_CLOCK_START_COUNT  = "1/410227307"
SPACECRAFT_CLOCK_STOP_COUNT   = "1/410313323"

MISSION_NAME                  = "INTERNATIONAL ROSETTA MISSION"
MISSION_ID                    = "ROSETTA"
MISSION_PHASE_NAME            = "COMET ESCORT 4"
TARGET_NAME                   = "67P/CHURYUMOV-GERASIMENKO 1 (1969 R1)"
TARGET_TYPE                   = "COMET"
INSTRUMENT_HOST_NAME          = "ROSETTA-ORBITER"
INSTRUMENT_HOST_ID            = "RO"
INSTRUMENT_ID                 = "RPCIES"
INSTRUMENT_NAME               = "
    ROSETTA PLASMA CONSORTIUM - ION AND ELECTRON SENSOR"
INSTRUMENT_TYPE               = "PLASMA INSTRUMENT"

COORDINATE_SYSTEM_ID          = "N/A"
COORDINATE_SYSTEM_NAME        = "N/A"
NOTE                          = "The values of the keywords
  SC_SUN_POSITION_VECTOR, SC_TARGET_POSITION_VECTOR,
  SC_TARGET_VELOCITY_VECTOR are related to the Comet-centered Solar
Orbital
```

```
  frame. The values of SUB_SPACECRAFT_LATITUDE and SUB_SPACECRAFT_LONGITUDE
  refer to the Cheops reference frame. All values are computed for the time
  t=START_TIME. Distances are given in <km>, velocities in <km/s>, and
  angles in <deg>.
  Unit for SC_SUN_POSITION_VECTOR is km
  Unit for SC_TARGET_POSITION_VECTOR is km
  Unit for SC_TARGET_VELOCITY_VECTOR is km/s
  Unit for SPACECRAFT_ALTITUDE is km"

PRODUCER_ID                  = "RPC_IES_TEAM"
PRODUCER_FULL_NAME           = "BRAD TRANTHAM"
PRODUCER_INSTITUTION_NAME    = "SOUTHWEST RESEARCH INSTITUTE, SAN ANTONIO"
DATA_QUALITY_ID              = "0"
DATA_QUALITY_DESC            = "Data quality not assessed"

SC_SUN_POSITION_VECTOR       =
    (2.653E8, -1.142E8, -8.903E7)

SC_TARGET_POSITION_VECTOR    =
    (1.257E1, -2.604E1, 7.47E1)

SC_TARGET_VELOCITY_VECTOR    =
    (1.702E-4, 2.861E-4, 1.253E-4)

SPACECRAFT_ALTITUDE          = 7.834E1

SUB_SPACECRAFT_LATITUDE      = 3.68E1
SUB_SPACECRAFT_LONGITUDE     = 1.435E2

DESCRIPTION                  = "
```

```
    This file contains IES raw electron sensor counts acquired during
    the Comet Escort 4 phase between 2016-01-01T00:03:08.891 and
    2016-01-01T23:56:44.919."

^HEADER                      = ("RPCIES2016001_ELC_V2.TAB", 1)
^TABLE                       = ("RPCIES2016001_ELC_V2.TAB", 2)
OBJECT                       = HEADER
  HEADER_TYPE                = "TEXT"
  INTERCHANGE_FORMAT         = ASCII
  BYTES                      = 387
  RECORDS                    = 1
  DESCRIPTION                  = "Row of comma delimited, quoted column
names"
END_OBJECT                   = HEADER

OBJECT                       = TABLE
  INTERCHANGE_FORMAT         = ASCII
  ROWS                       = 169848
  COLUMNS                    = 23
  ROW_BYTES                  = 387
  DESCRIPTION                = "
    Data dimensions (time x energy x elevation x azimuth) are
337x128x16x16.
    Sometimes anode data are combined on board in certain operating
modes
    because of telemetry limitations. In those cases each of the
anodes
    is given identical values (sum/number of anodes)."

  OBJECT                     = COLUMN
    NAME                     = "SPACECRAFT EVENT TIME (UTC)"
    COLUMN_NUMBER            = 1
    DATA_TYPE                = TIME
```

```
    START_BYTE                = 1
    BYTES                     = 21
    FORMAT                    = "A21"
    DESCRIPTION               = "
      This field contains the UTC time at the spacecraft at the beginning
      of the sample integration. This field has been generated from
      the spacecraft clock counter using the SPICE toolkit and appropriate
      leap seconds and spacecraft clock kernels. Time is provided in the
      standard PDS DOY format (i.e. 2005-125T00:00:00.215).
      All records from a single integration are assigned the same time.
      The amount of accumulation time is governed by the science mode.
      Details can be found in DOCUMENT/IES_MODES.PDF. A complete integration
      cycle requires the instrument to sweep through 16 elevation steps
      (or angles) for each of the 128 energy steps. Each elevation
      step takes 1/16th of an energy step to complete.
      During each accumulation interval, counts are acquired simultaneously
      from each of the 16 azimuths (or anodes)."
  END_OBJECT                  = COLUMN

  OBJECT                      = COLUMN
    NAME                      = "MODE"
    COLUMN_NUMBER             = 2
    START_BYTE                = 23
    BYTES                     = 11
    FORMAT                    = "A11"
    DATA_TYPE                 = CHARACTER
    DESCRIPTION               = "
```

```
    Instrument mode, which determines the values used for the energy
    and elevation steps."
END_OBJECT                  = COLUMN

OBJECT                      = COLUMN
  NAME                      = "ENERGY_START_STEP"
  COLUMN_NUMBER             = 3
  START_BYTE                = 35
  BYTES                     = 16
  DATA_TYPE                 = ASCII_INTEGER
  FORMAT                    = "I16"
  DESCRIPTION               = "
    To fit within the data rate allocated to the instrument,
    counts acquired at discrete adjacent energy steps are summed
    together and telemetered. The number of energy steps that are
    summed together depends on the instrument mode.
    The ENERGY_START_STEP number corresponds to the lowest step
    number of that range."
END_OBJECT                  = COLUMN

OBJECT                      = COLUMN
  NAME                      = "ENERGY_STOP_STEP"
  COLUMN_NUMBER             = 4
  START_BYTE                = 52
  BYTES                     = 16
  DATA_TYPE                 = ASCII_INTEGER
  FORMAT                    = "I16"
  DESCRIPTION               = "
    To fit within the data rate allocated to the instrument,
    counts acquired at discrete adjacent energy steps are summed
    together and telemetered. The number of energy steps that are
    summed together depends on the instrument mode.
```

```
      The ENERGY_STOP_STEP number corresponds to the highest step
      number of that range."
  END_OBJECT                   = COLUMN

  OBJECT                       = COLUMN
    NAME                       = "ANGLE_START_STEP"
    COLUMN_NUMBER              = 5
    START_BYTE                 = 69
    BYTES                      = 16
    DATA_TYPE                  = ASCII_INTEGER
    FORMAT                     = "I16"
    DESCRIPTION                = "
      To fit within the data rate allocated to the instrument,
      counts acquired at discrete adjacent elevation steps (or angles)
      are summed together and telemetered. The number of elevation
steps
      that are summed together depends on the instrument mode.
      The ANGLE_START_STEP number corresponds to the lowest step
      number of that range."

  END_OBJECT                   = COLUMN

  OBJECT                       = COLUMN
    NAME                       = "ANGLE_STOP_STEP"
    COLUMN_NUMBER              = 6
    START_BYTE                 = 86
    BYTES                      = 16
    DATA_TYPE                  = ASCII_INTEGER
    FORMAT                     = "I16"
    DESCRIPTION                = "
      To fit within the data rate allocated to the instrument,
      counts acquired at discrete adjacent elevation steps (or angles)
```

```
      are summed together and telemetered. The number of elevation
steps
      that are summed together depends on the instrument mode.
      The ANGLE_STOP_STEP number corresponds to the highest step
      number of that range."

  END_OBJECT                   = COLUMN

  OBJECT                       = COLUMN
    NAME                       = "AZIMUTH 0 COUNTS"
    COLUMN_NUMBER              = 7
    START_BYTE                 = 103
    BYTES                      = 16
    DATA_TYPE                  = ASCII_REAL
    FORMAT                     = "F16.4"
    MISSING_CONSTANT           = "-1.000"
    DESCRIPTION                = "
      This field contains electron counts observed in
      azimuth bin 0 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                   = COLUMN
  OBJECT                       = COLUMN
    NAME                       = "AZIMUTH 1 COUNTS"
    COLUMN_NUMBER              = 8
    START_BYTE                 = 120
    BYTES                      = 16
    DATA_TYPE                  = ASCII_REAL
    FORMAT                     = "F16.4"
    MISSING_CONSTANT           = "-1.000"
    DESCRIPTION                = "
      This field contains electron counts observed in
```

```
     azimuth bin 1 divided by the size of the azimuth
     bin grouping. A fill value of -1 is used when data is
     not available for this bin."
 END_OBJECT                  = COLUMN
 OBJECT                      = COLUMN
   NAME                      = "AZIMUTH 2 COUNTS"
   COLUMN_NUMBER             = 9
   START_BYTE                = 137
   BYTES                     = 16
   DATA_TYPE                 = ASCII_REAL
   FORMAT                    = "F16.4"
   MISSING_CONSTANT          = "-1.000"
   DESCRIPTION               = "
     This field contains electron counts observed in
     azimuth bin 2 divided by the size of the azimuth
     bin grouping. A fill value of -1 is used when data is
     not available for this bin."
 END_OBJECT                  = COLUMN
 OBJECT                      = COLUMN
   NAME                      = "AZIMUTH 3 COUNTS"
   COLUMN_NUMBER             = 10
   START_BYTE                = 154
   BYTES                     = 16
   DATA_TYPE                 = ASCII_REAL
   FORMAT                    = "F16.4"
   MISSING_CONSTANT          = "-1.000"
   DESCRIPTION               = "
     This field contains electron counts observed in
     azimuth bin 3 divided by the size of the azimuth
     bin grouping. A fill value of -1 is used when data is
     not available for this bin."
 END_OBJECT                  = COLUMN
```

```
OBJECT                    = COLUMN
  NAME                    = "AZIMUTH 4 COUNTS"
  COLUMN_NUMBER           = 11
  START_BYTE              = 171
  BYTES                   = 16
  DATA_TYPE               = ASCII_REAL
  FORMAT                  = "F16.4"
  MISSING_CONSTANT        = "-1.000"
  DESCRIPTION             = "
    This field contains electron counts observed in
    azimuth bin 4 divided by the size of the azimuth
    bin grouping. A fill value of -1 is used when data is
    not available for this bin."
END_OBJECT                = COLUMN
OBJECT                    = COLUMN
  NAME                    = "AZIMUTH 5 COUNTS"
  COLUMN_NUMBER           = 12
  START_BYTE              = 188
  BYTES                   = 16
  DATA_TYPE               = ASCII_REAL
  FORMAT                  = "F16.4"
  MISSING_CONSTANT        = "-1.000"
  DESCRIPTION             = "
    This field contains electron counts observed in
    azimuth bin 5 divided by the size of the azimuth
    bin grouping. A fill value of -1 is used when data is
    not available for this bin."
END_OBJECT                = COLUMN
OBJECT                    = COLUMN
  NAME                    = "AZIMUTH 6 COUNTS"
  COLUMN_NUMBER           = 13
  START_BYTE              = 205
```

```
    BYTES                    = 16
    DATA_TYPE                = ASCII_REAL
    FORMAT                   = "F16.4"
    MISSING_CONSTANT         = "-1.000"
    DESCRIPTION              = "
      This field contains electron counts observed in
      azimuth bin 6 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                 = COLUMN
  OBJECT                     = COLUMN
    NAME                     = "AZIMUTH 7 COUNTS"
    COLUMN_NUMBER            = 14
    START_BYTE               = 222
    BYTES                    = 16
    DATA_TYPE                = ASCII_REAL
    FORMAT                   = "F16.4"
    MISSING_CONSTANT         = "-1.000"
    DESCRIPTION              = "
      This field contains electron counts observed in
      azimuth bin 7 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                 = COLUMN
  OBJECT                     = COLUMN
    NAME                     = "AZIMUTH 8 COUNTS"
    COLUMN_NUMBER            = 15
    START_BYTE               = 239
    BYTES                    = 16
    DATA_TYPE                = ASCII_REAL
    FORMAT                   = "F16.4"
    MISSING_CONSTANT         = "-1.000"
```

```
    DESCRIPTION              = "
      This field contains electron counts observed in
      azimuth bin 8 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                 = COLUMN
  OBJECT                     = COLUMN
    NAME                     = "AZIMUTH 9 COUNTS"
    COLUMN_NUMBER            = 16
    START_BYTE               = 256
    BYTES                    = 16
    DATA_TYPE                = ASCII_REAL
    FORMAT                   = "F16.4"
    MISSING_CONSTANT         = "-1.000"
    DESCRIPTION              = "
      This field contains electron counts observed in
      azimuth bin 9 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                 = COLUMN
  OBJECT                     = COLUMN
    NAME                     = "AZIMUTH 10 COUNTS"
    COLUMN_NUMBER            = 17
    START_BYTE               = 273
    BYTES                    = 16
    DATA_TYPE                = ASCII_REAL
    FORMAT                   = "F16.4"
    MISSING_CONSTANT         = "-1.000"
    DESCRIPTION              = "
      This field contains electron counts observed in
      azimuth bin 10 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
```

```
    not available for this bin."
  END_OBJECT                  = COLUMN
  OBJECT                      = COLUMN
    NAME                      = "AZIMUTH 11 COUNTS"
    COLUMN_NUMBER             = 18
    START_BYTE                = 290
    BYTES                     = 16
    DATA_TYPE                 = ASCII_REAL
    FORMAT                    = "F16.4"
    MISSING_CONSTANT          = "-1.000"
    DESCRIPTION               = "
      This field contains electron counts observed in
      azimuth bin 11 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                  = COLUMN
  OBJECT                      = COLUMN
    NAME                      = "AZIMUTH 12 COUNTS"
    COLUMN_NUMBER             = 19
    START_BYTE                = 307
    BYTES                     = 16
    DATA_TYPE                 = ASCII_REAL
    FORMAT                    = "F16.4"
    MISSING_CONSTANT          = "-1.000"
    DESCRIPTION               = "
      This field contains electron counts observed in
      azimuth bin 12 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                  = COLUMN
  OBJECT                      = COLUMN
    NAME                      = "AZIMUTH 13 COUNTS"
```

```
    COLUMN_NUMBER            = 20
    START_BYTE               = 324
    BYTES                    = 16
    DATA_TYPE                = ASCII_REAL
    FORMAT                   = "F16.4"
    MISSING_CONSTANT         = "-1.000"
    DESCRIPTION              = "
      This field contains electron counts observed in
      azimuth bin 13 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                 = COLUMN
  OBJECT                     = COLUMN
    NAME                     = "AZIMUTH 14 COUNTS"
    COLUMN_NUMBER            = 21
    START_BYTE               = 341
    BYTES                    = 16
    DATA_TYPE                = ASCII_REAL
    FORMAT                   = "F16.4"
    MISSING_CONSTANT         = "-1.000"
    DESCRIPTION              = "
      This field contains electron counts observed in
      azimuth bin 14 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                 = COLUMN
  OBJECT                     = COLUMN
    NAME                     = "AZIMUTH 15 COUNTS"
    COLUMN_NUMBER            = 22
    START_BYTE               = 358
    BYTES                    = 16
    DATA_TYPE                = ASCII_REAL
```

```
    FORMAT                    = "F16.4"
    MISSING_CONSTANT          = "-1.000"
    DESCRIPTION               = "
      This field contains electron counts observed in
      azimuth bin 15 divided by the size of the azimuth
      bin grouping. A fill value of -1 is used when data is
      not available for this bin."
  END_OBJECT                  = COLUMN
  OBJECT                      = COLUMN
    NAME                      = "QUALITY FLAGS"
    COLUMN_NUMBER             = 23
    START_BYTE                = 375
    DATA_TYPE                 = CHARACTER
    BYTES                     = 11
    FORMAT                    = "A11"
    DESCRIPTION               = "
     These flags describe the quality of the data.
     The quality is coded in a 8 byte string. Each character can have
     the following values:
      VALUE:    MEANING:
        x       property described by flag is still unknown
        0       no disturbance, good quality
        1..9    specific disturbance/problems, see below

     Description of the specific flags:

     FLAG-STRING FLAG DESCRIPTION
         FLAG-STRING FLAG DESCRIPTION
         54321
         ::::--------- 1 MCP VOLTAGE
         ::::            0 = MCP voltage at 2500 V (Nominal)
         ::::            1 = MCP voltage above 2500 V (Gain Test)
```

```
         ::::             2 = MCP voltage at 0 (Low Voltage Mode)
         ::::
         ::::---------- 2 SUN POINTING
         :::              0 = Sun is in field of view and not blocked
         :::                  1 = Sun is in field of view but may be
blocked
         :::              2 = Sun is out of field of view
         :::
         :::-----------  3  INTERFERENCE  FROM  ION  COMPOSITION  ANALYZER
INSTRUMENT
         ::               0 = No interference
         ::               1 = Interference may be observed
         ::
         ::------------ 4 TRANSITION CYCLE
         :                0 = Not a transition cycle
         :                1 = Transition cycle
         :
         :------------- 5 ENHANCED COUNTS DUE TO PENETRATING RADIATION
                          0  =  No  enhanced  counts  due  to  penetrating
radiation
                          1   =   Enhanced   counts   due   to   penetrating
radiation"
  END_OBJECT                 = COLUMN
END_OBJECT                   = TABLE

END
```