ROSETTA-NAVCAM

to

Planetary Science Archive Interface Control Document

Prepared By: ______________________________

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Table 1: Distribution List.

Recipient	Organisation	Contact
Rosetta SGS	ESA/ESAC	
PSA	ESA/ESAC	

Table 2: Document Change Log.

Date of Update	Update to Document	Version	Name
2010 Oct 20	Creation of document	V 1.0	Colin Archibald
2012 Jun 26	Corrections	V 2.0	Maud Barthelemy
2013 Jan 08	Corrections - added Sections 3.1, 4.2.1, 4.2.2, 4.2.3	V 3.0	Bernhard Geiger
2013 Aug 30	Corrections in Sections 3.2, 4.1.2	V 3.1	Bernhard Geiger
2015 Feb 06	Major revision - authorship changed - description of the comet phase datasets	V 4.0	Bernhard Geiger
2015 Sep 28	Minor revision - included equations for geometric calibration, factor between gain levels, missing temperature value flag; clarifications on the content of label keywords and comet reference system	V 4.1	Bernhard Geiger
2015 Dec 14	Minor revision - updated details of reference RD7; updated the mission phase table; added comment on effective focal length; mentioned scheduling of context images by SGS	V 4.2	Bernhard Geiger
2016 Feb 03	Minor revision - updated contact addresses and mission phase tables	V 4.3	Bernhard Geiger
2016 Mar 08	Minor revision after archive review - included information on boresight directions and gain level; FITS versions are now in a separate folder; swapped the order of sub-sections in Section 3.2; mentioned proprietary rights for manufacturer reference documents	V 5.0	Bernhard Geiger
2016 Mar 31	Minor revision - corrected name of EXTRAS directory	V 5.1	Bernhard Geiger
2016 Jul 18	Minor revision - updated mission phase table	V 5.2	Bernhard Geiger
2016 Sep 22	Minor revision - browse images are now of original size	V 5.3	Bernhard Geiger

2016 Oct 28	Revision for dataset version V1.1 - obsolete Section 7 removed after adaptation of label content for cruise phase datasets; completed entries in Table 7; updated statements in Section 3.2.1; mentioned V1.1 in Sections 4.1.4 and 4.2.1; updated text in Section 4.2.5 and Table 13 to consider generic targets; added new types and revised text in Section 4.4; changed name of target vector related FITS keywords in Table 15 and added text in note	V 5.4	Bernhard Geiger
2017 Dec 19	Minor revision after archive review - added clarifications and further information on line/column number convention, window and boresight coordinates in Sections 4.2 and 6.2, context images in Section 4.4, and missing data files in Section 5.3	V 5.5	Bernhard Geiger
2019 Mar 29	Revision for level 3 datasets - added reference documents RD8 and RD9; updated text and added level 3 specific information in Sections 3.2.2, 4.1.2, 4.3, 5.3, 6.1, and 6.2; minor changes in other sections	V 6.0	Bernhard Geiger
2019 Jul 16	Minor revision after archive review - file names in Section 5.3; dataset level information in Sections 3.2.2, 4.1.1, and 4.1.2	V6.1	Bernhard Geiger
2020 Jun 01	Minor revision - updated label file example in Section 6.1	V6.2	Bernhard Geiger
2020 Dec 09	Minor revision - updated RD8 and PRODUCT_CREATION_TIME in the label file example of Section 6.1	V6.3	Bernhard Geiger

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List of Acronyms

A/D Analogue-to-Digital

AIU Avionics Interface Unit

AOCS Attitude and Orbit Control System

APID Application Process Identifier

CAM-BAF Camera Baffle

CAM-EU Camera Electronic Unit

CAM-OH Camera Optical Head

CCD Charge Coupled Device

CODMAC Committee On Data Management, Archiving, and Computation

DDS Data Distribution System

DMS Data Management System

DNA Defocused imaging with No Attenuation

EAICD Experiment to Archive Interface Control Document

ESA European Space Agency

ESAC European Space Astronomy Centre

ESOC European Space Operations Centre

EU Electronic Unit

FA Focused imaging with Attenuation

FITS Flexible Image Transport System

FNA Focused imaging with No Attenuation

FOV Field of View

ftp file transfer protocol

HK Housekeeping

JPEG Joint Photographic Experts Group

NASA National Aeronautics and Space Administration

NavCam Navigation Camera

OBT On-Board Time

OH Optical Head

PDS Planetary Data System

PSA Planetary Science Archive

PSA-DH Planetary Science Archive Data Handler

RMOC Rosetta Mission Operations Centre

RO Rosetta Orbiter

S/C Spacecraft

SCIOPS Science Operations Department

SGS Science Ground Segment

SSMM Solid State Mass Memory

TC Telecommand

TM Telemetry

UTC Coordinated Universal Time

WCS World Coordinate System (FITS)

1 Introduction

1.1 Purpose and Scope

This Experiment to Archive Interface Control Document (EAICD) has two main purposes. Firstly, it gives users of the Navigation Camera (NavCam) instrument data a detailed description of the product and how it was generated, including data sources and destinations. Secondly, it acts as an interface between the NavCam data producers and the data archiving authority. One point of note is that there are two identical NavCams installed on the Rosetta spacecraft, however, for the purposes of this document the singular is generally referred to when discussing the NavCams.

1.2 Archiving Authorities

The Planetary Data System (PDS) standard is used as the archiving standard by:

- the National Aeronautics and Space Administration (NASA) for U.S. Planetary Missions, implemented by PDS;
- the European Space Agency (ESA) for European Planetary Missions, implemented by the Science Operations Department (SCIOPS) of ESA.

ESA implements an on-line science archive, the Planetary Science Archive (PSA), for several reasons:

- to support and ease data ingestion;
- to offer additional services to the scientific user community and science operations teams, such as, e.g.:
  1. queries that allow searches across instruments, missions and scientific disciplines;
  2. several data delivery options, such as:
     - direct download of data products, linked files and datasets;
     - file transfer protocol (ftp) download of data products, linked files and datasets.

The PSA aims for on-line 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 NavCam instrument on Rosetta from the Spacecraft (S/C) until the insertion into the PSA by ESA. It includes information on how data were processed, formatted, labelled and uniquely identified; along with discussing the general naming schemes for NavCam data volumes, datasets, data and label files. The standards used to generate such products are explained and the design of the dataset structure and data products are also given within this document.

1.4 Intended Readership

The staff of the archiving authority (PSA, PDS), members of the Rosetta Science Ground Segment and the instrument team community as well as any potential user of the NavCam data.

1.5 Applicable Documents

- AD1: Rosetta Archive Generation, Validation and Transfer Plan, January 10, 2006, RO-EST-PL-5011
- AD2: Rosetta Archive Conventions, Issue 7, Rev. 6, March 21, 2014, RO-EST-TN-3372

1.6 Reference Documents

- RD1: Rosetta Navigation Camera User's Manual, January 2002, RO-GAL-MA-2008
- RD2: Rosetta Navigation Camera Design Description, January 2002, RO-GAL-RP-2007
- RD3: Navigation Camera TM/TC and Software ICD, November 2001, RO-MMT-IF-2007
- RD4: Rosetta SPICE Frame Kernel, ROS_V25.TF
- RD5: Rosetta Data Delivery Interface Document, Appendix H, November 2013, RO-ESC-IF-5003
- RD6: Scholten F., Preusker F., Jorda L., and Hviid S., Reference Frames and Mapping Schemes of Comet 67P/C-G, RO-C-MULTI-5-67P-SHAPE-V1.0:CHEOPS_REF_FRAME_V1, ESA Planetary Science Archive and NASA Planetary Data System, 2015.
- RD7: Preusker F., et al., Shape model, reference system definition, and cartographic mapping standards for comet 67P/Churyumov-Gerasimenko - Stereo-photogrammetric analysis of Rosetta/OSIRIS image data, 2015, Astronomy & Astrophysics, 583, A33. https://dx.doi.org/10.1051/0004-6361/201526349
- RD8: Geiger B., Andrés R., and Statella T., Radiometric Calibration of the Rosetta Navigation Camera, 2020, Journal of Astronomical Instrumentation, in revision.
- RD9: Statella T. and Geiger B., Cross-calibration of the Rosetta Navigation Camera based on images of the 67P comet nucleus, 2017, Monthly Notices of the Royal Astronomical Society, 469, S285-S294. https://dx.doi.org/10.1093/mnras/stx1589

Note: The reference documents RD1, RD2, and RD3 contain proprietary information by the instrument manufacturer and are therefore not publicly available.

1.7 Contact Names and Addresses

Table 3: List of contacts for the NavCam instrument archive.

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2 Overview of Instrument Design

In order to fully satisfy the requirements and objectives regarding navigation and attitude control, Galileo Avionica developed a mission-specific Navigation Camera for Rosetta by building on the heritage of existing models. Table 4 provides an overview of some of the physical and operational parameters of the NavCam (from [RD2]).

Table 4: Overview of NavCam properties.

Parameter	**Value**	**Comment**
Mass CAM-OH	6.050 kg	Camera Optical Head
Mass CAM-EU	2.700 kg	Camera Electronic Unit
Mass CAM-BAF	1.408 kg	Camera Baffle
Total Mass	10.158 kg	
Total Power	16.8 W	
Field of View	$5° \times 5°$	
Sensor Type	CCD	CCD47-20 by e2v
Number of Pixels	1024×1024	
Dynamic Range	12 bits	Saturation at Digital Number 4095
Focal Length	152.5 mm	Effective Focal Length
Pixel Size	13 μm	
Pixel Angular Size	17.6 arcsec	
Aperture	70 mm 30 mm	Non-Attenuated Modes Attenuated Mode
F/Number	f/2.2 f/5.1	Non-Attenuated Modes Attenuated Mode
Limit Magnitude	$M_v = 11$	Exposure time 5 s, SNR ≥ 5
Saturation Magnitude	$M_v = 1.6$ $M_v = 0.8$	Whole spectral range, G2 Class; exposure time = 10ms
Integration Time	10 ms 30 s	Minimum, Maximum
Bias error (1 σ)	0.2 pixels	$M_v = 11$, exposure time = 5 s, Defocused mode
NEA (1 σ)	0.1 pixels	$M_v = 11$, exposure time = 5 s, Defocused mode
Commanded Window Size	20×20 1024×1024	Minimum pixel array Maximum pixel array
CCD Operative Temp. Range	-50°C +50°C	Minimum Maximum
CCD Performance Temp. Range	-25°C 0°C	Minimum Maximum

2.1 Architecture and Configurations

The Rosetta NavCam consists of a Camera Optical Head (CAM-OH), a Camera Electronic Unit (CAM-EU) and a Camera Baffle (CAM-BAF). Information given in this section is mainly extracted from the User's Manual [RD1] and the Design Description Document [RD2]. In general the Rosetta NavCam camera has three major functions:

1. Acquire navigation images of asteroids and the comet nucleus (Imaging mode, also performed in Asteroid Tracking Mode).
2. Track one extended object, during asteroid fly-by and comet approach phases (in Asteroid Tracking Mode).
3. Track point-like targets (in Point Target Tracking Mode).

2.1.1 Camera Optical Head

The Camera Optical Head for the Rosetta NavCam contains the optical system, the CCD detector and the electronics required to operate the CCD. It also supports the dust cover and attenuation mechanism in front of the optics. Figure 1 depicts three possible configurations of the optical system with exchangeable first element.

- DNA mode. Defocused not attenuated. The first element is a plano-parallel window. The aperture is 70mm. This mode is used for determining the position of point sources with improved centroiding. During the comet escort phase this mode is also used by default as a dust cover when the camera is not operated.
  ROSETTA:CAM_COVER_POSITION = DEFOC_NATT
- FA mode. Focused attenuated. The first lens is a quasi-plano parallel window, i.e. a lens with a very low converging power, in order to focus the image on the CCD. One face has an attenuation coating in order to decrease the transmission. The aperture is 30mm. This mode is used for imaging and navigation close to the extended comet nucleus.
  ROSETTA:CAM_COVER_POSITION = FOC_ATT
- FNA mode. Focused not attenuated. The first lens is a quasi-plano parallel window with an aperture of 70mm. The image is focused on the CCD and there is no attenuation coating.
  ROSETTA:CAM_COVER_POSITION = FOC_NATT.

For each acquired image the mission specific keyword ROSETTA:CAM_COVER_POSITION records the applicable cover position in the meta-information of the data product files (see Table 14). The effects of the reduced aperture and the attenuation coating combined result in a reduction of the transmission by a factor of ~580 for the attenuated mode. For the defocused mode the point spread function is broader. For a point source located in the centre of a pixel

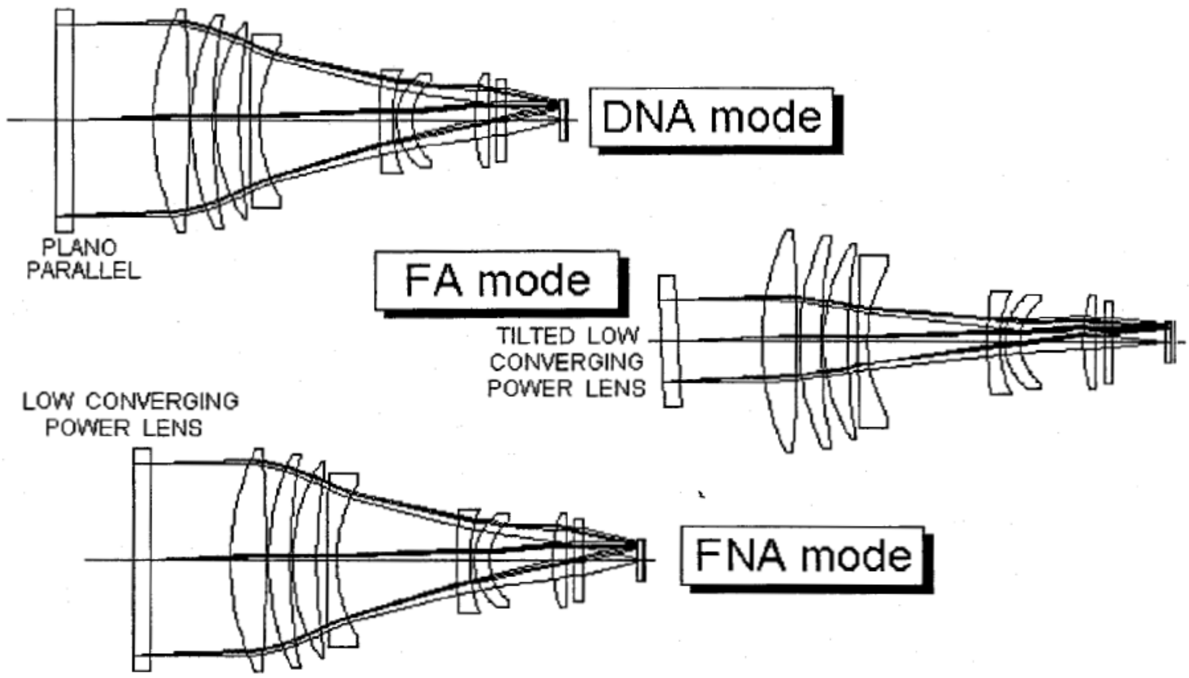

Figure 1: Optical system of the NavCam with exchangeable first element. The lenses are made of radiation resistant glasses with high transmission in the visible wavelength range (LAK9 G15 and SF6 G05 produced by Schott) [RD2].

approximately 50-55% of the signal are counted in the respective pixel, whereas this fraction ranges between 65 and 70% for the focused modes.
The CCD detector is a front-illuminated frame transfer device with a broad spectral sensitivity in the visible range. Two different values of the gain can be selected when commanding the camera.

1. High Gain – 10 electrons per Digital Number. Increases the grey signal level resolution when faint targets are imaged. In this case the A/D Converter saturates (at 12 bits) before saturation of the CCD is reached.
   ROSETTA:CAM_GAIN = HIGH

2. Low Gain – 17 electrons per Digital Number. The A/D Converter saturates at the same time as the CCD and so the full dynamic range can be used.
   ROSETTA:CAM_GAIN = LOW

The relative amplification factor between high and low gain is approximately 1.7. The chosen gain settings are documented in the mission specific keyword ROSETTA:CAM_GAIN of the product files (see Table 14).

2.1.2 Camera Electronic Unit

The Camera Electronic Unit contains the digital electronics and interfaces for data transfer with the Avionics Interface Unit (AIU) and the Solid State Mass Memory (SSMM). Another major function of this module is to provide the programmable constant-current driver for both the heater in the optical head and the stepper motor that actuates the attenuation cover mechanism of the NavCam.

2.1.3 Camera Baffle

The Camera Baffle provides protection against stray light produced by the Sun and reflected from planetary bodies and the satellite. This level of protection allows the tracking of faint objects. The baffle is mechanically supported by the S/C structure so as to avoid mechanical stress of the optical head. This is done owing to the required high pointing stability of the camera boresight in order to achieve the desired accuracy.

2.2 Operating Modes

The following series of operating modes are available in order to exploit the capabilities of the NavCam:

- Off Mode.
- Initialisation Mode.
- Stand-by Mode.
- Imaging Mode. In this mode the instrument operates as a standard camera in order to acquire images of star-fields or extended objects in the field of view such as the comet nucleus during the escort phase.
  INSTRUMENT_MODE_ID = "IMAGING"
- Point Target Tracking Mode. In this mode the NavCam can track simultaneously up to five point-like objects in the field of view.
- Asteroid (Extended Object) Tracking Mode. In this mode the NavCam can detect and track an extended object in the field of view. Optionally information on the position of this object can be fed into the autonomous attitude control system of the spacecraft. (This was done during the asteroid fly-bys.) In the Asteroid Tracking Mode images can also be acquired and downlinked in the same way as in the Imaging Mode.
  INSTRUMENT_MODE_ID = "ASTEROID TRACKING"
- Self Test Mode.

Image data can be generated and downlinked to ground in the Imaging and Asteroid (Extended Object) Tracking modes. In the archived datasets, the used mode is indicated by the INSTRUMENT_MODE_ID keyword of the label files as indicated above (see also Table 13).

3 Data Handling Process and Product Generation

The NavCam data are primarily used by the Flight Dynamics Team of the Rosetta Mission Operations Centre (RMOC) located at ESOC in Darmstadt, Germany. The images acquired with this camera are essential for determining the spacecraft position with respect to the comet nucleus and hence for safely navigating Rosetta. In addition, the images are also processed from the raw telemetry data at the Rosetta Science Ground Segment (SGS) based at ESAC near Madrid, Spain. The data are made available to the Rosetta instrument team community shortly after acquisition in order to support analysis and interpretation of their scientific data. Later, datasets of the product files are prepared for public release via the Planetary Science Archive (PSA).

3.1 Telemetry Data

For generating the product files the following telemetry data are processed:

- Science Data Report: TM APID 460 (CAM1) and 476 (CAM2), Type 20, Subtype 13. This set of telemetry data contains images as well as a number of meta data parameters. The latter are included in the label files of the generated data products.
- Housekeeping and Health-Check Report: TM APID 452 (CAM1) and 468 (CAM2), Type 3, Subtype 25. From the set of available housekeeping parameters only the CCD temperature and the optics temperature are extracted and included in the label files of the generated data products.

3.2 Data Product Levels

Table 5 summarises the definition of data product levels according to both PSA and CODMAC (Committee On Data Management, Archiving, and Computation).

3.2.1 Uncalibrated Data

Uncalibrated data, i.e. products at CODMAC level 2, were released for the entire cruise phase including images from the Earth and Mars swing-bys as well as distant (unresolved) navigation images of the visited asteroids 2878 Steins and 21 Lutetia. During the years 2015 and 2016 the images acquired after hibernation exit in the comet approach and escort phases were successively archived and made available. The uncalibrated data products consist of image files with extensive meta-information. For each image pixel the original unaltered digital number values are given as read out from the CCD.

Table 5: Data Processing Levels.

PSA	CODMAC	Description
1a	1	Raw telemetry packet data that have been separated by instrument. This is the level which is distributed by the DDS (ESOC).
1b	2	Level 1a data that have been sorted by instrument data types and instrument modes. Data are in scientifically useful form, e.g. as images. These data are still uncalibrated.
2	3	Level 1b data with calibration and corrections applied to yield data in scientific units.
3	5	Higher level data products developed for specific scientific investigations.

3.2.2 Radiometrically Calibrated Data

Radiometrically calibrated data, i.e. products at CODMAC level 3, were generated after the end of operations of the Rosetta mission. This processing step includes the removal of artefacts caused by the optical system and the CCD detector from the raw images and converting the digital number counts into physical radiance units. The calibration studies and procedures applied to generate the level 3 data products are described in detail in the articles RD8 and RD9. Level 3 datasets were generated for all comet mission phases after hibernation exit in early 2014 (see Table 8), but not for the cruise phase.

3.2.3 Geometrically Calibrated Data

Accurate geometric information is required for the operational objective of the NavCam and the respective image characteristics are therefore well established (see Section 4.2.4). However, it is not appropriate to generate geometrically calibrated data products by re-sampling the images. The correction shall better be taken into account for each specific application by directly using the existing data products. It is not planned by the Rosetta SGS to generate higher level data products such as map projections on a shape model for the comet nucleus images.

4 Archive Conventions and Meta-Information

This chapter describes general rules and conventions for producing the datasets and also gives an overview of important meta-information included in the product files.

4.1 Format and Conventions

The directory tree must be compatible, in terms of directory organisation and naming and file organisation, with the PDS standards and such that:

- each logical archive volume shall contain one NavCam PDS dataset;
- datasets will contain data from both NavCams;
- one dataset shall be created for each separate mission phase;
- a different dataset shall be created for each processing level;
- the top level directory of each logical archive volume shall match that of the NavCam dataset ID; and,
- the volume set name shall be as that of the dataset.

4.1.1 Dataset ID Formation

The dataset ID formation shall be done according to the following rule:

DATA_SET_ID = <INST_HOST>-<TARGET_ID>-<INST>-<CODMAC_LEVEL>-<MISSION_PHASE_ABBREVIATION>-<VERSION>

Each of the components are described, briefly, in Table 6, with a list of options for TARGET_ID and MISSION_PHASE being given in Tables 7 and 8, respectively. Examples include:

- RO-X-NAVCAM-2-PRL-COM-V1.1
- RO-C-NAVCAM-3-EXT1-MTP026-V1.0

In some instances there are several TARGET_ID terms in the DATA_SET_ID naming formation. These terms are combined and included in a list, separated by hyphens, between the <INST_HOST> and <INST> terms in the dataset name. Examples from the cruise phase include:

- RO-A-CAL-NAVCAM-2-AST2-V1.1
- RO-E-X-NAVCAM-2-CR1-V1.1

Table 6: Description of Components of the DATA_SET_ID.

Component	**Examples**	**Description**
INST_HOST	RO	Rosetta Orbiter
TARGET_ID	A, C, E, M	Asteroid, Comet, Earth, Mars
INST	NAVCAM	Navigation Camera
CODMAC_LEVEL	2, 3, 5	See Table 5
MISSION_PHASE_ ABBREVIATION	AST1, EAR3, CR4B, MARS	Asteroid 1 Flyby, Earth Swingby 3, Cruise 4-B, Mars Swingby, see Table 8
VERSION	Vx.y e.g. V1.0, V1.1, V2.0	x and y are numerical values indicating the version level and revision number

Table 7: List of used TARGET_TYPE and TARGET_NAME keyword values.

TARGET_TYPE	**TARGET_NAME**	**TARGET_ID**
COMET	67P/CHURYUMOV-GERASIMENKO 1 (1969R1) 9P/TEMPEL 1 (1867 G1)	C
ASTEROID	21 LUTETIA 2867 STEINS	A
PLANET	EARTH	E
PLANET	MARS	M
SATELLITE	MOON	
STAR	ALPHA LYR, ZETA CAS, ALPHA CAS ALPHA GRU, GAMMA GRU, ALPHA_VIR BETA HYI, ETA BOO, AREA 98, STARFIELD	CAL
CALIBRATION	BIAS, DARK SKY, FLAT FIELD, SCAT LIGHT	CAL
NEBULA	M42	
OPEN CLUSTER	PLEIADES	
DUST	DUST	
N/A	CHECKOUT	X

Table 8: List of MISSION_PHASE_NAME values and available dataset levels.

Phase Name	Abbreviation	Start Time	Levels
GROUND	GRND	2000-01-01 00:00:00	
LAUNCH	LEOP	2004-03-03 00:00:00	
COMMISSIONING 1	CVP1	2004-03-05 00:00:00	
CRUISE 1	CR1	2004-06-07 00:00:00	2
COMMISSIONING 2	CVP2	2004-09-06 00:00:00	2
EARTH SWING-BY 1	EAR1	2004-10-17 00:00:00	2
CRUISE 2	CR2	2005-04-05 00:00:00	2
MARS SWING-BY	MARS	2006-07-29 00:00:00	2
CRUISE 3	CR3	2007-05-29 00:00:00	
EARTH SWING-BY 2	EAR2	2007-09-13 00:00:00	2
CRUISE 4-1	CR4A	2008-01-28 00:00:00	
STEINS FLY-BY	AST1	2008-08-04 00:00:00	2
CRUISE 4-2	CR4B	2008-10-06 00:00:00	2
EARTH SWING-BY 3	EAR3	2009-09-14 00:00:00	2
CRUISE 5	CR5	2009-12-14 00:00:00	
LUTETIA FLY-BY	AST2	2010-05-17 00:00:00	2
RENDEZVOUS MANOEUVRE 1	RVM1	2010-09-04 00:00:00	2
CRUISE 6	CR6	2011-07-14 00:00:00	
PRELANDING COMMISSIONING	PRL-COM	2014-01-20 10:00:00	2, 3
PRELANDING MTP003	PRL-MTP003	2014-05-07 12:48:00	2, 3
PRELANDING MTP004	PRL-MTP004	2014-06-04 10:50:00	2, 3
PRELANDING MTP005	PRL-MTP005	2014-07-02 08:35:00	2, 3
PRELANDING MTP006	PRL-MTP006	2014-08-01 10:00:00	2, 3
PRELANDING MTP007	PRL-MTP007	2014-09-02 10:00:00	2, 3
PRELANDING MTP008	PRL-MTP008	2014-09-23 10:00:00	2, 3
PRELANDING MTP009	PRL-MTP009	2014-10-24 10:00:00	2, 3
COMET ESCORT 1 MTP010	ESC1-MTP010	2014-11-21 23:25:00	2, 3
COMET ESCORT 1 MTP011	ESC1-MTP011	2014-12-19 23:25:00	2, 3
COMET ESCORT 1 MTP012	ESC1-MTP012	2015-01-13 23:25:00	2, 3
COMET ESCORT 1 MTP013	ESC1-MTP013	2015-02-10 23:25:00	2, 3
COMET ESCORT 2 MTP014	ESC2-MTP014	2015-03-10 23:25:00	2, 3
COMET ESCORT 2 MTP015	ESC2-MTP015	2015-04-08 11:25:00	2, 3
COMET ESCORT 2 MTP016	ESC2-MTP016	2015-05-05 23:25:00	2, 3
COMET ESCORT 2 MTP017	ESC2-MTP017	2015-06-02 23:25:00	2, 3
COMET ESCORT 3 MTP018	ESC3-MTP018	2015-06-30 23:25:00	2, 3

COMET ESCORT 3 MTP019	ESC3-MTP019	2015-07-28 23:25:00	2, 3
COMET ESCORT 3 MTP020	ESC3-MTP020	2015-08-25 23:25:00	2, 3
COMET ESCORT 3 MTP021	ESC3-MTP021	2015-09-22 23:25:00	2, 3
COMET ESCORT 4 MTP022	ESC4-MTP022	2015-10-20 23:25:00	2, 3
COMET ESCORT 4 MTP023	ESC4-MTP023	2015-11-17 23:25:00	2, 3
COMET ESCORT 4 MTP024	ESC4-MTP024	2015-12-15 23:25:00	2, 3
ROSETTA EXTENSION 1 MTP025	EXT1-MTP025	2016-01-12 23:25:00	2, 3
ROSETTA EXTENSION 1 MTP026	EXT1-MTP026	2016-02-09 23:25:00	2, 3
ROSETTA EXTENSION 1 MTP027	EXT1-MTP027	2016-03-08 23:25:00	2, 3
ROSETTA EXTENSION 2 MTP028	EXT2-MTP028	2016-04-05 23:25:00	2, 3
ROSETTA EXTENSION 2 MTP029	EXT2-MTP029	2016-05-03 23:25:00	2, 3
ROSETTA EXTENSION 2 MTP030	EXT2-MTP030	2016-05-31 23:25:00	2, 3
ROSETTA EXTENSION 3 MTP031	EXT3-MTP031	2016-06-28 23:25:00	2, 3
ROSETTA EXTENSION 3 MTP032	EXT3-MTP032	2016-07-26 23:25:00	2, 3
ROSETTA EXTENSION 3 MTP033	EXT3-MTP033	2016-08-09 23:25:00	2, 3
ROSETTA EXTENSION 3 MTP034	EXT3-MTP034	2016-09-02 06:40:00	2, 3
ROSETTA EXTENSION 3 MTP035	EXT3-MTP035	2016-09-26 06:40:00	2, 3

Level 2 datasets are available for all mission phases during which images were acquired and comprise all data of both cameras (CAM1 and CAM2). Radiometrically calibrated level 3 datasets were produced for comet mission phases after hibernation exit as indicated in Table 8 and contain images acquired with camera CAM1 only. Only very few images were taken with the redundant camera CAM2 in this period.

4.1.2 File Naming Convention

Each image data product is generated in the form of a binary file (*.IMG) and a FITS-format file (*.FIT) with associated label files (*.LBL) of the same name that point to the image file. The label files contain meta-information about the camera operating parameters and geometric conditions. For every image a browse version file (*.JPG or *.PNG) and an associated label file are created. The file naming convention for these files is as follows:

<MISSION>_<CAM#>_<YYYYMMDDThhmmss><X><F>.<EXT>

Table 9 summarises the definitions of each part. The parameter <YYYYMMDDThhmmss> is the Coordinated Universal Time (UTC) without the fractional seconds (see Section 4.1.4) and provides the date and time at which the image was acquired on board the spacecraft.
For level 3 products a quality map file (*Q.IMG) is provided with each calibrated image file (*C.IMG). The corresponding level 3 FITS-format file (*CF.FIT) contains the calibrated image as well as the associated quality map.

Table 9: File naming parameters.

Variable	Possible Values	Description
MISSION	ROS	The Rosetta mission.
CAM#	CAM1, CAM2	Denotes which NavCam produced the data.
EXT	IMG, FIT, JPG, PNG, LBL	Denotes the file type.
X	C, Q, or absent	Is present for level 3 data: C for image and label file, Q for quality map. Absent for level 2 products.
F	F, or absent	Is present for the FITS format file and its label file. Absent otherwise.

4.1.3 PDS Standards

Each complete volume produced will be compliant with both the PDS and PSA standards. In general each individual file is created using PDS Version 3 standards. The PDS format uses the ISO 9660 level 2 standard for the file names. Hence, no complete file name shall be longer than 31 characters and the "27.3" structure shall be obeyed, that is, a maximum of 27 characters before the "." for the file name and 3 characters after for the extension type.

4.1.4 Time Standards

Two time standards are used in the meta-information of the NavCam data product files:

- Coordinated Universal Time (UTC) is expressed in the format
  <YYYYMMDDThhmmss.fff>
  where YYYYMMDD provides the calendar date (year, month and day), T is a fixed separator and hhmmss.fff indicates the time in hours, minutes, seconds and fractions of a second. UTC is used in the following keywords for time stamping the data products:
  - PRODUCT_CREATION_TIME
  - IMAGE_TIME
  - START_TIME
  - STOP_TIME

  Here START_TIME = IMAGE_TIME - 0.5 $\times$EXPOSURE_DURATION and
  STOP_TIME = IMAGE_TIME + 0.5$\times$EXPOSURE_TIME.

- Spacecraft Clock Time is given in the format
  1/<time counter high value>.<time counter low value>
  where the high counter roughly corresponds to the number of seconds since initialisation, and the low value counts ticks of duration 1/65536 second. (Example: 1/123772074.26377). The following keywords contain spacecraft clock time:

  - SPACECRAFT_CLOCK_START_COUNT
  - SPACECRAFT_CLOCK_STOP_COUNT

For level 2 V1.0 datasets up to and including MTP012 rounding errors of 1ms can occur in the START_TIME and STOP_TIME keyword values due to an inappropriate computation procedure. In the corresponding V1.1 datasets this was corrected.

4.2 Reference Frames and Geometry

4.2.1 Camera Reference Frames

For data processing and analysis purposes the NavCam reference frames are defined as follows:

- The +Z axis points along the camera boresight (optical axis).
- The +X axis is parallel to the apparent image columns. It is nominally co-aligned with the S/C +X axis.
- The +Y axis completes the right hand frame. It is nominally parallel to the apparent image lines and co-aligned with the S/C +Y axis.
- The origin of the frame is located at the camera focal point. See Section 4.2.4 for the pixel position on the detector corresponding to the boresight direction.

The actual NavCam boresight directions in the spacecraft reference frame were determined by in-flight calibration and are as follows.

- CAM1 (NAVCAM-A): (-0.000584, -0.003128, 0.999995).
- CAM2 (NAVCAM-B): (0.000116, 0.002098, 0.999998).

The full alignment rotation matrices are specified in the Rosetta SPICE frame-kernel [RD4]. Note that the values for CAM1 were updated in version 2.5 of the frame-kernel, which has been used for generating the level 2 archive datasets (V1.0) from period MTP018 onwards. For version V1.1 all cruise and comet phase datasets were created with the latest boresight alignment information.

4.2.2 Image Orientation

The images in the data product files are oriented such that the CCD columns (and therefore the X axis) appear in vertical direction and the lines (and therefore the Y axis) in horizontal direction. The binary files start with the first pixel of the first line read out from the CCD. This first line corresponds to the bottom of the image in the orientation mentioned above. Accordingly, the relevant keywords in the image description section of the product label files are

specified as SAMPLE_DISPLAY_DIRECTION = "RIGHT" and LINE_DISPLAY_DIRECTION = "UP".
The orientation of the X and Y axes is such that line and column number counts increase with increasing coordinate value. However, the optics of the instrument introduces an inversion of the image. This means that the signs of both coordinate values need to be reversed when transforming the position of an object in space into image coordinates. Or in other words, the image needs to be rotated by 180 degrees in order to match the orientation of the imaged scene.

4.2.3 Window Size and Position

The camera software allows the user to specify sub-frames in order to reduce the data volume for downlink. In the product label files the size of the images is indicated by the standard keywords LINES and LINE_SAMPLES of the image description section. The specific keywords
ROSETTA:CAM_WINDOW_POS_ALONG_ROW
and
ROSETTA:CAM_WINDOW_POS_ALONG_COL,
respectively, indicate the central column and row numbers of the commanded sub-images (see Table 14). Following the convention used in the telecommands and telemetry data of the instrument, the pixel indices start at values of 0. For full size images with 1024×1024 pixels the values of the row and column position keywords are set to 511. The pixel coordinate ranges contained in a windowed image can be determined as:

- along rows, i.e. column indices,
  from CAM_WINDOW_POS_ALONG_ROW - INT[(LINE_SAMPLES - 1)/2]
  to CAM_WINDOW_POS_ALONG_ROW + INT[LINE_SAMPLES/2]
- along columns, i.e. row indices,
  from CAM_WINDOW_POS_ALONG_COL - INT[(LINES - 1)/2] + 1
  to CAM_WINDOW_POS_ALONG_COL + INT[LINES/2].

4.2.4 Geometric Calibration

The optical system of the camera is designed in such a way that geometric distortion over the whole field of view is small (∼1% at the edge). Nevertheless, for the purposes of precise navigation and astrometric registration these effects need to be taken into account. The simplified procedure below for computing the view direction as a function of image pixel was extracted from Appendix H of the Data Delivery Interface Document [RD5]. It is accurate to one pixel over the full CCD.
The boresight direction of the instrument corresponds to the centre of the pixel (511, 511). For a given pixel position (i, j) on the camera CCD, the corresponding direction vector (x, y, z) in camera frame can be obtained as follows with parameter values as listed in Table 10:

Table 10: Parameters for geometric correction.

Parameter	CAM1	CAM2
cx	-0.00012044038	-0.00011708484
cy	-0.000114420733	-0.000111645333
fx	152.5159	152.4893
fy	152.4949	152.4854

- Convert pixel coordinates into spatial position in the detector plane relative to the centre of pixel (511, 511):
  $px = (i - 511) \cdot 0.013$,
  $py = (j - 511) \cdot 0.013$.
- Apply a radial distortion correction relative to the linear position:
  $pxCorr = px \cdot [1 + cx \cdot (px^2 + py^2)]$,
  $pyCorr = py \cdot [1 + cy \cdot (px^2 + py^2)]$.
- The (un-normalised) direction vector in camera frame is then given by:
  $(x, y, z) = (-pxCorr/fx, -pyCorr/fy, 1)$.

The sign change in x- and y-coordinates assures the appropriate image orientation as mentioned in Section 4.2.2.

4.2.5 Geometric Information in Label Files

The label files include the following geometric variables:

- SC_SUN_POSITION_VECTOR
  The vector from the spacecraft to the Sun in equatorial J2000 inertial frame.
- SC_TARGET_POSITION_VECTOR
  The vector from the spacecraft to the centre of the target in equatorial J2000 inertial frame.
- SC_TARGET_VELOCITY_VECTOR
  The spacecraft to target velocity vector in equatorial J2000 inertial frame.
- TARGET_CENTER_DISTANCE
  The distance between the spacecraft and the target centre.
- SUB_SPACECRAFT_LATITUDE and SUB_SPACECRAFT_LONGITUDE
  The latitude and longitude of the sub-spacecraft point in target body-fixed reference frame. For 67P this frame (67P/C-G_CK) is implicitly specified by the information provided by

Flight Dynamics in the comet attitude file CATT [RD5]. By construction the "Cheops reference frame" introduced in [RD6,RD7] is equivalent to the Flight Dynamics body-fixed frame. For cruise phase targets the used reference frames are ITRF93 (for the Earth), IAU_MOON, IAU_MARS, STEINS_FIXED, LUTETIA_FIXED, and IAU_TEMPEL_1.

- RIGHT_ASCENSION and DECLINATION
  Right Ascension and Declination of the camera boresight direction in equatorial J2000 inertial frame. (For windowed images these coordinates can be located outside of the acquired sub-frame.)
- CELESTIAL_NORTH_CLOCK_ANGLE
  The direction of celestial north at the centre of the image - measured from the 'upward' direction, clockwise to the direction toward celestial north.
- SOLAR_ELONGATION
  The angle between the line of sight of observation and the direction to the Sun.

All geometric values are calculated for the time t = IMAGE_TIME (and not START_TIME). The values of the keywords SC_SUN_POSITION_VECTOR, SC_TARGET_POSITION_VECTOR, SC_TARGET_VELOCITY_VECTOR, and TARGET_CENTER_DISTANCE are determined taking into account light time and aberration corrections. RIGHT_ASCENSION and DECLINATION are computed with aberration corrections. No correction is applied for obtaining the values of SUB_SPACECRAFT_LATITUDE and SUB_SPACECRAFT_LONGITUDE. The target dependent variables are computed for solar system bodies (as reported in TARGET_NAME) and specified as "N/A" otherwise. None of the geometric variables included in the label files require the usage of a reference model for the shape of the target body for their computation.

4.3 Data Quality

4.3.1 Level 2 Products

In level 2 products the keyword DATA_QUALITY_ID indicates whether the lines of an image were completely acquired (value 0) or the image is incomplete and lines are missing (value 1). The number of missing lines is given in the keyword ROSETTA:CAM_MISSING_LINES (see Table 14).

The keyword ROSETTA:CAM_DATA_VALID with the possible values OK or NOT_OK reports the result of a periodic instrument health check which is included in the science telemetry data. This error flag is set, for example, if the instrument CCD temperature is not within the performance range of [-25°C, 0°C]. This is the case for a large fraction of the images taken during the comet escort phase. However, the lower temperatures measured are still within the operating range and do not affect the image quality.

Instrument temperatures are extracted from housekeeping telemetry (see Section 3.1). If for a given image acquisition time no housekeeping information is available in an interval of ±1 minute, the values are reported as "UNK" in the keyword INSTRUMENT_TEMPERATURE.

4.3.2 Level 3 Products

In the level 3 datasets an 8 bit quality map is provided with each of the radiometrically calibrated images. Bit values set to 1 in the quality map indicate the occurrence of anomalies or the application of artefact corrections for the corresponding image pixels as follows:

- bit 0: Vignetting correction applied.
- bit 1: Pixel-pair artefact corrected by averaging.
- bit 2: Pixel-pair artefact corrected by interpolation.
- bit 3: Warm pixel corrected by interpolation.
- bit 4: Pixel value is negative after bias and smear correction.
- bit 5: Pixel is saturated in the raw data (i.e. value of 4095 in level 2 product).
- bit 6: Bad pixel belonging to the bottom row of a full-frame image.
- bit 7: Missing information in telemetry data (i.e. value of 0 in level 2 product).

The calibration and artefact correction procedure is described in detail in reference document RD8.

The label keywords DATA_QUALITY_ID and ROSETTA:CAM_DATA_VALID were omitted for level 3 products in order to avoid misinterpretation by users who do not check the rather limited significance of these keywords in the documentation. Instead, the label files of the radiometrically calibrated products contain keywords reporting the number of affected pixels for each of the 8 bits of the quality map (see Table 15).

4.4 Target Name and Observation Type

The used values of the TARGET_NAME keyword and the corresponding TARGET_TYPE are summarised in Table 7. The keyword OBSERVATION_TYPE was used in the label files in order to provide information about the purpose of the images acquired. The values of this keyword are as follows:

- NAVIGATION IMAGE
  The image was commanded for navigation purposes by the Flight Dynamics team.

- CONTEXT IMAGE
  The image was requested by the ALICE instrument team via the Science Ground Segment in order to provide context information for their scientific measurements. During mission phases with low available resources a large fraction of these images were reduced to narrow vertical strips coinciding with the ALICE slit in order to save data volume. From August 2015 additional context images were also scheduled directly by the Science Ground Segment for regular activity monitoring around perihelion.

- CALIBRATION
  The image was acquired for calibration purposes.

- DUST CHARACTERISATION
  The image was specifically scheduled for characterising the dust environment. (Two dust characterisation images acquired at 2015-08-25T16:15:02 and 2015-08-25T16:45:01 were wrongly labelled in the level 2 product files. This was corrected in level 3.)

- CHECKOUT
  The image was acquired as an instrument checkout or test.

- CRUISE IMAGE
  The image was acquired during the cruise phase. This keyword value was assigned for all cruise phase images.

For some of the comet navigation images the nucleus was not visible in the camera's field of view due to trajectory offsets resulting in large pointing errors with respect to the comet position. Nevertheless, the TARGET_NAME was then still specified as "67P/CHURYUMOV-GERASIMENKO 1 (1969 R1)". In addition, there were also a number of context images scheduled during periods with off-nucleus pointing, for which no specific purpose was identified and the comet was assigned as the target by default.

5 Dataset Content

This section contains information common to all datasets produced for the Rosetta NavCam.

5.1 Volume Set

The following conditions shall remain true for the NavCam datasets at all times:

- Each logical archive volume shall contain one NavCam dataset.

- Necessary documentation for the logical archive volumes shall be provided by the Planetary Science Archive Data Handlers (PSA-DHs). Any other non-data file necessary for the logical archive volume will be provided by the PSA-DHs.

- It shall be possible to modify and implement the structure of the directory tree with new sub-directories, whenever needed. The creation and management of the directories shall be performed by the PSA-DHs.

The keywords mandatory for the VOLUME object of the Rosetta mission are presented in Table 11:

Table 11: Mandatory keywords and standard values for the VOLUME object.

Keyword	**Required**	**Max. Length**	**Standard Value(s)**
DATA_SET_ID	yes	40	see Section 4.1.1
DESCRIPTION	yes	N/A	"N/A"
MEDIUM_TYPE	yes	30	"ELECTRONIC"
PUBLICATION_DATE	yes	10	YYYY-MM-DD
VOLUME_FORMAT	yes	20	"ANSI"
VOLUME_ID	yes	12	"N/A"
VOLUME_NAME	yes	60	"N/A"
VOLUME_SERIES_NAME	yes	60	"N/A"
VOLUME_SET_NAME	yes	60	"N/A"
VOLUME_SET_ID	yes	40	"N/A"
VOLUME_VERSION_ID	yes	12	"N/A"
VOLUMES	yes	N/A	"UNK"

5.2 Dataset Naming

The dataset naming for the Rosetta NavCam follows the following formation rule:

DATA_SET_NAME = <INSTRUMENT_HOST_NAME> <TARGET>(<OPTIONAL>) <INST> <CODMAC_LEVEL> <MISSION_PHASE_ABBREVIATION> <VERSION>

where each of these parameters is defined in Table 12.
Examples include:

- "ROSETTA-ORBITER CHECK NAVCAM 2 PRELANDING COMMISSIONING V1.1"
- "ROSETTA-ORBITER 67P NAVCAM 2 PRELANDING MTP004 V1.1"

Table 12: Dataset naming parameters.

Parameter	Value(s)
INSTRUMENT_HOST_NAME	ROSETTA-ORBITER
TARGET	see Table 7
INST	NAVCAM
CODMAC_LEVEL	see Table 5
MISSION_PHASE_ABBREVIATION	see Table 8
VERSION	e.g. V1.0, V2.4 etc.

5.3 Directories

Root Directory

The top-level structure of the ROOT directory of a data archive volume corresponds to chapter 19 of the PDS Standards Reference (summarised here):

- **AAREADME.TXT**: This file describes the complete volume. It provides an overview of what can be found in the volume including the organisational attributes and general instructions for use along with contact information.
- **ERRATA.TXT**: If present, this file describes known errors or deficiencies in this archive volume set.
- **VOLDESC.CAT**: This file contains the VOLUME object, which gives a high-level description of the volume contents.

Sub-directories (except the DATA and EXTRAS directories) include a file, **xxxxINFO.TXT**, that briefly describes the contents of that directory. In case that an important instrument characteristic cannot be described with an existing PDS keyword, the information will be supplied in a separate parameter file.

BROWSE Directory

This directory contains one or two sub-directories (CAM1 and/or CAM2) with a set of images in *.JPG or *.PNG format (one corresponding to each *.IMG file in the DATA directory) and an associated *.LBL for each one. Other files that are included here are:

- **BROWINFO.TXT**: This file describes the contents of the directory.
- ***.LBL**: Detached label files for the browse products.
- ***.JPG**: Browse images in JPEG format for level 2 products. These images were created from the raw binary data using the convert tool of the ImageMagick package (v6.8.9-6)

and standard parameter settings (-contrast-stretch 2%x1%). The grey scale conversion from the raw data was not tuned to specific image contents and therefore in some cases the resulting image can be dominated by detector noise.

- ***.PNG**: Browse images in PNG format for level 3 products. The grey scales are approximately equivalent to the corresponding level 2 browse images. The purpose of the browse images is to reflect the content of the actual product files including possibly remaining artefacts rather than suppressing them.

CALIB Directory

This directory is only present for level 3 datasets and contains the following files used in the radiometric calibration procedure:

- **CALINFO.TXT**: This file describes the content of the directory.
- **BIAS_<GAIN>_<DATE>.FIT**: Bias fields for <GAIN> = HIGH and LOW created on day <DATE>.
- **VIGNETTING_<COV>_<DATE>.FIT**: Vignetting fields for <COV> = ATT and NATT created on day <DATE>. NATT is applicable for cover positions DEFOC_NATT and FOC_NATT whereas ATT is used for FOC_ATT. See Section 2.1.1.
- ***.LBL**: The corresponding detached label files.

CATALOG Directory

This directory contains the catalogue object files for the complete volume. Files include:

- **CATINFO.TXT**: A description of the contents of the CATALOG directory.
- **MISSION.CAT**: Contains mission catalogue information about the Rosetta Mission (provided by ESA).
- **INSTHOST.CAT**: Contains instrument host catalogue information about the Rosetta S/C and the mounting relationship of the instruments within the S/C (provided by ESA).
- **NAVCAM_INST.CAT**: Contains instrument catalogue information about the instrument (likely to be the same in all deliveries, unless updates are needed).
- **DATASET.CAT**: Contains dataset catalogue information about the dataset currently being submitted.
- **REF.CAT**: Reference catalogue information about every journal article, book or other published reference mentioned in the above catalogue objects or their components.

- **SOFTWARE.CAT**: Software catalogue information about the software submitted in the dataset.
- **TARGET.CAT**: Contains target catalogue information about the observation targets, i.e. comet, asteroid, Earth or Mars (provided by ESA).
- **NAVCAM_PERS.CAT**: Contains personnel catalogue information about the instrument team responsible for generating the data products.

It should be noted here that the last two files are optional and may not be found in the volume.

DATA Directory

This directory contains one or two sub-directories (CAM1 and/or CAM2) with the data products in the form of binary files (*.IMG) with a corresponding detached *.LBL (label) file. For level 3 products there is a binary quality map file associated with each image file.

DOCUMENT Directory

Included here is a copy of all the documentation relative to the data production and the volume as a whole. Specific files are:

- **DOCINFO.TXT**: A description of the contents of the document directory.
- **RO-SGS-IF-0001.PDF**: The Experiment to Archive Interface Control Document (EAICD) (this document) for the NavCam instrument.
- **RO-SGS-IF-0001.ASC**: The ASCII version of the above file.
- **RO-SGS-IF-0001.LBL**: The label of the above files.

Only for level 2 products and if applicable for the respective dataset, this directory also includes the following files:

- **LOST_IMAGES_<MISSION_PHASE_ABBREVIATION>.ASC**: A text file listing scheduled images that were not acquired or were lost after acquisition.
- **LOST_IMAGES_<MISSION_PHASE_ABBREVIATION>.LBL**: The corresponding label file.
- **LOST_ROWS_<MISSION_PHASE_ABBREVIATION>.TAB**: A table listing incomplete images for which a number of rows were lost after acquisition.
- **LOST_ROWS_<MISSION_PHASE_ABBREVIATION>.LBL**: The corresponding label file.

EXTRAS Directory

This directory contains one or two sub-directories (CAM1 and/or CAM2) with the data products in the form of FITS-format (*.FIT) files with a corresponding detached *.LBL (label) file.

- **EXTRINFO.TXT**: This file describes the content of the directory.

INDEX Directory

Contains index files which summarise all of the data products in the volume by mode, key instrument parameters or mission phase. Particular files include:

- **INDXINFO.TXT**: A description of the contents of the directory.
- **INDEX.TAB**: Includes the index of the volume in a tabular format.
- **INDEX.LBL**: The detached label file for the file INDEX.TAB. The INDEX_TABLE specific object is used to identify and describe the columns of the index table.
- **BROWSE_INDEX.TAB**: This file includes an index of the browse products in tabular format.
- **BROWSE_INDEX.LBL**: The detached label for BROWSE_INDEX.TAB.
- **NAVCAM_<MISSION_PHASE_ABBREVIATION>_INDEX.TAB**: This file includes an index of the image products included in the dataset.
- **NAVCAM_<MISSION_PHASE_ABBREVIATION>_INDEX.LBL**: The corresponding detached label file.
- **GEO_NAVCAM_<MISSION_PHASE_ABBREVIATION>_INDEX.TAB**: This file includes a geometry index for the image products included in the dataset.
- **GEO_NAVCAM_<MISSION_PHASE_ABBREVIATION>_INDEX.LBL**: The corresponding detached label file.

6 Product File Content

According to the PDS formatting standard, each data product must be accompanied by a descriptive *.LBL to describe the content. For the NavCam these label files shall be in the detached form and will appear as separate files (see Section 4.1.2). The image data are provided in binary as well as in a FITS format version. There are separate label files for each of them. The product file versions in binary format with their PDS format label files are stored in the DATA directory, whereas the FITS format image files and their label files are contained in the EXTRAS directory.

6.1 Content of *.LBL Files

The following shall remain true for all label files in all volumes for the Rosetta NavCam:

- The format follows PDS standards for formatting and character usage.
- The labels shall use only valid keywords that appear in both the PDS and PSA dictionaries.
- The character set used shall be that of ASCII 7 bit; specifically characters within and including the code range 001 to 127.
- The characters <CR> and <LF> shall be used and shall be present at the end of each line of every label file.
- Each label file shall not exceed a maximum 80-character limit; including the <CR> <LF> characters.
- Every line that is less than the permitted 80 characters maximum shall be padded out to be of a length equal to 80.

Table 13 provides the list of standard keywords used in label files within the NavCam volumes and Table 14 contains Rosetta mission specific dictionary entries. Additional mission specific keywords used in level 3 products are listed in 15.

Table 13: Keywords used in the label files.

Keyword	**Max. Length**	**Value(s)**
PDS_VERSION_ID	6	PDS3
FILE_NAME	N/A	filename
RECORD_TYPE	20	FIXED_LENGTH
RECORD_BYTES	N/A	bytes per image line (for binary)
FILE_RECORDS	N/A	number of image lines (for binary)
INTERCHANGE FORMAT	6	BINARY or FITS
DATA_SET_ID	40	see Section 4.1.1
DATA_SET_NAME	60	see Section 5.2
PRODUCT_ID	40	filename without extension
PRODUCT_CREATION_TIME	24	YYYY-MM-DDThh:mm:ss.fff
PRODUCT_TYPE	30	EDR
PROCESSING_LEVEL_ID	N/A	”2”
IMAGE_TIME	24	YYYY-MM-DDThh:mm:ss.fff
START_TIME	24	YYYY-MM-DDThh:mm:ss.fff

STOP_TIME	24	YYYY-MM-DDThh:mm:ss.fff
SPACECRAFT_CLOCK_START _COUNT	30	see Section 4.1.4
SPACECRAFT_CLOCK_STOP _COUNT	30	see Section 4.1.4
MISSION_ID	N/A	ROSETTA
MISSION_NAME	60	"INTERNATIONAL ROSETTA MISSION"
MISSION_PHASE_NAME	30	see Table 8
INSTRUMENT_HOST_ID	6	RO
INSTRUMENT_HOST_NAME	60	"ROSETTA-ORBITER"
TARGET_NAME	120	see Table 7
TARGET_TYPE	20	see Table 7
OBSERVATION_TYPE	30	see Section 4.4
PRODUCER_ID	20	"ESA-ESAC"
PRODUCER_FULL_NAME	60	"BERNHARD GEIGER"
PRODUCER_INSTITUTION _NAME	60	"EUROPEAN SPACE AGENCY-ESAC"
INSTRUMENT_ID	12	NAVCAM
INSTRUMENT_NAME	60	"NAVIGATION CAMERA"
INSTRUMENT_TYPE	30	"CCD CAMERA"
CHANNEL_ID	4	"CAM1" or "CAM2"
EXPOSURE_DURATION	N/A	sss.fff <s>
DATA_QUALITY_ID	3	0 or 1 – only in level 2
DATA_QUALITY_DESC	N/A	"0: Image Complete, 1: Lines Missing." – only in level 2
INSTRUMENT_MODE_ID	20	"IMAGING" or "ASTEROID TRACKING"
INSTRUMENT_MODE_DESC	N/A	"Instrument OPERATING MODE (from TM data)"
INSTRUMENT_TEMPERATURE	N/A	CCD and optics temperature retrieved from HK TM
INSTRUMENT_TEMPERATURE _POINT	60	("CCD_T1", "OPTICS_T7")
COORDINATE_SYSTEM_ID	30	J2000
SC_SUN_POSITION_VECTOR	N/A	vector from spacecraft to Sun in J2000 coordinates

SC_TARGET_POSITION_VECTOR	N/A	vector from spacecraft to target in J2000 coordinates
SC_TARGET_VELOCITY_VECTOR	N/A	relative target to spacecraft velocity vector in J2000
TARGET_CENTER_DISTANCE	N/A	distance between spacecraft and target
SUB_SPACECRAFT_LATITUDE	N/A	latitude of the sub-spacecraft point on the surface)
SUB_SPACECRAFT_LONGITUDE	N/A	longitude of the sub-spacecraft point on the surface)
RIGHT_ASCENSION	N/A	right ascension of boresight direction (J2000)
DECLINATION	N/A	declination of boresight direction (J2000)
CELESTIAL_NORTH_CLOCK_ANGLE	N/A	direction of celestial North on the image
SOLAR_ELONGATION	N/A	angle between boresight and Sun directions
NOTE	N/A	list of SPICE kernels and description of coordinate systems used

Table 14: Rosetta mission specific dictionary entries.

Keyword	**Value(s)**
ROSETTA:CAM_ABSOLUTE_FRAME_NUMBER	frame number since instrument start-up
ROSETTA:CAM_MODE_FRAME_NUMBER	frame number in current mode
ROSETTA:CAM_COVER_POSITION	FOC_NATT, FOC_ATT , or DEFOC_NATT, see p.5
ROSETTA:CAM_GAIN	LOW or HIGH, see p.6
ROSETTA:CAM_DATA_VALID	OK or NOT_OK, see p.18 – only in level 2
ROSETTA:CAM_WINDOW_POS_ALONG_ROW	see p.16
ROSETTA:CAM_WINDOW_POS_ALONG_COL	see p.16
ROSETTA:CAM_MISSING_LINES	number of missing image lines, see p.18
ROSETTA:PIPELINE_VERSION_ID	version identifier of the data processing pipeline

Table 15: Additional mission specific dictionary entries for level 3 products.

Keyword	Value(s)
ROSETTA:CAM_PIX_VIGNETTING	number of pixels with vignetting correction applied
ROSETTA:CAM_PIX_PAIR_AVERAGED	number of averaged pixel-pair pixels
ROSETTA:CAM_PIX_PAIR_INTERPOLATED	number of interpolated pixel-pair pixels
ROSETTA:CAM_PIX_WARM	number of interpolated warm pixels
ROSETTA:CAM_PIX_NEGATIVE	number of pixels with negative values after correction
ROSETTA:CAM_PIX_SATURATED	number of saturated pixels
ROSETTA:CAM_PIX_BADROW	number of bad row pixels
ROSETTA:CAM_PIX_MISSING	number of missing pixels
ROSETTA:CAM_RADIANCE_DNSTEP	spectral radiance step in W m^{-2} sr^{-1} nm^{-1} corresponding to 1 DN

The following is an example for the label file of one of the level 3 binary image files in a dataset:

```
PDS_VERSION_ID                  = PDS3

/***      FILE CHARACTERISTICS                                           ***/
RECORD_TYPE                     = UNDEFINED
INTERCHANGE_FORMAT              = BINARY

/***      POINTERS TO DATA OBJECTS                                       ***/
^IMAGE                          = "ROS_CAM1_20160306T155652C.IMG"
^QUALITY_FLAGS_IMAGE            = "ROS_CAM1_20160306T155652Q.IMG"

/***      IDENTIFICATION DATA ELEMENTS                                   ***/
DATA_SET_ID                     = "RO-C-NAVCAM-3-EXT1-MTP026-V1.0"
DATA_SET_NAME = "ROSETTA-ORBITER 67P NAVCAM 3 ROSETTA EXTENSION 1 MTP026 V1.0"
PRODUCT_ID                      = "ROS_CAM1_20160306T155652C"
SOURCE_PRODUCT_ID  = "RO-C-NAVCAM-2-EXT1-MTP026-V1.1:ROS_CAM1_20160306T155652"
PRODUCT_CREATION_TIME           = 2020-09-29T15:28:14
PRODUCT_TYPE                    = EDR
PROCESSING_LEVEL_ID             = "3"
IMAGE_TIME                      = 2016-03-06T15:56:52.626
START_TIME                      = 2016-03-06T15:56:50.961
STOP_TIME                       = 2016-03-06T15:56:54.291
SPACECRAFT_CLOCK_START_COUNT    = "1/415900527.16961"
SPACECRAFT_CLOCK_STOP_COUNT     = "1/415900530.38587"
MISSION_ID                      = "ROSETTA"
MISSION_NAME                    = "INTERNATIONAL ROSETTA MISSION"
MISSION_PHASE_NAME              = "ROSETTA EXTENSION 1 MTP026"
INSTRUMENT_HOST_ID              = RO
INSTRUMENT_HOST_NAME            = "ROSETTA-ORBITER"
TARGET_NAME                     = "67P/CHURYUMOV-GERASIMENKO 1 (1969 R1)"
TARGET_TYPE                     = "COMET"
OBSERVATION_TYPE                = "NAVIGATION IMAGE"
PRODUCER_ID                     = "ESA-ESAC"
PRODUCER_FULL_NAME              = "BERNHARD GEIGER"
PRODUCER_INSTITUTION_NAME       = "EUROPEAN SPACE AGENCY-ESAC"

/***      INSTRUMENT RELATED PARAMETERS                                  ***/
INSTRUMENT_ID                   = NAVCAM
INSTRUMENT_NAME                 = "NAVIGATION CAMERA"
INSTRUMENT_TYPE                 = "CCD CAMERA"
CHANNEL_ID                      = "CAM1"
EXPOSURE_DURATION               = 3.33 <s>
INSTRUMENT_MODE_ID              = "IMAGING"
INSTRUMENT_MODE_DESC            = "Instrument OPERATING MODE (from TM data)"
```

```
INSTRUMENT_TEMPERATURE          = (-34.04 <degC>,1.34 <degC>)
INSTRUMENT_TEMPERATURE_POINT    = ("CCD_T1","OPTICS_T7")

/***      ROSETTA MISSION SPECIFIC DATA DICTIONARY ENTRIES                ***/
ROSETTA:CAM_ABSOLUTE_FRAME_NUMBER = 7645173
ROSETTA:CAM_MODE_FRAME_NUMBER   = 844
ROSETTA:CAM_COVER_POSITION      = FOC_ATT
ROSETTA:CAM_GAIN                = HIGH
ROSETTA:CAM_WINDOW_POS_ALONG_ROW = 511
ROSETTA:CAM_WINDOW_POS_ALONG_COL = 511
ROSETTA:CAM_MISSING_LINES       = 0
ROSETTA:CAM_PIX_VIGNETTING      = 14744
ROSETTA:CAM_PIX_PAIR_AVERAGED   = 26896
ROSETTA:CAM_PIX_PAIR_INTERPOLATED = 4
ROSETTA:CAM_PIX_WARM            = 1147
ROSETTA:CAM_PIX_NEGATIVE        = 41
ROSETTA:CAM_PIX_SATURATED       = 5
ROSETTA:CAM_PIX_BADROW          = 1024
ROSETTA:CAM_PIX_MISSING         = 0
ROSETTA:CAM_RADIANCE_DNSTEP     = 2.14414414414e-07
ROSETTA:PIPELINE_VERSION_ID     = "CAL-1.0.0"

/***      SPACECRAFT POSITION AND POINTING (J2000)                        ***/
COORDINATE_SYSTEM_ID            = J2000
SC_SUN_POSITION_VECTOR          = (369440692.102 <km>,
                              -41587269.044 <km>,
                              -61604797.152 <km>)
SC_TARGET_POSITION_VECTOR       = (-3.093 <km>,
                                  -1.846 <km>,
                                 -19.007 <km>)
SC_TARGET_VELOCITY_VECTOR       = (-0.017 <m/s>,
                                 -0.179 <m/s>,
                                  0.034 <m/s>)
TARGET_CENTER_DISTANCE          = 19.345 <km>
SUB_SPACECRAFT_LATITUDE         = 71.656257 <deg>
SUB_SPACECRAFT_LONGITUDE        = 160.095375 <deg>
RIGHT_ASCENSION                 = 240.483645 <deg>
DECLINATION                     = -81.202320 <deg>
CELESTIAL_NORTH_CLOCK_ANGLE     = 293.977339 <deg>
SOLAR_ELONGATION                = 84.127036 <deg>
NOTE                            = "SPICE KERNELS USED:
                                  NAIF0011.TLS
                                  ROS_160929_STEP.TSC
                                  ROS_V26.TF
                                  RORB_DV_257_02_______00344.BSP
```

```
                                     RATT_DV_257_02_01____00344.BC
                                     CORB_DV_257_02_______00344.BSP
                                     CATT_DV_257_02_______00344.BC
                                     ROS_CHURYUMOV_V01.TF
                                     DE405.BSP
The values of the keywords SC_SUN_POSITION_VECTOR, SC_TARGET_POSITION_VECTOR,
SC_TARGET_VELOCITY_VECTOR, CELESTIAL_NORTH_CLOCK_ANGLE, RIGHT_ASCENSION, and
DECLINATION are related to the equatorial J2000 inertial frame.
The values of SUB_SPACECRAFT_LATITUDE and SUB_SPACECRAFT_LONGITUDE refer to
the Cheops reference frame which is identical to the Flight Dynamics
body-fixed frame implicitly specified by the information provided in the
comet attitude file CATT.
All values are computed for the time t = IMAGE_TIME. Distances are given in
<km>, velocities in <m/s>, and angles in <deg>."

/***      IMAGE DESCRIPTION                                              ***/

OBJECT                         = IMAGE
   DERIVED_MAXIMUM             = 0.000828053511214
   DERIVED_MINIMUM             = -5.83237579121e-07
   LINES                       = 1024
   LINE_SAMPLES                = 1024
   SAMPLE_TYPE                 = "PC_REAL"
   SAMPLE_BITS                 = 32
   UNIT                        = "W/(m**2*sr*nm)"
   SOURCE_SAMPLE_BITS          = 12
   SAMPLE_DISPLAY_DIRECTION    = "RIGHT"
   LINE_DISPLAY_DIRECTION      = "UP"
END_OBJECT                     = IMAGE

OBJECT                         = QUALITY_FLAGS_IMAGE
   LINES                       = 1024
   LINE_SAMPLES                = 1024
   SAMPLE_TYPE                 = "LSB_UNSIGNED_INTEGER"
   SAMPLE_BITS                 = 8
   SAMPLE_DISPLAY_DIRECTION    = "RIGHT"
   LINE_DISPLAY_DIRECTION      = "UP"
   DESCRIPTION                 = "
For each pixel, the bit values in the quality map give information about the
processing steps applied. The significance of bit values set to 1 is:
bit 0  vignetting correction applied
bit 1  pixel-pair artefact correction applied (average)
bit 2  pixel-pair artefact correction applied (interpolation)
bit 3  warm pixel correction applied (interpolation)
bit 4  negative value after bias subtraction and smear correction
```

```
bit 5  pixel was saturated in raw data (i.e. DN=4095 in Level 2 product)
bit 6  bad pixel belonging to the bottom row of a full-frame image
bit 7  missing information in telemetry data (i.e. DN=0 in Level 2 product)  "
END_OBJECT                    = QUALITY_FLAGS_IMAGE
END
```

6.2 Content of *.FIT File Header

The labels for the FITS-format file versions contain identical meta-information and only minor changes owing to the differences of the image file format. The *.FIT image files also contain meta-data in their header so that the files can be used independently of the PDS dataset structure. Astrometric registration information is included in the form of WCS keywords. However, the geometric distortion (see Section 4.2.4) towards the edge of the field of view is not modelled here. Table 16 shows the correspondence between PDS and FITS keywords used in the label file and the header, respectively. For target dependent PDS keywords specified as "N/A" the corresponding FITS keywords are omitted.

Table 16: Correspondence between PDS and FITS keywords.

PDS Keyword	**FITS Keyword**
DATA_SET_ID	DATASET
PRODUCT_ID	OBS_ID
PRODUCT_CREATION_TIME	DATE
PROCESSING_LEVEL_ID	CODMAC
IMAGE_TIME	IMG-TIME
START_TIME	DATE-OBS
STOP_TIME	TIME-END
SPACECRAFT_CLOCK_START_COUNT	SCLKSTAR
SPACECRAFT_CLOCK_STOP_COUNT	SCLKSTOP
MISSION_PHASE_NAME	MISSPHAS
INSTRUMENT_HOST_NAME	part of INSTRUME
TARGET_NAME	OBJECT
OBSERVATION_TYPE	OBS_TYPE
PRODUCER_FULL_NAME	AUTHOR
PRODUCER_INSTITUTION_NAME	ORIGIN
INSTRUMENT_NAME	part of INSTRUME
CHANNEL_ID	part of INSTRUME
EXPOSURE_DURATION	EXPTIME
INSTRUMENT_MODE_ID	OBS_MODE

INSTRUMENT_TEMPERATURE	CCDTEMP, OPTTEMP
ROSETTA:CAM_ABSOLUTE_FRAME_NUMBER	ABSFRAME
ROSETTA:CAM_MODE_FRAME_NUMBER	MODFRAME
ROSETTA:CAM_COVER_POSITION	FILTER
ROSETTA:CAM_GAIN	GAIN
ROSETTA:CAM_DATA_VALID	DATA_VAL – only in level 2
ROSETTA:CAM_WINDOW_POS_ALONG_ROW	used in CRPIX1 (see note below)
ROSETTA:CAM_WINDOW_POS_ALONG_COL	used in CRPIX2 (see note below)
ROSETTA:CAM_MISSING_LINES	LINEMISS
ROSETTA:CAM_PIX_VIGNETTING	PIX_VIGN – only in level 3
ROSETTA:CAM_PIX_PAIR_AVERAGED	PIX_AVER – only in level 3
ROSETTA:CAM_PIX_PAIR_INTERPOLATED	PIX_INTE – only in level 3
ROSETTA:CAM_PIX_WARM	PIX_WARM – only in level 3
ROSETTA:CAM_PIX_NEGATIVE	PIX_NEGA – only in level 3
ROSETTA:CAM_PIX_SATURATED	PIX_SATU – only in level 3
ROSETTA:CAM_PIX_BADROW	PIX_BADR – only in level 3
ROSETTA:CAM_PIX_MISSING	PIX_MISS – only in level 3
ROSETTA:CAM_RADIANCE_DNSTEP	R_DNSTEP – only in level 3
ROSETTA:PIPELINE_VERSION_ID	CONFIGUR
COORDINATE_SYSTEM_ID	EQUINOX
SC_SUN_POSITION_VECTOR	SC-SUN_X,SC-SUN_Y,SC-SUN_Z
SC_TARGET_POSITION_VECTOR	SC-TAR_X,SC-TAR_Y,SC-TAR_Z
SC_TARGET_VELOCITY_VECTOR	SC-TARVX,SC-TARVY,SC-TARVZ
TARGET_CENTER_DISTANCE	TARGDIST
SUB_SPACECRAFT_LATITUDE	SSP_LAT
SUB_SPACECRAFT_LONGITUDE	SSP_LON
RIGHT_ASCENSION	CRVAL1
DECLINATION	CRVAL2
CELESTIAL_NORTH_CLOCK_ANGLE	implicit in CDx_y
SOLAR_ELONGATION	SUNANGLE
NOTE	SP_KERNx
DERIVED_MAXIMUM	DATAMAX
DERIVED_MINIMUM	DATAMIN
LINES	NAXIS2
LINE_SAMPLES	NAXIS1
SAMPLE_BITS	BITPIX

UNIT	BUNIT
SOURCE_SAMPLE_BITS	used for SATURATE - only in level 2

Note: The FITS-WCS keywords CRPIX1 and CRPIX2 denote the (FITS) pixel coordinates of the reference point for sky position, projection, and rotation. In the convention applicable for FITS files the pixel counts start at values of 1. The FITS file coordinates of the centre of the (bottom left) pixel in the first row and the first column are (1.0, 1.0). For a full size image with 1024×1024 pixels the FITS file coordinates of the centre of the CCD are therefore (512.5, 512.5). In the case of windowed images, the reference coordinates (CRPIX1, CRPIX2) can be located outside of the image.

The boresight direction, for which the sky coordinates were computed, corresponds to the centre of CCD pixel (511, 511) [in the index count convention of Section 4.2.4 starting at 0] rather than to the centre of the CCD. For level 3 products the values of CRPIX1 and CRPIX2 were determined from the PDS keywords indicating window size and position as
CRPIX1 = 511 - { CAM_WINDOW_POS_ALONG_ROW - INT[(LINE_SAMPLES+1)/2] }
CRPIX2 = 511 - { CAM_WINDOW_POS_ALONG_COL - INT[(LINES+1)/2] } ,
which results in values of (512.0, 512.0) for full size images. The available level 2 products contain an erroneous offset of 0.5 in these FITS keywords, i.e. values of (512.5, 512.5) for full size images.