OSIRIS-REx Camera Suite (OCAMS) Uncalibrated / Calibrated Data Product Software Interface Specification

OSIRIS-REx DOCUMENT

UA-SIS-9.4.4-300, Rev_7.0

04/04/2019

RELEASED

Prepared by Dani DellaGiustina
(danidg@orex.lpl.arizona.edu)
Updated by M. Katherine Crombie
(crombie@orex.lpl.arizona.edu)

CM FOREWORD

This document is an OSIRIS-REx Project controlled document. Changes to this document require prior approval of the OSIRIS-REx Configuration Control Board (CCB) and Configuration Management Lead (CML). Proposed changes shall be submitted to the OSIRIS-REx Project CML, along with supportive material justifying the proposed change.

Questions or comments concerning this document should be addressed to:

SPOC Configuration Management Team
1415 N. 6th Avenue
Tucson, AZ 85705

Email: spoc-cm@orex.lpl.arizona.edu

SIGNATURE PAGE

Approvers
On file
Dani DellaGiustina (Original Author) OSIRIS-REx Lead Image Processing Scientist
On file
M. Katherine Crombie (Updating Author) OSIRIS-REx Archive Scientist
On file
Dathon Golish Imaging Scientist
On file
Bashar Rizk OCAMS Instrument Scientist
N/A
N/A

Approvers
On file
Nathan Mogk SPOC Systems Engineer
On file
Mike Fitzgibbon OCAMS Software Engineer
On file
Karl Harshman SPOC Project Manager/OCAMS Software Lead
N/A
N/A
N/A

DOCUMENT CHANGE LOG

Version	Description of Change/Remarks	Engineering Change #	DATE (MM/DD/YYYY)
1.1	Initial Release	N/A	05/28/2015
2.0	Modify per Engineering Change Request (ECR)	0006	12/09/2015
3.0	Modify per ECR	0022	04/12/2016
4.0	Modify per ECR	0060, 0064, 0077, CR-123	05/07/2018
5.0	Update per CR	CR-322	10/26/2018
6.0	Update per CR	CR-387	01/22/2019
7.0	Update per CR	CR-395	04/04/2019

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TBRS AND TBDS

Table 1. List of TBDs/TBRs

SECTION ID	DESCRIPTION OF TBD/TBR	DATE OF RESOLUTION
7.5	OCAMS Housekeeping Conversion Polynomials will be provided when they are determined for the flight units.	3/16/2018 – Moved to separate document. AP-8.
7.6	Example PDS labels	3/16/2018
2	OCAMS Instrument Paper is TBW	3/16/2018
4.3.2.1	OCAMS Lookup Tables (LUTs)	3/16/2018
4.3.3	Table 4 Data Volume will be filled in when Rev C of DRM is available	1/15/2017

1 PURPOSE AND SCOPE

The data products described by this Software Interface Specification (SIS) are the OSIRIS-REx Camera Suite (OCAMS) reconstructed telemetry (raw), reduced and calibrated data products. The OSIRIS-REx Science Processing and Operation Center (SPOC) located at the University of Arizona (UA) produce these data products and distribute them to both the OSIRIS-REx Science Team and the Planetary Data System (PDS).

The purpose of this document is to provide users of the data product with a detailed description of the product and a description of how it was generated, including data sources and destinations. The document is intended to provide enough information to enable users to read and understand the data product. The users for whom this document is intended are the scientists who will analyze the data, including those associated with the project and those in the general planetary science community.

2 APPLICABLE DOCUMENTS AND CONSTRAINTS

This Data Product SIS is consistent with the following Planetary Data System Documents:

1. Planetary Data System Standards Reference, Version 1.7.0, September 15, 2016.
2. PDS4 Data Dictionary – Abridged – Version 1.7.0.0, September 30, 2016.
3. PDS4 Information Model Specification, V.1.7.0.0, September 30, 2016.

This Data Product SIS is responsive to the following OSIRIS-REx documents:

4. OSIRIS-REx Science Data Management Plan, UA-PLN-9.4.4-004, Rev 4.0, May, 2016.
5. OSIRIS-REx Science Processing and Operations Center and Planetary Data System Small Bodies Node Interface Control Document, UA-ICD-9.4.4-101, Rev 1.0, October 2013.
6. SPOC – OCAMS Interface Control Document, UA-9.4.4-1002, Version 4.0, June 20. 2017.
7. OSIRIS-REx Coordinate System for Bennu V2, Jan 13, 2016.
8. OSIRIS-REx Housekeeping Conversions Document, Rev. C, December 4, 2015.

This Data Product SIS is consistent with the following documents:

9. Rizk, et al., OCAMS: The OSIRIS-REx Camera Suite, Space Science Reviews, 2018.

Finally, this SIS is meant to be consistent with the contract negotiated between the OSIRIS-REx Project and the Science Processing and Operations Center.

3 RELATIONSHIPS WITH OTHER INTERFACES

Changes to the data products described in this SIS affect software, products or documents listed in Table 2. Only those products indicated with an (A) will be archived.

Table 2. Interface Relationships

Name	Type	Owner
SPOC Database Schema	Product	SPOC
OCAMS MapCam Reconstructed Telemetry (A)	Product	SPOC
OCAMS MapCam Reduced (A)	Product	SPOC
OCAMS MapCam Calibrated (A)	Product	SPOC
OCAMS PolyCam Reconstructed Telemetry (A)	Product	SPOC
OCAMS PolyCam Reduced (A)	Product	SPOC
OCAMS PolyCam Calibrated (A)	Product	SPOC
OCAMS SamCam Reconstructed Telemetry (A)	Product	SPOC
OCAMS SamCam Reduced (A)	Product	SPOC
OCAMS SamCam Calibrated (A)	Product	SPOC
OCAMS Pipeline Software	Software	SPOC
SPOC Archive Packager	Software	SPOC
OSIRIS-REx Science Data Management Plan	Document	Project

4 DATA PRODUCT CHARACTERISTICS AND ENVIRONMENT

4.1 Instrument Overview

The OSIRIS-REx Camera Suite (OCAMS) is a set of three cameras designed to support the mission through all phases, from approach to sample collection (Figure 1). The asteroid is first acquired through the **PolyCam**, an 8" Ritchey-Chretien telescope capable of detecting up to 12th magnitude objects limited by spacecraft jitter. As features on the asteroid become resolvable, PolyCam is used for preliminary mapping at a surface resolution of <25 cm. **MapCam** performs mapping at a suite of phase angles using a panchromatic and four-color filters. The color filters are the *b'*, *v*, *w*, and *x*-bands, which, except for the *b'* filter, are similar in bandwidth to the ECAS filter set used by ground-based astronomers (Figure 2)[Tholen, 1989]. Several major survey campaigns are conducted with both the MapCam and PolyCam to select and characterize potential sample sites on Bennu. Reconnaissance

sample site flyover sorties provide centimeter and sub-centimeter scale Polycam images to provide both context and confirmation of TAGSAM (Touch And Go Sample Acquisition Mechanism) ingestible material. The final sampling sequence is documented by the wide-field **SamCam** and gives the context for the recovered sample. All cameras use identical detector arrays with different focal lengths separated by a factor of 5. The 3 cameras in the instrument suite provide overlapping capabilities and are functionally redundant. [Smith et al. 2013, Rizk et al. 2018].

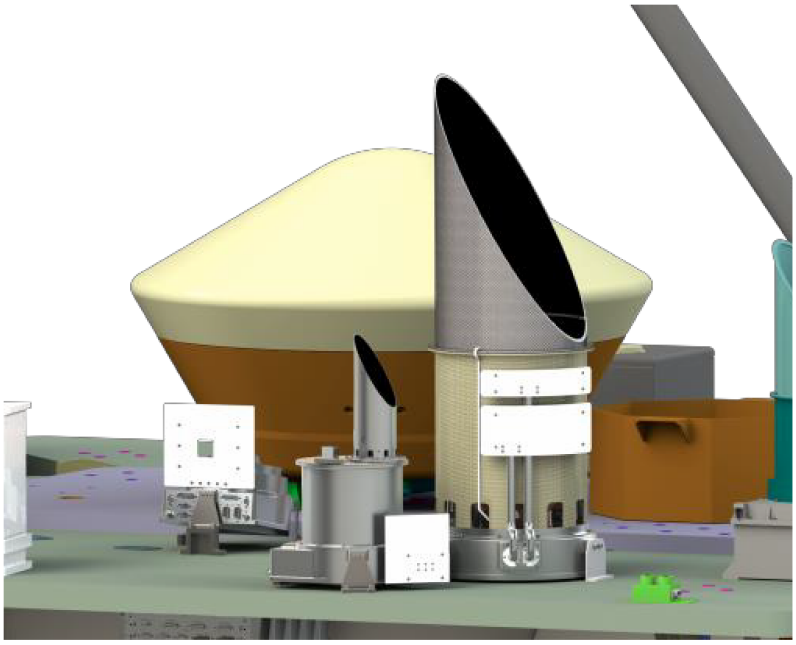


Figure 1. OCAMS Camera Suite.

The three cameras are seen on the instrument deck with the Sample Return Capsule in the background. In the center from left to right: SamCam, MapCam, PolyCam. Notice the electronics control module underneath the deck.

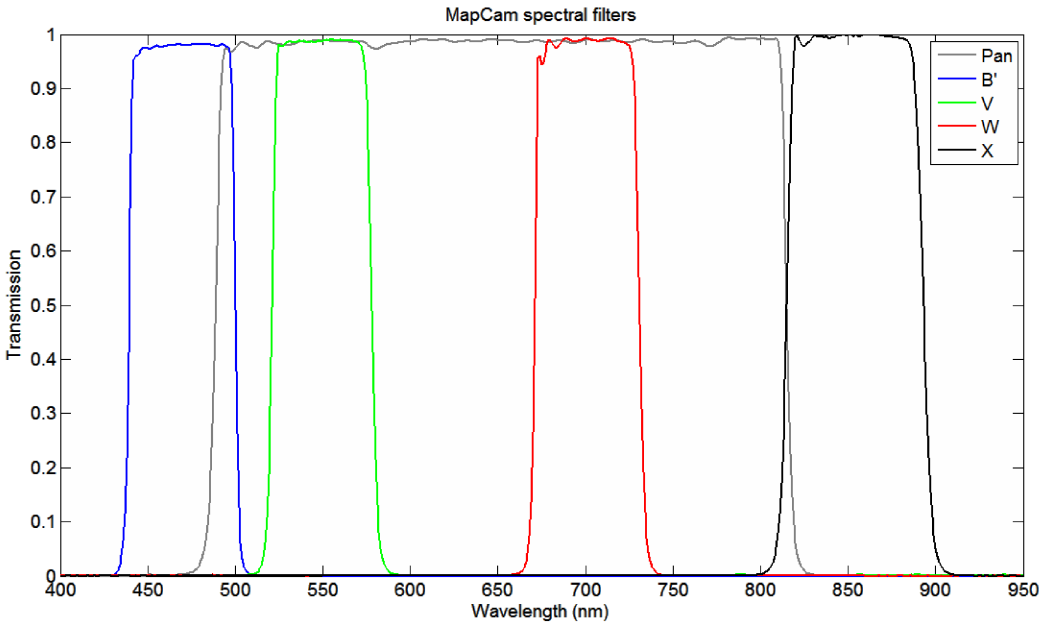


Figure 2. Transmission curves for MapCam's color and panchromatic filters.

4.1.1 Observational Profile and Data Acquisition

Each instrument aboard OSIRIS-REx has specific scientific objectives that support the overall mission objective of collecting and returning to Earth a pristine sample of the asteroid Bennu. Instrument specific observation campaigns have been outlined for each phase of the mission to support sample site selection and overall Bennu characterization. Dates given for the various campaigns are the nominal planning dates and will be updated to actual dates at the conclusion of the mission. The OCAMS observation profile is as follows:

Table 3. OCAMS Observation Profile

Mission Phase	Camera	Observation Campaign Description
Outbound Cruise		
	All	Instrument Health Check, Self-Test
	All	CTE Characterization (charge transfer efficiency in the radiation environment)
	All	Open Cluster Calibration (geometric distortion)
	MapCam	Solar Twin Calibrations (radiometric calibration)
	All	Dark Model Calibration (dark current evolution in the radiation environment)
	All	Calibration Tracing Lamp (pixel-to-pixel fixed noise pattern)
	SamCam	Glint Characterization
	All	Earth-Moon Flyby Observations

Mission Phase	Camera	Observation Campaign Description
Approach		
	PolyCam	Optical Navigation Imaging
	PolyCam	Optical Acquisition of Bennu
	MapCam	Satellite Search
	MapCam	Integrated Light Curve Photometry
	MapCam	Integrated Phase Function Photometry
		Optical Navigation Images
	PolyCam/MapCam	Preliminary Shape Model Imaging
		Dust Environment Survey
Preliminary Survey		
	MapCam	Survey Imaging, North Pole Flyby 1, (12/4/2018)
	MapCam	Survey Imaging, North Pole Flyby 2, (12/6/2018)
	MapCam	Survey Imaging, North Pole Flyby 3, (12/8/2018)
	MapCam	Survey Imaging, Equatorial Flyby, (12/12/2018)
	MapCam	Survey Imaging, South Pole Flyby, (12/16/2018)
Orbit A (1.5km)		
		No Planned Observations
Detailed Survey		
	PolyCam	Baseball Diamond, Flyby 1 (03/07/2019)
	MapCam	Baseball Diamond, Flyby 2 (03/14/2019)
	PolyCam	Baseball Diamond, Flyby 3 (03/21/2019)
	PolyCam	Baseball Diamond, Flyby 4 (03/28/2019)
	PolyCam	Baseball Diamond, Flyby 5 (04/04/2019)
	PolyCam	Baseball Diamond, Flyby 6 (04/11/2019)
	MapCam	Baseball Diamond, Flyby 7 (04/18/2019)
	MapCam	Equatorial Survey, 3 pm, (04/25/2019)
	MapCam	Equatorial Survey, 3:20 am (Plume Search), (05/02/2019)
	MapCam	Equatorial Survey, 12:30 pm, (05/09/2019)
	MapCam	Equatorial Survey, 10 am, (05/16/2019)
	MapCam	Equatorial Survey, 6 am, (05/23/2019)
	MapCam	Equatorial Survey, 8:40pm (Plume Search), (05/30/2019)
	MapCam	Equatorial Survey, 6 pm, (06/05/2019)
Orbital B (1.0km)		
	PolyCam	Global Mapping, (09/2019 - 10/2019)
Reconnaissance		

Mission Phase	Camera	Observation Campaign Description
	PolyCam/MapCam	Site-Specific Imaging
TAG-Rehearsal		
	SamCam	Glint Calibration
	MapCam	Checkpoint Rehearsal
	MapCam & SamCam	Matchpoint Rehearsal
Sample Collection		
	SamCam	Glint Calibration
	MapCam & SamCam	TAG Sampling
	SamCam	Post-Sample Imaging

4.2 Data Product Overview

This SIS describes image and engineering data acquired by OCAMS. Images from all three OCAMS imagers and their associated calibration files are similarly formatted. OCAMS image data are provided natively as binary Flexible Image Transport System (FITS) files. Reconstructed Telemetry data products contain two header data units (HDUs), Uncalibrated data products contain one HDU, and Radiometrically Calibrated products contain one HDU. The first HDU in the Reconstructed Telemetry raw image products contains an image with only the active pixels from the detector array (1024x1024) and a second HDU containing the same image with the overscan and covered regions of the detector array preserved (1112x1044). The overscan regions and the covered regions can be used by the data processing pipeline for bias/dark/charge smear correction. Once the images have been corrected, the overscan and covered pixels are no longer needed, so each Reduced and Calibrated data product contains images with only the active pixels from the detector array. Reduced data products are stored as FITS files with one HDU containing a 1024x1024 image. Calibrated data products are stored as FITS files with one HDU containing a 1024x1024 image with pixel values in physical units. Images are delivered to the PDS as 2D-array structures labeled according to PDS4 standards. It is important to note that image axis labeling from the FITS standard to the PDS standard is opposite. The FITS standard is first-index-fastest, where NAXIS1 is the most quickly changing subscript, whereas the PDS axis labeling convention is last-index-fastest notation. This means that NAXIS2 is labeled in the PDS4 array as axis 1 with and <axis_name> of “line”, and NAXIS1 is labeled as axis 2 with an <axis_name> of “sample”. In this document the FITS axis labeling standard is used to refer to all axes in data products. Images are acquired on a schedule set by the mission Design Reference Mission (DRM). Engineering data acquired with each image include Housekeeping (HK) data and Detector ID packet data (Ancillary Image Information). Housekeeping (HK) data are stored in the SPOC database. Housekeeping records are also acquired periodically, nominally every 2 seconds. The interval over which

housekeeping records are collected can be modified by command, with a range from 1 to 360 seconds. Calibration files necessary to process image data are stored as FITS files. The specific data products described by this SIS are:

1. OCAMS Reconstructed Telemetry (Raw) Images – These images are reconstructed science packet telemetry with associated timing and spatial information (observation geometry) in a FITS format.
2. OCAMS Reduced Images – Reduced images are images that have been corrected to remove instrument noise (bias/dark/charge smear/flat). These images are stored as FITS files.
3. OCAMS Calibrated Images – Calibrated images are images that have been corrected for environmental factors and are converted into units of radiance, spectral radiance, or reflectance. These images are stored as FITS files.
4. OCAMS Housekeeping Data – The housekeeping data are the periodic readings of 39 ADC values and 7 digital channel values stored as binary tables.
5. OCAMS Ancillary Image Information – The detector ID Packet data are the configuration parameters of the detector when an image was taken. These are sent down with each image acquired and stored in a separate engineering data product stored as binary tables.
6. OCAMS Message Data – OCAMS instrument messages give diagnostic information about the instrument stored as binary tables.
7. OCAMS Memory Dump Data – OCAMS memory dumps describing the state of the instrument stored as binary tables.
8. OCAMS Calibration Files - Bad Pixel Map (BP), Bias Correction File (Bias), Dark Current Correction File (D), Bias/Dark Correction File (BD)Flat Field Correction File (FF), and Radiometric Calibration File (R).

Observation geometry (e.g. phase, incidence, emission angles etc.) associated with each image (and pixel within each image) can be calculated using the USGS ISIS3 software and the OSIRIS-REx OCAMS specific camera models. Please see https://isis.astrogeology.usgs.gov for further information on geometric processing of OCAMS images.

4.3 Data Processing

All OSIRIS-REx mission science data processing is performed at the University of Arizona Science Processing and Operations Center (SPOC). OCAMS science and housekeeping telemetry are received by the SPOC via the Lockheed Martin Mission Support Area (MSA) and the DSN. Telemetry data are reconstructed and stored in the SPOC data repository. Reconstructed Telemetry raw image and housekeeping data (OREx Level 0) are retrieved from the data repository, housekeeping physical unit conversions are applied and stored, and reconstructed telemetry raw image data are fed into the OCAMS specific data processing pipeline. The pipeline produces reduced and calibrated OCAMS image. Image and housekeeping data are stored in the SPOC database. Output image data are written as

FITS files and output housekeeping data are written as binary tables. Production rates of images vary over the course of the mission, as images are acquired to meet specific science goals outlined in Table 3. Reconstructed Telemetry raw image data are approximately 4.5 MB, reduced 4.0 MB, and calibrated 8.0 MB. Housekeeping data are acquired at a maximum rate of once every second and are packaged into a single file per day. Level-0 raw Housekeeping records are 150 bytes with a maximum daily file size of approximately 11MB. L1 reduced housekeeping records are 226 bytes per record, for a maximum daily file size of approximately 17.5 MB. Typically, housekeeping data files will be significantly smaller than the maximum file sizes. Ancillary image information is taken at a rate of once per image. Single ancillary image information records are 259 bytes. These data will be packaged as a single file per day. Maximum file size is on the order of 1MB. Specifics of the data processing pipeline can be found in Section 4.3.3 and data format specifications in Section 5 and Appendix 7.4.

4.3.1 Data Processing Level

Table 4 shows the OSIRIS-REx data processing levels of all science data products described by this SIS. Correlation to NASA and CODMAC data processing levels and definitions can be found in Appendix 7.3. Calibration file data processing levels are not discussed, as calibration files require special production techniques.

Table 4. OCAMS Data Processing Levels

OCAMS Data Product	NASA Product Level	OSIRIS-REx Data Processing Level	Description
OCAMS MapCam Reconstructed Telemetry Raw Images	Level-0	L0	Images reassembled from downlinked data packets
OCAMS PolyCam Reconstructed Telemetry Raw Images	Level-0	L0	Images reassembled from downlinked data packets
OCAMS SamCam Reconstructed Telemetry Images	Level-0	L0	Images reassembled from downlinked data packets
OCAMS MapCam Reduced Images	Level-1	L1	Images with instrumental noise signatures removed
OCAMS PolyCam Reduced Images	Level-1	L1	Images with instrumental noise signatures removed
OCAMS SamCam Reduced Images	Level-1	L1	Images with instrumental noise signatures removed
OCAMS MapCam Calibrated Images	Level-2	L2	Images calibrated to physical units ($W\,m^{-2}sr^{-1}$, $W\,m^{-2}sr^{-1}\mu m^{-1}$, or I/F)

OCAMS PolyCam Calibrated Images	Level-2	L2	Images calibrated to physical units *(W m^{-2}sr^{-1}* or I/F)
OCAMS SamCam Calibrated Images	Level-2	L2	Images calibrated to physical units *(W m^{-2}sr^{-1}* or I/F)
OCAMS Ancillary Image Information	Level-0	L0	Command and ID Packet Information
OCAMS Housekeeping Data	Level-0 Level-1	L0 L1	Instrument telemetry Converted Instrument Telemetry

4.3.2 Data Product Generation

As mentioned previously, all OSIRIS-REx science data processing is completed at the SPOC located at the University of Arizona. The decision was made early in the mission lifecycle, that all processing would be centralized to facilitate the relatively quick turnaround needed by the science and operations teams to make tactical decisions about sample site selection.

4.3.2.1 Level 0 - Reconstructed Telemetry (Raw)

OCAMS image and housekeeping telemetry are received from the DSN and passed through the Lockheed Martin Mission Support Area (LM MSA) to the SPOC. The SPOC ingests, sorts, reconstructs, decompresses (if necessary) and stores telemetry data as raw science observation data that includes science observations, timing and spatial information. Timing, spatial and spacecraft attitude information are attached to image headers using spacecraft pointing information (quaternions) that has been received from the spacecraft just prior to receipt of image telemetry. This information is in the form of a SPICE C-kernel that is produced at the Navigational and Ancillary Information Facility (NAIF) and made available to the SPOC via the Flight Operations Bucket (FOB). The C-kernel, attitude header and other timing information is processed by the SPOC to yield the timing, spatial and ancillary information to be attached to the Level 0 raw image headers.

It is possible that image data will be compressed. Up to 12 look up tables (LUTs) can be used to compress the imaging data, although no LUTs are routinely used. Four different tables are currently onboard, the most useful of which approximates the effect of a square-root table. Header data in the telemetry stream will indicate if compression has been applied and which LUT is to be used for decompression. Images will be decompressed and converted to standard reconstructed telemetry format for use.

Reconstructed Telemetry OCAMS raw image and housekeeping data are stored in the OSIRIS-REx SPOC data repository for retrieval by an automated data processing pipeline that corrects and calibrates the reconstructed telemetry images, turning them into the base data products that will be processed into higher level data products used for scientific

analysis. Reconstructed Telemetry raw image and housekeeping data formats are described in Section 5.2.

The OCAMS reconstructed telemetry image data product design is:

- A FITS file with HDU 1 (header/data unit) containing the primary metadata header fields and the primary data unit of the active array (1024(NAXIS1 = sample) x1024 (NAXIS2 = line)).
- HDU 2 will contain CCD region metadata header fields and the secondary data unit of the active array and extended pixel regions (1112(sample)x1044(line)).

The OCAMS reconstructed telemetry housekeeping/instrument information data product design is:

- Ancillary Image Information – Binary Table
- Housekeeping - Binary Table
- Message Data – Binary Table
- Memory Dump Data – Binary Table

The telemetry housekeeping/ instrument information are binary files that are described with PDS4 compliant XML labels (see Section 5.2 for a full description of these data products).

4.3.2.2 Level 1 - Reduced

Reconstructed Telemetry OCAMS data are retrieved from the SPOC data repository by the OCAMS data processing pipeline. The pipeline is an automated series of processing steps that result in a noise corrected image data product that is ready for radiometric, spectral and geometric correction.

The OCAMS pipeline is fed with reconstructed telemetry raw image data. Standard noise reduction processing (bias correction, dark correction, charge smear removal, and flat fielding) is performed on the reconstructed telemetry raw level-0 images. The final corrected image is saved to the SPOC data repository and subsequently to the archive as the level-1 noise corrected reduced image data product. All calibration files used in the creation of this image are identified through keywords in the image headers.

Reconstructed Telemetry housekeeping data are delivered from the spacecraft in digital numbers (DNs). The instrument telemetry housekeeping digest process converts the DN values to physical units where appropriate based on the engineering conversion equations given in Applicable Document 8, OCAMS Housekeeping Conversions.

The final level-1 image data is:

- A FITS file with a single HDU (header/data unit) containing header metadata records and a data unit of the uncalibrated active array (1024x1024).

The final level-1 housekeeping data product is:

- A generic binary table with one record per housekeeping observation.

4.3.2.3 Level 2 - Calibrated

The level 2 calibrated image is radiometrically calibrated to produce an image with values in physical units of either radiance (W $m^{-2}sr^{-1}$), spectral radiance (W $m^{-2}sr^{-1}\mu m^{-1}$), or reflectance (I/F, unitless).

The final level-2 image data is:

- A FITS file with a single HDU (header/data unit) containing header metadata records and a data unit of the radiometrically calibrated active array (1024x1024).

4.3.3 Data Flow

OCAMS reduced and calibrated data products are built up in sequential data processing steps addressing specific corrections or calibrations. All data products are built from raw telemetry ingested into the SPOC data repository system. The OCAMS data processing pipeline queries the SPOC data repository for the raw telemetry science and ancillary data. Data products generated by the OCAMS pipeline are returned to the SPOC data repository for storage. The OSIRIS-REx Instrument and Science Teams access the data repository through a query tool.

Table 5 shows the expected OCAMS data collection by detector and mission phase. The number of expected images is specified as well as the expected data volume of the processed data products. (Note: Level-0 data products are 4.4 MB, Level-1 data products are 4.0 MB and Level-2 data products are 8.0 MB)

Table 5. OCAMS Data Products/ Volume by Mission Phase

Mission Phase	Launch	Cruise	Approach	Prelim Survey	Orbit A	Detailed Survey	Orbit B	Recon	TAG Reher	Sample Collect
PolyCam # Images	191	233	2279	4104	0	1671	596	802	0	1910
PolyCam RT (MB)	848	1033	10119	18222	0	7419	2646	3561	0	8480.
PolyCam Uncal (MB)	800	976	9549	17196	0	7001	2497.	3360	0	8003
PolyCam Cal (MB)	1700	2074	2028	36526	0	14872	5304	7138	0	16999
MapCam # Images	192	1207	2179	92	0	3985	2529	1126	368	483
MapCam RT (MB)	852	5359	9675	408	0	17693	11229	4999	1634	2145
MapCam Uncal (MB)	804	5057	9130	385	0	16697	10597	4718	1542	2024
MapCam Cal (MB)	1709	10742	19393	819	0	35467	2250	10021	3275	4299
SamCam # Images	191	233	191	0	0	0	191	42	194	519

Mission Phase	Launch	Cruise	Approach	Prelim Survey	Orbit A	Detailed Survey	Orbit B	Recon	TAG Reher	Sample Collect
SamCam RT (MB)	848.	1035	848	0	0	0	848	187	861	2304
SamCam Uncal (MB)	800.	976	800	0	0	0	800	176	813	2175
SamCam Cal (MB)	1700	2074	1700	0	0	0	1700	374	1727	4619

It is possible that more than one version of the Reconstructed Telemetry raw, Reduced and Calibrated images maybe produced. This is not intended to be routine but may occur if one or more calibration files needs to be updated. Any changes to the data processing pipeline are configuration controlled and follow the standard OSIRIS-REx configuration control process. Re-processed images are identified in the filename (see 4.3.4) and are noted as to why re-processing was necessary.

4.3.4 Labeling and Identification

All OCAMS data products are labeled with PDS4 compliant detached XML labels. These labels describe the content and format of the associated data product. Labels and products are associated by file name with the label having the same name as the data product except that the label file has an .xml extension.

Labels are constructed with the PDS4 Product Class, Product_Observational sub-class. The Product_Observational sub-class describes a set of information objects produced by an observing system. A hierarchical description of the contents of Product_Observational products is

Product_Observational
- Identification_Area - attributes that identify and name an object
  - Logical_Identifier - name/location of file
  - Version_ID - version of product
  - Title - Descriptive name of product
  - Information_model_version - version of PDS4 information model used to create product
  - Product_Class - attribute provides the name of the product class (Product_Observational)
  - Modification_History - attributes describing changes in data product
- Observation_Area - attributes that provide information about the circumstances under which the data were collected.
  - Time_Coordinates - time attributes of data product
  - Primary_Results_Summary - high-level description of the types of products included in the collection or bundle; facilitates data discovery.

Investigation_Area - mission, observing campaign or other coordinated, large-scale data collection attributes
Observing_System - observing system (instrument) attributes
Target_Identification - observation target attributes
Mission_Area - mission specific attributes needed to describe data product
File_Area_Observational - describes a file and one or more tagged_data_objects contained within.
File - identifies the file that contains one or more data objects
Table_Binary - defines a simple binary table.

Information in the preceding paragraphs was distilled from the PDS4 Information Model provided by PDS. Additional information on product labels can be found at https://pds.nasa.gov/pds4/about/index.shtml.

OSIRIS-REx science data products are identified (named) according to the OSIRIS-REx Naming Conventions Document (UA-HBK-9.4.4-905). The following paragraphs are excerpts of this document that describe how OCAMS image and housekeeping files are named. The generalized file naming convention is:

UTC Time + "_" + Instrument + "_" + Product Type + "." + PDS Type

UTC Time in the YYYYMMDD"T"HHMMSS"S"sss format is derived from SCLK time of the observation in spacecraft clock ticks as translated by the appropriate SPICE SCLK kernel. Daily products can use the date format YYYYMMDD instead of the full UTC time of the first observation.

The **instrument** is one of the following:

Table 6. Instrument Abbreviations

Abbreviation	Instrument Name
ocm	OCAMS
pol	PolyCam
map	MapCam
sam	SamCam
ncm	NavCam
nft	NFT
stw	StowCam
ola	OLA

ote	OTES
ovr	OVIRS
rex	REXIS
rxm	REXIS Solar-X-Ray Monitor

The **product type** is the step in the data processing system that executed to produce this particular data product. The product types for OCAMS are:

Table 7. OCAMS Data Product Type

Product Type	Definition
L0	Reconstructed Telemetry
L0ss	Reconstructed Telemetry, Sun Safe Blocking Filter
L0x	Reconstructed Telemetry, MapCam X-filter, Bandpass centered at 860 nm
L0w	Reconstructed Telemetry, MapCam W-filter, Bandpass centered at 700 nm
L0v	Reconstructed Telemetry, MapCam V-filter, Bandpass centered at 550 nm
L0b	Reconstructed Telemetry, MapCam B-filter, Bandpass centered at 470 nm
L0pan	Reconstructed Telemetry, MapCam Panchromatic (500-800 nm) filter focused at ≥125 m
L0sscal	Reconstructed Telemetry, Sun Safe blocking filter/Calibration position
L0pan30	Reconstructed Telemetry, MapCam Panchromatic (500-800 nm) filter focused at 30 m
L0pan1	Reconstructed Telemetry, SamCam Panchromatic (500-800 nm) filter focused at 5 m (same as L0pan4 and L0pan5)
L0diop	Reconstructed Telemetry, Panchromatic Diopter (500-800 nm) filter focused at 2 m
L0pan4	Reconstructed Telemetry, SamCam Panchromatic (500-800 nm) filter focused at 5 m (same as L0pan1 and L0pan5)
L0pan5	Reconstructed Telemetry, SamCam Panchromatic (500-800 nm) filter focused at 5 m (same as L0pan4 and L0pan1)
L0unknown	Reconstructed Telementry with a motor position (MTR_POS) and camera id (CAMERAID) not defined in Table 10 – OCAMS Filter names.
L1	Bias, Dark, Flat Field Corrected

Product Type	Definition
L1ss	Bias, Dark, Flat Field Corrected, Sun Safe Blocking Filter
L1x	Bias, Dark, Flat Field Corrected, MapCam X-filter, Bandpass centered at 860 nm
L1w	Bias, Dark, Flat Field Corrected, MapCam W-filter, Bandpass centered at 700 nm
L1v	Bias, Dark, Flat Field Corrected, MapCam V-filter, Bandpass centered at 550 nm
L1b	Bias, Dark, Flat Field Corrected, MapCam B-filter, Bandpass centered at 470 nm
L1pan	Bias, Dark, Flat Field Corrected, MapCam Panchromatic (500-800 nm) filter focused at ≥125 m
L1pan30	Bias, Dark, Flat Field Corrected, MapCam Panchromatic (500-800 nm) filter focused at 30 m
L1pan1	Bias, Dark, Flat Field Corrected, SamCam Panchromatic (500-800 nm) filter focused at 5 m
L1diop	Bias, Dark, Flat Field Corrected, Panchromatic Diopter (500-800 nm) filter focused at 2 m
L1pan4	Bias, Dark, Flat Field Corrected, SamCam Panchromatic (500-800 nm) filter focused at 5 m
L1pan5	Bias, Dark, Flat Field Corrected, SamCam Panchromatic (500-800 nm) filter focused at 5 m
radL2	Radiometrically Calibrated (Radiance Units). This only exists for panchromatic images.
specradL2x	Spectral Radiance Units, MapCam X-filter, Bandpass centered at 860 nm
specradL2w	Spectral Radiance Units, MapCam W-filter, Bandpass centered at 700 nm
specradL2v	Spectral Radiance Units, MapCam V-filter, Bandpass centered at 550 nm
specradL2b	Spectral Radiance Units, MapCam B-filter, Bandpass centered at 470 nm
radL2pan	Radiance Units, MapCam Panchromatic (500-800 nm) filter focused at ≥125 m
radL2pan30	Radiance Units, MapCam Panchromatic (500-800 nm) filter focused at 30 m
radL2pan1	Radiance Units, SamCam Panchromatic (500-800 nm) filter focused at 5 m
radL2diop	Radiance Units, Panchromatic Diopter (500-800 nm) filter focused at 2 m
radL2pan4	Radiance Units, SamCam Panchromatic (500-800 nm) filter focused at 5 m
radL2pan5	Radiance Units, SamCam Panchromatic (500-800 nm) filter focused at 5 m
iofL2	Radiometrically Calibrated (Reflectance Units)
iofL2ss	Reflectance Units, Sun Safe Blocking Filter

Product Type	Definition
iofL2x	Reflectance Units, MapCam X-filter, Bandpass centered at 860 nm
iofL2w	Reflectance Units, MapCam W-filter, Bandpass centered at 700 nm
iofL2v	Reflectance Units, MapCam V-filter, Bandpass centered at 550 nm
iofL2b	Reflectance Units, MapCam B-filter, Bandpass centered at 470 nm
iofL2pan	Reflectance Units, MapCam Panchromatic (500-800 nm) filter focused at ≥125 m
iofL2pan30	Reflectance Units, MapCam Panchromatic (500-800 nm) filter focused at 30 m
iofL2pan1	Reflectance Units, SamCam Panchromatic (500-800 nm) filter focused at 5 m
iofL2diop	Reflectance Units, Panchromatic Diopter (500-800 nm) filter focused at 2 m
iofL2pan4	Reflectance Units, SamCam Panchromatic (500-800 nm) filter focused at 5 m
iofL2pan5	Reflectance Units, SamCam Panchromatic (500-800 nm) filter focused at 5 m
hkL0	Housekeeping Level 0
hkL1	Housekeeping Level 1
anciL0	Ancillary Image Information
dump	Memory dump
msg	Messages

Note that the filter name always reflects the motor position as received in the imager header. If the commanded filter position was not set or the filter did not arrive in the proper position, OCAMS would safe itself.

The **PDS type** file suffix indicates the type of file the data product is. OCAMS data products have one of two file type suffixes, .fits for image files and .dat for housekeeping tables.

An example files name for a single product as it makes its way through the data processing pipeline are:

20130122T100443S0000Z_map_L0x.fits
20130122T100443S0000Z_map_L1.fits
20130122T100443S0000Z_map_radL2x1.fits
20130122T100443S0000Z_map_iofL2x.fits

Calibration files will be named according to the convention:

ocams_[cam]_[tap]_[filter]_[*exposure]*_[calibration name]_[start date]_[end date]_v[version].fits

Where:

[cam] is the camera name truncated to three characters (sam, map, pol).

[tap] is the first letter of the tap (s, a, l or r for dual, all, left or right)

[filter] is the full name of the filter (e.g., all, pan, b, v, w, x, pan4, pan5, pan1, pan 30, diop, ss, sscal)

[*exposure*] only exists for darks and bias/darks. It is the actual exposure out to 6 decimal places with a 'p' used instead of the decimal point. It does NOT include the units ('ms') at the end. e.g., 500p285275

[calibration name] is the full name of the calibration type. (BP = Bad Pixel, Bias = Bias, Bias/Dark = BD, Flat Field =FF, Radiomentry =R)

[start date] is the starting date and time for the applicable time range of the calibration file in the format YYYYMMDDTHHmmss

[end date] is the ending date and time for the applicable time range of the calibration file in the format YYYYMMDDTHHmmss

[version] is an incrementing three-digit version number start from 001. The version will increase every time a calibration file is uploaded with a computed filename which is found to be the same as another already stored.

An example OCAMS calibration file names are;

- ocams_sam_a_all_BP_20150120T000000_20500101T000000
- ocams_map_a_v_FF_20150120T000000_20500101T000000

4.4 Standards Used in Generating Data Products

4.4.1 PDS Standards

All data products described in this SIS conform to PDS4 standards as described in the PDS Standards document noted in the Applicable Documents section of this SIS. Prior to public release, all data products will have passed both a data product format PDS peer review and a data product production pipeline PDS peer review to ensure compliance with applicable standards.

4.4.2 Time Standards

Time Standards used by the OSIRIS-REx mission conform to PDS time standards. All OSIRIS-REx data products contain both the spacecraft clock time at the start of data acquisition and a conversion to UTC of both the start and middle of the data acquisition to facilitate comparison of data products.

4.4.3 Coordinate Systems

All coordinate systems used by the OSIRIS-REx mission conform to IAU standards. A complete discussion of the coordinate systems and how they are deployed in the mission can be found in the document "OSIRIS-REx Coordinate System Plan" found in the archive documents directory.

4.4.4 Data Storage Conventions

FITS data products are stored according to the FITS 3.0 Standard. Binary data products are stored as big-endian (MSB) binary.

4.5 Data Validation

The SPOC has a comprehensive Verification and Validation Plan for all software used at or developed by the SPOC. All software is configuration controlled and any changes made follow the SPOC Configuration Control Plan, which includes substantive testing of changes. During day-to-day production of L0 data products from telemetry, check sums and spot checks are used to validate that software is producing data products correctly.

In addition to software verification and validation, each OSIRIS-REx data product has been peer reviewed for both PDS data format acceptability and scientific usefulness. No changes are expected to data formats after peer review. The SPOC Configuration Control Plan governs any changes, should they be needed.

When data is prepared for submission to the PDS, both the OCAMS and SPOC Teams will use PDS / mission-provided validation tools for conformance to the PDS4 standards. The OCAMS and Image Processing Working Groups will validate the scientific data within the data products using a variety of methods and tools.

5 DETAILED DATA PRODUCT SPECIFICATIONS

5.1 Data Product Structure and Organization

The OSIRIS-REx data archive is organized by instrument. The OCAMS portion of the archive is organized by mission phase and then by processing level. Both image and housekeeping data are stored together. All image data is stored as FITS files with a detached PDS label. The detached PDS labels are PDS4 compliant XML labels that describe the contents of the image file and record the significant portions of the FITS header for data processing and interpretation. See the Label Example sub-directory in the OCAMS document collection for an example label.

Housekeeping and Ancillary Image Information Data are stored as a binary tables with detached PDS labels. The detached PDS labels are PDS4 compliant XML labels that describe the specific structure of the binary table. The tables are:

1. L0 Housekeeping – a daily collection of 96-field, 150-byte records of raw instrument housekeeping telemetry. Data are in digital number (DN) format.
2. L1 Housekeeping – a daily collection of 94-fields, 250-byte records of analog to digital (ADC) DN values converted to physical units and all bit fields converted to byte values.
3. Ancillary Image Information – a daily collection of 162-field, 259-byte records of command and ID packet information in DN format. DN values converted to physical units are found in the L1 image headers and labels.

The OCAMS bundle directory structure is as follows:

orex.ocams

calibration – calibration files used in processing
data_eng – ancillary image information products
- cruise_1
- ega
- cruise_2
- approach
- preliminary survey
- orbital a
- detailed survey
- orbital b
- reconnaissance
- rehearsal
- TAG (Touch-and-go)

data_hkl0 – raw level 0 housekeeping
- cruise_1
- ega
- cruise_2
- approach
- preliminary survey
- orbital a
- detailed survey
- orbital b
- reconnaissance
- rehearsal
- TAG (Touch-and-go)

data_hkl1 – reduced level 1 housekeeping
- cruise_1
- ega
- cruise_2
- approach
- preliminary survey
- orbital a
- detailed survey
- orbital b
- reconnaissance
- rehearsal
- TAG (Touch-and-go)

data_raw – level 0 raw image products
- cruise_1

ega
cruise_2
approach
preliminary survey
orbital a
detailed survey
orbital b
reconnaissance
rehearsal
TAG (Touch-and-go)

data_reduced – level 1 reduced image products
cruise_1
ega
cruise_2
approach
preliminary survey
orbital a
detailed survey
orbital b
reconnaissance
rehearsal
TAG (Touch-and-go)

data_calibrated – level 2 calibrated image products
cruise_1
ega
cruise_2
approach
preliminary survey
orbital a
detailed survey
orbital b
reconnaissance
rehearsal
TAG (Touch-and-go)

document – OCAMS documentation
label_examples

5.2 Data Format Descriptions

All OCAMS science data is stored natively in FITS file formats and delivered to the PDS in PDS4 compliant 2D Image arrays. Reconstructed Telemetry (raw) image (L0) FITS headers and PDS Labels contain raw (DN) telemetry values for ADC readings. Reduced (L1) FITS headers and PDS labels have ADC readings that are converted to physical units, e.g. 1252 -> 22.21C for the keyword 'MCFWHTMP', in the example below. Calibrated (L2) FITS headers and PDS labels also contain attributes in physical units where appropriate. All FITS keywords that are relevant for scientific interpretation of the data products are captured in the PDS label generally in the mission class.

5.2.1 OCAMS Image File Formats

5.2.2 Level 0 Raw Image Format

The L0 raw OCAMS image format is a two HDU FITS file, with the first HDU containing a 1024(sample) x1024 (line) active array image, and the second a 1112(sample) x1044 (line) active plus extended area array image in units of DN. Metadata contained in the FITS header and its mapping to class and attribute in the PDS4 .xml label structure is listed in the table below. Metadata descriptions may be abbreviated in the FITS header, with full descriptions in the label.

Table 8. OCAMS L0 raw image metadata

Attribute Name	FITS Keyword	Units	Description
element_array.data_type	BITPIX		number of bits per data pixel (16 for L0)
axes	NAXIS		number of data axes
axis_array.sequence_number	NAXIS1		length of FITS data axis 1 equivalent to sample
axis_array.sequence_number	NAXIS2		length of FITS data axis 2 equivalent to line
n/a - FITS specific	EXTEND		FITS dataset may contain extensions
element_array.value_offset	BZERO		offset data range to that of unsigned short
element_array.scaling_factor	BSCALE		default scaling factor
n/a - FITS specific	DATE		Creation date (YYYY-MM-DD) of FITS header, not the date of observation
investigation_area.name	MISSION		Mission: OSIRIS-REx
observing_system.name	HOSTNAME		PDS terminology for spacecraft name
observing_system_component.name	INSTRUME		Instrument: OSIRIS-Rex Camera Suite
target_identification.name	TARGET		Name of the target of interest for observation
n/a - FITS specific	ORIGIN		University of Arizona Science Processing and Operations Center
mission_identification.mission_phase_name	MPHASE		Mission phase of the OSIRIS REx mission. Mission phase possibilities include outbound cruise, approach, preliminary survey, orbital a, detailed survey, orbital b, reconnaissance, rehearsal, and TAG (Touch-and-go)
primary_results_summary.purpose	ACTIVITY		Equivalent to primary result summary
mission_area.apid	APID		Application Identification Number
mission_area.ground_receipt_time	GRT		Ground Receive Time in UTC (YYYY-MM-DDThh:mm:ss.sss)
mission_area.sclk_string	SCLK_STR		Spacecraft Clock String at start of image observation
mission_area.mid_obs_et	ET	s	Ephemeris Time (seconds past J2000 epoch, TDB - Barycentric Dynamical Time) at the mid-observation time
mission_area.date_of_observation	DATE_OBS		Observation start time in UTC (YYYY-MM-DDThh:mm:ss.sss)
mission_area.mid_obs	MIDOBS		Spacecraft mid-obs time, UTC [YYYY-MM-DDThh:mm:ss.sss] (DATE_OBS + .5*EXPTIME).
mission_area.exposure	EXPTIME	ms	Exposure time in milliseconds
mission_area.exposec	EXPOSEC	s	Exposure time in seconds

Attribute Name	FITS Keyword	Units	Description
mission_area.delta_obs	DELTAOBS	s	Delta between mid-observation time and spacecraft clock string (Mid-observation time) - (SCLK_STR timestamp), in seconds used to verify exposure time.
mission_area.int_time	n/a	ms	Image integration time
mission_area.meta_ker	META_KER		Metakernel that holds all the spice kernels used for processing
mission_area.ckqual	CKQUAL		Quality of C-Kernel (nominal = 'RECONSTRUCT', contingency = 'PREDICT')
geom.qcos	SC_QA		Spacecraft quaternion in J2000 (q0 = cos(t/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time. SPICE quaternion standard is that Q0 is the scalar value.
geom.qsin1	SC_QX		Spacecraft quaternion in J2000 (q1 = sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time. SPICE quaternion standard is that Q0 is the scalar value.
geom.qsin2	SC_QY		Spacecraft quaternion in J2000 (q2= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qsin3	SC_QZ		Spacecraft quaternion in J2000 (q3= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qcos	INST_QA		Instrument quaternion in J2000 (q0 = cos(t/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels.

Attribute Name	FITS Keyword	Units	Description
			Calculations will be based on the MIDOBS time. SPICE quaternion standard is that Q0 is the scalar value.
geom.qsin1	INST_QX		Instrument quaternion in J2000 (q1= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qsin2	INST_QY		Instrument quaternion in J2000 (q2= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qsin3	INST_QZ		Instrument quaternion in J2000 (q3= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
mission_area.object	OBJECT		Object Name
mission_area.ctype1	CTYPE1		Coordinate type for reference pixel, values are either ''RA---TAN'' = gnomic or tangent plane or "SIP" - simple image polynomial.
mission_area.ctype2	CTYPE2		Coordinate type for the reference pixel, values are either ''DEC--TAN'' = gnomic or tangent plane or "SIP" - simple image polynomial.
geom.right_ascension_angle	CRVAL1	Deg	Right ascension of the reference pixel or boresight vector in degrees.
geom.declination_angle	CRVAL2	Deg	Declination of reference pixel or boresight vector in degrees.
mission_area.cunit1	CUNIT1	Deg	Units for reference pixel 1 (CRPIX1)
mission_area.cunit2	CUNIT2	Deg	Units for reference pixel 2 (CRPIX2)
geom.horizontal_coordinate_pixel	CRPIX1		X coordinate pixel number of the boresight reference point to which the projection and the rotation refer.
geom.verticle_coordinate_pixel	CRPIX2		Y coordinate pixel number of the boresight reference point to which the projection and the rotation refer.
mission_area.cd1_1	CD1_1	Deg	Change in RA per pixel along first axis (sample) evaluated at reference pixel
mission_area.cd1_2	CD1_2	Deg	Change in RA per pixel along second axis (line) evaluated at reference pixel

Attribute Name	FITS Keyword	Units	Description
mission_area.cd2_1	CD2_1	Deg	Change in DEC per pixel along first axis (sample) evaluated at reference pixel
mission_area.cd2_2	CD2_2	Deg	Change in DEC per pixel along second axis (line) evaluated at reference pixel
mission_area.radesys	RADESYS		International Celestial Reference System (ICRS)
mission_area.equinox	EQUINOX		Epoch of mean equator and equinox (J2000)
geom.celestial_north_clock_angle	ORIENTAT	Deg	The angle (in degrees measured East of North) of the y axis of the detector projected on the sky
mission_area.boresight_lat	LAT	Deg	Boresight latitude of the imaging location
mission_area.boresight_lon	LON	Deg	Boresight longitude of the imaging location
mission_area.bennu_ra	BENNURA	Deg	Right Ascension of the vector, expressed in the Earth Mean Equator of the J2000 Epoch, from the ORX spacecraft toward the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value
mission_area.bennu_dec	BENNUDEC	Deg	Declination of the vector, expressed in the Earth Mean Equator of the J2000 Epoch, from the ORX spacecraft toward the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value
mission_area.bennu_naxis1_offset	BENNUNX1	Pixel	Approximate offset from CRPIX1 pixel in +NAXIS1 direction of the location of the center of the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value; assumes undistorted optics
mission_area.bennu_naxis2_offset	BENNUNX2	Pixel	Approximate offset from CRPIX2 pixel in +NAXIS2 direction of the location of the center of the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value; assumes undistorted optics
mission_area.bennana	BENNANA	Deg	Azimuth of the North polar Axis of the target named in FITS keyword BENNURDT (typically Bennu), positive from the +NAXIS2 direction toward the +NAXIS1 direction; see also BENNURDQ for a statement of the quality of this value; assumes undistorted optics; will be -999 if the calculation fails
mission_area.bennu_radec_target	BENNURDT		Target for the BENNURA, BENNUDEC, BENNUNX1 and BENNUNX2 FTIS keywords; typically, BENNU; may be NONE if the calculation failed. Target is not required to be in the field of view.
mission_area.bennu_radec_quality	BENNURDQ		(Quality: provenance) for the BENNURA, BENNUDEC, BENNUNX1, BENNUNX2 FITS keywords. This will be one of three values: (BEST: SPK), meaning the geometry was obtained from SPICE SP-Kernels; (POOR:

Attribute Name	FITS Keyword	Units	Description
			osculating elements; +/-1E6km), meaning the geometry was obtained from osculating orbital elements of Bennu w.r.t the Sun, and will have uncertainties of order 1E6km; (NONE: FAILURE), meaning both the SPK and elements methods failed; the parentheses, (), are only delimiters here and not part of the quality:provenance values.
mission_area.sc2sun_uvx	SUNSCUVX		X component of Cartesian coordinate system unit vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_uvy	SUNSCUVY		Y component of Cartesian coordinate system unit vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_uvz	SUNSCUVZ		Z component of Cartesian coordinate system unit vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_range_km	SUNSCRNG	km	Range component of spherical coordinate system vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_theta_deg	SUNSCTHE	Deg	Theta component (angle around +Z from XZ plane, positive from +X toward +Y) of spherical coordinate system vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_phi_deg	SUNSCPHI	Deg	Phi component (angle from XY plane, positive toward +Z) of spherical coordinate system vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.creator	CREATOR		Creator of this product
mission_area.file_creation	SPOCDATE		Date of creation of this file
mission_area.spoc_version	SPOCIVER		SPOC ingest software version information
mission_area.control_file	IN_FILE		Data origin/provenance information
mission_area.dispornt	DISPORNT		Image origin (0,0) is located in the bottom-left corner of the display. This is the standard FITS display orientation.
mission_area.min_pixel_value	MINVAL		Minimum image pixel value in dynamic range recorded by the instrument.
mission_area.max_pixel_value	MAXVAL		Maximum image pixel value in dynamic range recorded by the instrument.
mission_area.quality_flag	DQ_FLAG		Data quality flag, 0 = good. This field will be updated as more data quality flags are used in the automated processing of images.
mission_area.misspxls	MISSPXLF		Number of pixels in the entire 1112x1044 CCD that were zero filled as a result of data loss

Attribute Name	FITS Keyword	Units	Description
mission_area.misspxla	MISSPXLS		Number of pixels in the 1024x1024 active area that were zero filled as a result of data loss
mission_area.total_checksum	CHCKSUM		The pass/fail state of the image check sum as transmitted from the instrument.
mission_area.data_source	DATASRC		Origin of image data TEST or FLIGHT
mission_area.units	UNITS		Units of quantities in both the header (label) and image array
mission_area.camera_id	CAMERAID		ID of camera in use. 0- Map, 1-Sam, 2-Poly. Note that the numeric values for ACTV_CAM are different, but the named camera will be identical.
mission_area.ccd_rev_num	CCD_NUM		CCD revision number
mission_area.board_rev_num	CCD_BRD		CCD board revision number
mission_area.fpga_rev_num	FPGAREV		FPGA revision number
mission_area.device_id	DEVICEID		Analog to digital converter device revision identifier
mission_area.image_id	IMAGEID		Identifier that is associated with an image
mission_area.image_type_code	IMAGETYP		Type of image commanded. LIGHT (science observation), BIAS (calibration) , DARK (calibration), LAMP (calibration), OTHER
mission_area.egain	EGAIN	e-/ADU	Electronic gain in electrons per analog-to-digital units
mission_area.seconds_raw	SECOND	s	Camera control module (CCM) seconds for start of exposure
mission_area.subseconds_raw	SUBSEC		Camera control module sub-seconds for start of exposure
mission_area.readout_mode	READOUTM		Readout mode of detector
mission_area.detector_mode	IMG_CMD		Imaging command mode.
mission_area.vcte_csr	VCTECSR		Vertical over scan count
mission_area.hcte_csr	HCTECSR		Horizontal over scan count
mission_area.motor_pos	MTR_POS		Filter wheel or focus position
mission_area.filtname	FILTNAME		Filter name: SS - sun safe, X - 860 nm filter, W - 700 nm filter, V - 550 nm filter, B - 470 nm filter, PAN - panchromatic filter focused at greater than or equal to 125 m, SSCAL - sun safe blocking filter calibration prosition, PAN30 - panchromatic filter focuses at 30 m, PAN1 - panchromatic filter focused at 5 m, PAN4 - panchromatic filter focused at 5 m , PAN5 - panchromatic filter focused at 5 m
mission_area.secondary_ik_num	PCNAIFID		Secondary Instrument-Kernel number for variable optics. See the ORX OCAMS Instrument kernel (SPICE collection) for the full definition of this parameter.
mission_area.cal_lamp_sel	LAMP_SEL		Bitwise Camera of the active illumination lamp
mission_area.lut	LUT		Currently selected LUT number: 0=None. 1=square, 2=chop6, 3= chop8, 4=squareroot. The description of this field will be updated as more LUTS are added.
mission_area.mapcam_ccd_heater	MCCCDHTR		MapCam CCD heater, on/off state

Attribute Name	FITS Keyword	Units	Description
mission_area.mapcam_ccd_temp	MCCCDTMP	DN	MapCam CCD resistance temperature detector temperature
mission_area.polycam_ccd_heater	PCCCDHTR		PolyCam CCD heater, on/off state
mission_area.polycam_ccd_temp	PCCCDTMP	DN	PolyCam CCD resistance temperature detector (RTD) temperature
mission_area.samcam_ccd_heater	SCCCDHTR		SamCam CCD heater, on/off state
mission_area.samcam_ccd_temp	SCCCDTMP	DN	SamCam CCD resistance temperature detector (RTD) temperature
mission_area.main_config	MAIN_CFG		Main configuration
mission_area.power_control	PWR_CTRL		Power down control
mission_area.active	ACTV_CAM		Camera number of active camera (1-Map, 2-Sam, 3-Poly). Note that the numeric values are different than those of the CAMERAID.
mission_area.standby	CAM_PWR		Bitwise non-Off state of the cameras: 1=MapCam, 2=SamCam, 4=PolyCam
mission_area.min_cnt	MIN_CNT	min	Number of minutes since reset
mission_area.action_mode	ACTENABL		Action sequence enable mode: 0=off, 1=on
mission_area.motor_select	MTR_SEL		Camera number of the active motor
mission_area.motor_zone	MTR_ZONE		Width of the last home command's index (>31 is 31)
mission_area.index_led_sel	LED_SEL		Camera number of the active motor index LED set
mission_area.index_led_read	LED_SENS		Bitwise read of the active LED sensors
mission_area.mapcam_filt_house_heater	MCFWHHTR		State of the heater: 0=off, 1=on
mission_area.mapcam_fwh_temp	MCFWHTMP	DN	MapCam Filter Wheel Housing Thermistor
mission_area.mapcam_filt_motor_heater	MCFTMHTR		State of the heater: 0=off, 1=on
mission_area.mapcam_fwm_temp	MCFWMTMP	DN	MapCam Filter Wheel Motor Thermistor
mission_area.mapcam_lens_heater	MCLENHTR		State of the heater: 0=off, 1=on
mission_area.mapcam_len_temp	MCLENTMP	DN	MapCam Lens Thermistor
mission_area.mapcam_readout_elect_heater	MCROEHTR		State of the heater: 0=off, 1=on
mission_area.mapcam_roe_temp	MCROETMP	DN	MapCam Read Out Electronics Thermistor
mission_area.polycam_focus_house_heater	PCFOHHTR		State of the heater: 0=off, 1=on
mission_area.polycam_foh_temp	PCFOHTMP	DN	PolyCam Focus Housing Thermistor
mission_area.polycam_focus_motor_heater	PCFOMHTR		State of the heater: 0=off, 1=on
mission_area.polycam_fom_temp	PCFOMTMP	DN	PolyCam Focus Motor Thermistor
mission_area.polycam_primary_heater	PCMR1HTR		State of the heater: 0=off, 1=on
mission_area.polycam_mirror_1_temp	PCMR1TMP	DN	PolyCam Primary Mirror Thermistor
mission_area.polycam_readout_elect_heater	PCROEHTR		State of the heater: 0=off, 1=on
mission_area.polycam_roe_temp	PCROETMP	DN	PolyCam Read Out Electronics Thermistor
mission_area.samcam_filt_house_heater	SCFWHHTR		State of the heater: 0=off, 1=on
mission_area.samcam_fwh_temp	SCFWHTMP	DN	SamCam Filter Wheel Housing Thermistor
mission_area.samcam_filt_motor_heater	SCFWMHTR		State of the heater: 0=off, 1=on
mission_area.samcam_fwm_temp	SCFWMTMP	DN	SamCam Filter Wheel Motor Thermistor
mission_area.samcam_lens_heater	SCLENHTR		State of the heater: 0=off, 1=on
mission_area.samcam_len_temp	SCLENTMP	DN	SamCam Lens Thermistor
mission_area.samcam_readout_elect_heater	SCROEHTR		State of the heater: 0=off, 1=on
mission_area.samcam_roe_temp	SCROETMP	DN	SamCam Read Out Electronics Thermistor
mission_area.htr_brd_temp	HTRBDTMP	DN	Heater board temperature (unbuffered)
mission_area.dpu_brd_temp	DPUBDTMP	DN	Digital processing unit (DPU) board temperature.

Attribute Name	FITS Keyword	Units	Description
mission_area.lvps_brd_temp	LVPBDTMP	DN	Low voltage power supply (LVPS) board temperature
mission_area.motor_brd_temp	MTRBDTMP	DN	Motor Board Temperature
mission_area.sdram_csr	SDRAMCSR		SDRAM Memory Control/Status Register: 0=off, 1= 0n
mission_area.pwr_mon_vod_l_override	PMVODLOV		Power monitor high-performance charge couple device (HCCD) drain override. Enable = 1.
mission_area.pwr_mon_vdd_l_override	PMVDDLOV		Power monitor on-chip amplifier drain override. Enable = 1.
mission_area.pwr_mon_wbb_l_override	PMVBBLOV		Power monitor substrate bias override. Enable = 1.
mission_area.ccd_csr_reserved	CCDCSRRV		CCD control status register reserve bit
mission_area.ccd_rst_l_pulse	CCDRSTLP		CCD control status reg left reset pulse indicator. "1" = 25 ns RST_L pulse , "0" = 12.5 ns (Control/Status) Note: if ADC_INCLK = 10 MHz, RST_L is forced to 12.5 ns.
mission_area.ccd_rst_r_pulse	CCDRSTRP		CCD control status reg right reset pulse indicator. "1" = 25 ns RST_R pulse, "0" = 12.5 ns (Control/Status) Note: if ADC_INCLK = 10 MHz, RST_R is forced to 12.5 ns.
mission_area.encode_upper_pixel_bits	ENCUPPIX		Charge couple device control status register "1" = encode upper pixel bits
mission_area.imgs_to_capture	IMGSTCAP		Number of images to capture (Control/Status) Minimum/Default = 1; Maximum = 28
mission_area.storage_flush_block_flag	FLSTRBLK		Charge couple device control status register storage flush block flag. Enable = 1.
mission_area.adc_clamp_enable	ADCCLMPE		Analog to digital converter clamp enable during imaging. Enable = 1.
mission_area.vfreq_csr	VFREQCSR		CCD vertical clock frequency control, i.e., number of system clock cycles for each of the 8 vertical clock periods
mission_area.cx_pattern	CX_PATT		CCD vertical clock pattern. There are 8-bit periods per vertical clock cycle. CX_PATT determines the high to low ratio incremented each VFREQCSR count cycle.
mission_area.storage_flush_cnt	STOFLCNT	ms	Lower 12 bits are the milliseconds between storage portion flushes during integration. The 4 most significant bits are the pre-integration flush count.
mission_area.cs1h_ccd	CS1H_CCD		CCD Storage clock pattern. CCD Storage clock patterns during a storage to horizontal register transfer. There are 8-bit periods per storage clock cycle. The CS1H_CCD determines the high to low ratio incremented each VFREQCSR count cycle.
mission_area.cs2h_ccd	CS2H_CCD		CCD Storage clock pattern. CCD Storage clock patterns during a storage to horizontal register transfer. There are 8-bit periods per storage clock cycle. The CS2H_CCD determines the high to low ratio incremented each VFREQCSR count cycle.

Attribute Name	FITS Keyword	Units	Description
mission_area.cs3h_ccd	CS3H_CCD		CCD Storage clock patterns during a storage to horizontal register transfer. There are 8-bit periods per storage clock cycle. The CS3H_CCD determines the high to low ratio incremented each VFREQCSR count cycle.
mission_area.cs4h_ccd	CS4H_CCD		CCD Storage clock patterns during a storage to horizontal register transfer. There are 8-bit periods per storage clock cycle. The CS4H_CCD determines the high to low ratio incremented each VFREQCSR count cycle.
mission_area.tck_pattern	TCX_PATT		CCD transfer clock pattern. There are 8 bit periods per the clock cycle. TCK_PATTERN determines the high to low ratio.
mission_area.chan1_course_dac_reg_val	CDAC1		Channel 1 coarse DAC register. 0=off, 1=on.
mission_area.chan1_fine_dac_reg_val	FDAC1		Channel 1 fine DAC register. 0=off, 1=on.
mission_area.chan2_course_dac_reg_val	CDAC2		Channel 2 coarse DAC register. 0=off, 1=on.
mission_area.chan2_fine_dac_reg_val	FDAC2		Channel 2 fine DAC register. 0=off, 1=on.
mission_area.pga1_gain_amp	PGA1	DN	Channel 1 Programmable Gain Amplifier Value
mission_area.pga2_gain_amp	PGA2	DN	Channel 2 Programmable Gain Amplifier Value
mission_area.htr_test_pt	HTRTSTPT	DN	Ground (Analog)
mission_area.ground	GROUND	DN	Ground (Analog)
mission_area.volt_mon_sc	VOLTMNSC	DN	Primary Voltage from S/C
mission_area.volt_mon_minus_12	VOLMNM12	DN	-12 V Monitor
mission_area.volt_mon_plus_5	VOLTMNP5	DN	+5 V Monitor
mission_area.volt_mon_plus_24	VOLMNP24	DN	+24 V Monitor
mission_area.vref_mon_plus_5	VREFMNP5	DN	+5 V Reference Monitor
mission_area.volt_mon_minus_24	VMON_M24	DN	-24 V Monitor (buffered)
mission_area.volt_mon_plus_12	VMON_P12	DN	+12 V Monitor
mission_area.volt_4_5_therm_mon_1	VMON1_45	DN	+4.5 V Thermistor Monitor #1
mission_area.volt_4_5_therm_mon_2	VMON2_45	DN	+4.5 V Thermistor Monitor #2
mission_area.cur_htr	CUR_HTR	DN	Heater Current
mission_area.cur_index	CUR_IDX	DN	Index Lamp Current
mission_area.cur_lamp	CUR_LAMP	DN	Illumination Lamp Current
mission_area.cur_motor	CUR_MTR	DN	Motor Current
mission_area.cur_detector_minus_24	IDET_M24	DN	-24 V current detector
mission_area.cur_detector_plus_24	IDET_P24	DN	+24 V current detector
mission_area.cur_detector_plus_5	IDET_P5	DN	+5 V current detector
n/a - FITS specific	EXTNAME		FITS extension name
n/a - FITS specific	EXTVER		FITS extension version
mission_area.rdpxlmap	RDPXLMAP		String encoding how pixels read from CCD
mission_area.wrpxlmap	WRPXLMAP		String encoding how pixels are written to file

Table 9 shows the row and column specifications of the full OCAMS detector indicated by the ‘RDPXLMAP` and ‘WRPXLMAP’ keywords of the L0 image secondary header. The standard image acquisition mode (RDPXLMAP) is Mode 13, Left Tap; the standard write-out mode (WRPXLMAP) is Mode 13, Right Tap. If other modes are commanded due to

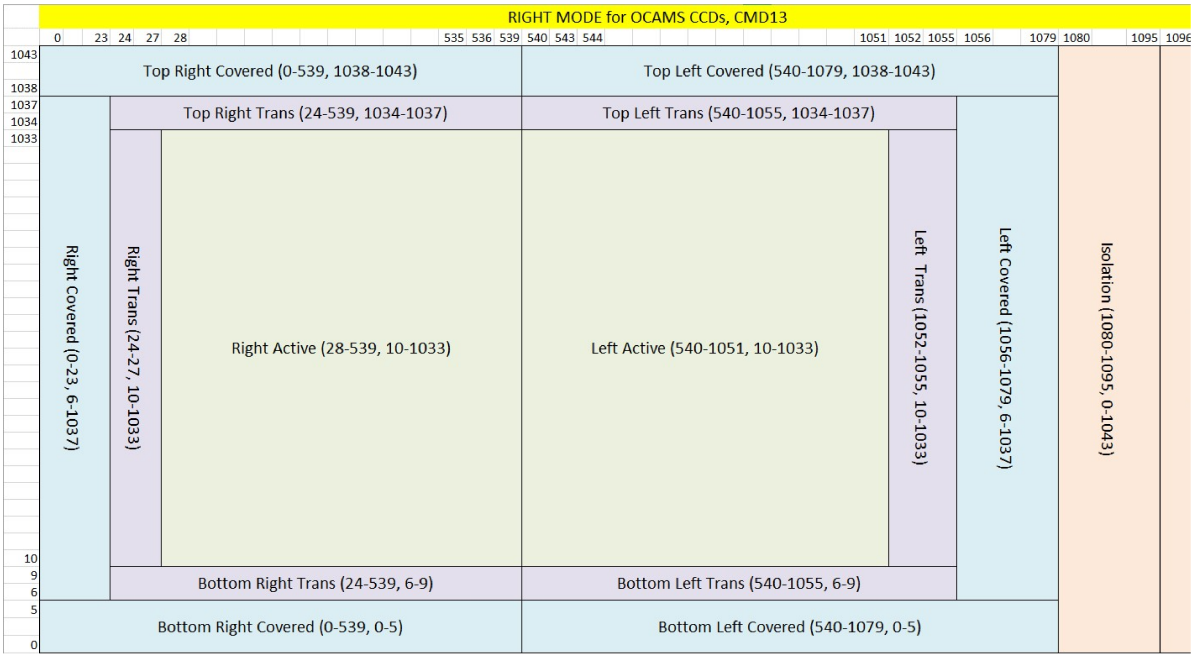
contingency or engineering diagnostics, the L0 data product will be reformatted to the Mode 13, Right Tap (R13H08) specification.

Table 9. OCAMS Detector Layout

Region	**Mode 13, Left Tap (Standard Acquisition Mode)**	**Mode 13, Right Tap (Standard fits write mode)**	**Mode 13, Dual**	**Mode 12, VCTE**
	Start Column:End Column, Start Row:End Row (0-based Integer Pixel Array Offsets, end pixels are inclusive)]			
Left Active Region	28:539, 10:1033	540:1051, 10:1033	28:539, 10:1033	44:555, 6:1027
Right Active Region	540:1051, 10:1033	28:539, 10:1033	572:1083, 10:1033	556:1067, 6:1027
Left Covered Region	0:23, 6:1037	1056:1079, 6:1037	0:23, 6:1037	16:39, 2:1027
Right Covered Region	1056:1079, 6:1037	0:23, 6:1037	1088:1111, 6:1037	1072:1095, 2:1027
Top Left Covered Region	0:539, 1038:1043	540:1079, 1038:1043	0:539, 1038:1043	-1:-1, -1:-1
Top Right Covered Region	540:1079, 1038:1043	0:539, 1038:1043	572:1111, 1038:1043	-1:-1, -1:-1
Bottom Left Covered Region	0:539, 0:5	540:1079, 0:5	0:539, 0:5	16:555, 0:1
Bottom Right Covered Region	540:1079, 0:5	0:539, 0:5	572:1111, 0:5	556:1095, 0:1
Left Transition Region	24:27, 10:1033	1052:1055, 11:1033	24:27, 10:1033	40:43, 6:1027
Right Transition Region	1052:1055, 10:1033	24:27, 10:1033	1084:1087, 10:1033	1068:1071, 6:1027
Top Left Transition Region	24:539, 1034:1037	540:1055, 1034:1037	24:539, 1034:1037	-1:-1, -1:-1
Bottom Left Transition Region	24:539, 6:9	540:1055, 6:9	24:539, 6:9	40:555, 2:5
Top Right Transition Region	540:1055, 1034:1037	24:539, 1034:1037	572:1087, 1034:1037	-1:-1, -1:-1
Bottom Right Transition Region	540:1055, 6:9	24:539, 6:9	572:1087, 6:9	556:1071, 2:5
Isolation Region	1080:1095, 0:1043	1080:1095, 0:1043	-1:-1, -1:-1	-1:-1, -1:-1
Left Overscan Region	-1:-1, -1:-1	-1:-1, -1:-1	540:555, 0:1043	0:15, 0:1043
Right Overscan Region	-1:-1, -1:-1	-1:-1, -1:-1	556:571, 0:1043	1096:1111, 0:1043
Overscan Region	1096:1111, 0:1043	1096:1111, 0:1043	-1:-1, -1:-1	16:1095, 1028:1043

Figure 3 illustrates the regions of the OCAMS detectors. Regions are identified with column and row end pixel, start pixel designations. The pixel designations match those given in Table 9.

Figure 3. OCAMS Detector Layout, Mode 13 Right-tap



The electronic gain (EGAIN) is approximately 4.5 electrons per digital number. Precise numbers are recorded in the Characterization Reports from Space Dynamics Laboratory delivered with the detectors. This value is not reported by telemetry but set on the ground. If this value were to be updated, it would be after significant analysis by the instrument team. Any update would trigger a note in the data set context file for this data product.

The 'FILTNAME' keyword is determined by a combination of the 'MTR_POS' keyword and the 'CAMERID' keywords. The following table describes the possible combinations:

Table 10. OCAMS Filter Names

FILTNAME	MTR_POS	CAMERAID	Description
SS	0	0	MapCam Sun Safe blocking filter
X	630	0	MapCam X-filter, Bandpass centered at 860 nm
W	540	0	MapCam W-filter, Bandpass centered at 700 nm
V	450	0	MapCam V-filter, Bandpass centered at 550 nm
B	360	0	MapCam B-filter, Bandpass centered at 470 nm
PAN	270	0	MapCam Panchromatic (500-800 nm) filter focused at ≥125 m
SSCAL	180	0	MapCam Sun Safe blocking filter/Calibration position
PAN30	90	0	MapCam Panchromatic (500-800 nm) filter focused at 30 m

SSCAL	0	1	SamCam Sun Safe blocking filter/Calibration position
PAN1	600	1	SamCam Panchromatic (500-800 nm) filter focused at 5 m
DIOP	480	1	Panchromatic Diopter (500-800 nm) filter focused at 2 m
SS	360	1	SamCam Sun Safe blocking filter
PAN4	240	1	SamCam Panchromatic (500-800 nm) filter focused at 5 m
PAN5	120	1	SamCam Panchromatic (500-800 nm) filter focused at 5 m

5.2.3 Level 1 Reduced Image Format

The OCAMS L1 reduced image format is a single HDU FITS file that contains the 1024 x 1024 active area bias, dark, charge smear, and flat-field corrected image in units of DN; housekeeping metadata in FITS header have been converted to physical units. Attributes that describe the full detector array are omitted from the L1 products, as only the active area of the detector is included in the L1 products. Metadata contained in the FITS header and its mapping to class and attribute the PDS4 .xml label structure is listed in the table below.

Table 11. OCAMS L1 reduced image metadata

Class. Attribute Name	FITS Keyword	Units	Description
element_array.data_type	BITPIX		number of bits per data pixel (16 for L0, -32 for L1)
axes	NAXIS		number of data axes
axis_array.sequence_number	NAXIS1		length of data axis 1
axis_array.sequence_number	NAXIS2		length of data axis 2
n/a - FITS specific	EXTEND		FITS dataset may contain extensions
n/a - FITS specific	DATE		Creation date UTC (CCC-MM-DD) of FITS header
investigation_area.name	MISSION		Mission: OSIRIS-REx
observing_system.name	HOSTNAME		PDS Terminology
observing_system_component.name	INSTRUME		Instrument: OSIRIS-Rex Camera Suite
target_identification.name	TARGET		Name of the target of interest for observation
n/a - FITS specific	ORIGIN		University of Arizona Science Processing and Operations Center
mission_identification.mission_phase_name	MPHASE		Mission phase of the OSIRIS REx mission. Mission phase possibilities include outbound cruise, approach, preliminary survey, orbital a, detailed survey, orbital b, reconnaissance, rehearsal, and TAG (Touch-and-go)
primary_results_summary.purpose	ACTIVITY		Equivalent to primary result summary
mission_area.apid	APID		Application Identification Number
mission_area.ground_receipt_time	GRT		Ground Receive Time in UTC (YYYY-MM-DDThh:mm:ss.sss)
mission_area.sclk_string	SCLK_STR		Spacecraft Clock String at start of image observation
mission_area.mid_obs_et	ET	s	The ephemeris time of the instrument clock.
mission_area.date_of_observation	DATE_OBS		Observation start time in UTC (YYYY-MM-DDThh:mm:ss.sss)

Class. Attribute Name	FITS Keyword	Units	Description
mission_area.mid_obs	MIDOBS		Spacecraft mid-obs time, UTC [YYYY-MM-DDThh:mm:ss.sss] (DATE_OBS + .5*EXPTIME).
mission_area.exposure	EXPTIME	ms	Exposure time in milliseconds
mission_area.exposec	EXPOSEC	s	Exposure time in seconds
mission_area.effective_exposure	EXPEFF	ms	Effective exposure time in millisecondsd after charge smear correction.
mission_area.delta_obs	DELTAOBS	s	Delta between mid-observation time and spacecraft clock string (Mid-observation time) - (SCLK_STR timestamp), in seconds used to verify exposure time.
mission_area.meta_ker	META_KER		Metakernel that holds all the spice kernels used for processing
mission_area.ckqual	CKQUAL		Quality of C-Kernel (nominal = 'RECONSTRUCT', contingency = 'PREDICT')
geom.qcos	SC_QA		Spacecraft quaternion in J2000 (q0 = cos(t/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time. SPICE quaternion standard is that Q0 is the scalar value.
geom.qsin1	SC_QX		Spacecraft quaternion in J2000 (q1 = sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time. SPICE quaternion standard is that Q0 is the scalar value.
geom.qsin2	SC_QY		Spacecraft quaternion in J2000 (q2= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qsin3	SC_QZ		Spacecraft quaternion in J2000 (q3= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qcos	INST_QA		Instrument quaternion in J2000 (q0 = cos(t/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the

Class. Attribute Name	FITS Keyword	Units	Description
			MIDOBS time. SPICE quaternion standard is that Q0 is the scalar value.
geom.qsin1	INST_QX		Instrument quaternion in J2000 (q1= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qsin2	INST_QY		Instrument quaternion in J2000 (q2= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qsin3	INST_QZ		Instrument quaternion in J2000 (q3= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
mission_area.object	OBJECT		Object Name
mission_area.ctype1	CTYPE1		Coordinate type for reference pixel, values are either ''RA---TAN'' = gnomic or tangent plane or "SIP" - simple image polynomial.
mission_area.ctype2	CTYPE2		Coordinate type for the reference pixel, values are either ''DEC--TAN'' = gnomic or tangent plane or "SIP" - simple image polynomial.
geom.right_ascension_angle	CRVAL1	Deg	Right ascension of the reference pixel or boresight vector in degrees.
geom.declination_angle	CRVAL2	Deg	Declination of reference pixel or boresight vector in degrees.
mission_area.cunit1	CUNIT1	Deg	Units for reference pixel 1 (CRPIX1)
mission_area.cunit2	CUNIT2	Deg	Units for reference pixel 2 (CRPIX2)
geom.horizontal_coordinate_pixel	CRPIX1		X coordinate pixel number of the boresight reference point to which the projection and the rotation refer.
geom.verticle_coordinate_pixel	CRPIX2		Y coordinate pixel number of the boresight reference point to which the projection and the rotation refer.
mission_area.cd1_1	CD1_1	Deg	Change in RA per pixel along first axis (sample) evaluated at reference pixel
mission_area.cd1_2	CD1_2	Deg	Change in RA per pixel along second axis (line) evaluated at reference pixel
mission_area.cd2_1	CD2_1	Deg	Change in DEC per pixel along first axis (sample) evaluated at reference pixel
mission_area.cd2_2	CD2_2	Deg	Change in DEC per pixel along second axis (line) evaluated at reference pixel
mission_area.radesys	RADESYS		International Celestial Reference System (ICRS)
mission_area.equinox	EQUINOX		Epoch of mean equator and equinox (J2000)

Class. Attribute Name	FITS Keyword	Units	Description
geom.celestial_north_clock_angle	ORIENTAT	Deg	The angle (in degrees measured East of North) of the y axis of the detector projected on the sky
mission_area.boresight_lat	LAT	Deg	Boresight latitude of the imaging location
mission_area.boresight_lon	LON	Deg	Boresight longitude of the imaging location
mission_area.bennu_ra	BENNURA	Deg	Right Ascension of the vector, expressed in the Earth Mean Equator of the J2000 Epoch, from the ORX spacecraft toward the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value
mission_area.bennu_dec	BENNUDEC	Deg	Declination of the vector, expressed in the Earth Mean Equator of the J2000 Epoch, from the ORX spacecraft toward the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value
mission_area.bennu_naxis1_offset	BENNUNX1	Pixel	Approximate offset from CRPIX1 pixel in +NAXIS1 direction of the location of the center of the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value; assumes undistorted optics
mission_area.bennu_naxis2_offset	BENNUNX2	Pixel	Approximate offset from CRPIX2 pixel in +NAXIS2 direction of the location of the center of the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value; assumes undistorted optics
mission_area.bennana	BENNANA	Deg	Azimuth of the North polar Axis of the target named in FITS keyword BENNURDT (typically Bennu), positive from the +NAXIS2 direction toward the +NAXIS1 direction; see also BENNURDQ for a statement of the quality of this value; assumes undistorted optics; will be -999 if the calculation fails
mission_area.bennu_radec_target	BENNURDT		Target for the BENNURA, BENNUDEC, BENNUNX1 and BENNUNX2 FTIS keywords; typically, BENNU; may be NONE if the calculation failed. Target is not required to be in the field of view.
mission_area.bennu_radec_quality	BENNURDQ		(Quality: provenance) for the BENNURA,BENNUDEC, BENNUNX1, BENNUNX2 FITS keywords. This will be one of three values: (BEST: SPK), meaning the geometry was obtained from SPICE SP-Kernels; (POOR: osculating elements; +/-1E6km), meaning the geometry was obtained from osculating orbital elements of Bennu w.r.t the Sun, and will have uncertainties of order 1E6km; (NONE: FAILURE), meaning both the SPK and elements methods failed; the parentheses, (), are only delimiters here and not part of the quality:provenance values.
mission_area.sc2sun_uvx	SUNSCUVX		X component of Cartesian coordinate system unit vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_uvy	SUNSCUVY		Y component of Cartesian coordinate system unit vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame

Class. Attribute Name	FITS Keyword	Units	Description
mission_area.sc2sun_uvz	SUNSCUVZ		Z component of Cartesian coordinate system unit vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_range_km	SUNSCRNG	km	Range component of spherical coordinate system vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_theta_deg	SUNSCTHE	Deg	Theta component (angle around +Z from XZ plane, positive from +X toward +Y) of spherical coordinate system vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_phi_deg	SUNSCPHI	Deg	Phi component (angle from XY plane, positive toward +Z) of spherical coordinate system vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.creator	CREATOR		Creator of this product
mission_area.file_creation	SPOCDATE		Date of creation of this file.
mission_area.spoc_version	SPOCIVER		SPOC Ingest version from GIT repository
mission_area.ocams_pl_ver	OCPLVER		OCAMS pipeline version from GIT repository
mission_area.control_file	IN_FILE		Data origin/provenance information
mission_area.dispornt	DISPORNT		Image origin (0,0) is located in the bottom-left corner of the display. This is the standard FITS display orientation.
mission_area.min_pixel_value	MINVAL		Max image pixel value in dynamic range recorded by the instrument.
mission_area.max_pixel_value	MAXVAL		Max image pixel value in dynamic range recorded by the instrument.
mission_area.quality_flag	DQ_FLAG		Data quality flag, 0 = good
mission_area.proc_desc_flag	PROCDES		Processing description flag, where the different processing levels are described in the CALIB section of the PDS volume.
mission_area.misspxla	MISSPXLS		Number of pixels in the 1024x1024 active area that were zero filled as a result of data loss
mission_area.data_source	DATASRC		Origin of image data TEST or FLIGHT
reference_list.bias_file	BIASFILE		Name of Bias file used in correction of image
reference_list.dark_file	DARKFILE		Name of Dark file used in correction of image
reference_list.flat_file	FLATFILE		Name of Flat file used in correction of image
reference_list.cte_file	CTE_FILE		CTE File used in correction of image (black if not used)
mission_area.units	UNITS		Units of quantities in both the header (label) and image array
mission_area.camera_id	CAMERAID		ID of camera in use. 0- Map, 1-Sam, 2-Poly. Note that the numeric values for ACTV_CAM are different, but the named camera will be identical.
mission_area.ccd_rev_num	CCD_NUM		CCD revision number
mission_area.board_rev_num	CCD_BRD		CCD board revision number
mission_area.fpga_rev_num	FPGAREV		FPGA revision number
mission_area.device_id	DEVICEID		Analog to digital converter device revision identifier
mission_area.image_id	IMAGEID		Identifier that is associated with an image
mission_area.image_type_code	IMAGETYP		Type of image commanded. LIGHT (science observation), BIAS (calibration) , DARK (calibration), LAMP (calibration), OTHER

Class. Attribute Name	FITS Keyword	Units	Description
mission_area.egain	EGAIN	e-/ADU	Electronic gain in electrons per analog-to-digital units
mission_area.seconds_raw	SECOND	s	Camera control module (CCM) seconds for start of exposure
mission_area.subseconds_raw	SUBSEC		Camera control module sub-seconds for start of exposure
mission_area.readout_mode	READOUTM		Readout mode of detector
mission_area.detector_mode	IMG_CMD		Imaging command mode.
mission_area.vcte_csr	VCTECSR		Vertical over scan count
mission_area.hcte_csr	HCTECSR		Horizontal over scan count
mission_area.motor_pos	MTR_POS		Filter wheel or focus position
mission_area.filtname	FILTNAME		Filter name: SS - sun safe, X - 860 nm filter, W - 700 nm filter, V - 550 nm filter, B - 470 nm filter, PAN - panchromatic filter focused at greater than or equal to 125 m, SSCAL - sun safe blocking filter calibration prosition, PAN30 - panchromatic filter focuses at 30 m, PAN1 - panchromatic filter focused at 5 m, PAN4 - panchromatic filter focused at 5 m , PAN5 - panchromatic filter focused at 5 m
mission_area.secondary_ik_num	PCNAIFID		Secondary Instrument-Kernel number for variable optics. See the ORX OCAMS Instrument kernel (SPICE collection) for the full definition of this parameter.
mission_area.cal_lamp_sel	LAMP_SEL		Bitwise Camera of the active illumination lamp
mission_area.lut	LUT		Currently selected LUT number: 0=None. The description of this field will be updated as more LUTS are added.
mission_area.mapcam_ccd_heater	MCCCDHTR		MapCam CCD heater, on/off state
mission_area.mapcam_ccd_temp_x	MCCCDTMP	Deg C	MapCam CCD resistance temperature detector (RTD) temperature
mission_area.polycam_ccd_heater	PCCCDHTR		PolyCam CCD heater, on/off state
mission_area.polycam_ccd_temp_x	PCCCDTMP	Deg C	PolyCam CCD resistance temperature detector (RTD) temperature
mission_area.samcam_ccd_heater	SCCCDHTR		SamCam CCD heater, on/off state
mission_area.samcam_ccd_temp_x	SCCCDTMP	Deg C	SamCam CCD resistance temperature device (RTD) temperature
mission_area.main_config	MAIN_CFG		Main configuration
mission_area.power_control	PWR_CTRL		Power down control
mission_area.active	ACTV_CAM		Camera number of active camera (1-Map, 2-Sam, 3-Poly). Note that the numeric values are different than those of the CAMERAID.
mission_area.standby	CAM_PWR		Bitwise non-Off state of the cameras: 1=MapCam, 2=SamCam, 4=PolyCam
mission_area.min_cnt	MIN_CNT	min	Number of minutes since reset
mission_area.action_mode	ACTENABL		Action sequence enable mode: 0=off, 1=on
mission_area.motor_select	MTR_SEL		Camera number of the active motor
mission_area.motor_zone	MTR_ZONE		Width of the last home command's index (>31 is 31)
mission_area.index_led_sel	LED_SEL		Camera number of the active motor index LED set
mission_area.index_led_read	LED_SENS		Bitwise read of the active LED sensors
mission_area.mapcam_filt_house_heater	MCFWHHTR		State of the heater: 0=off, 1=on
mission_area.mapcam_fwh_temp_x	MCFWHTMP	Deg C	MapCam Filter Wheel Housing Thermistor
mission_area.mapcam_filt_motor_heater	MCFTMHTR		State of the heater: 0=off, 1=on
mission_area.mapcam_fwm_temp_x	MCFWMTMP	Deg C	MapCam Filter Wheel Housing Thermistor

Class. Attribute Name	FITS Keyword	Units	Description
mission_area.mapcam_lens_heater	MCLENHTR		State of the heater: 0=off, 1=on
mission_area.mapcam_len_temp_x	MCLENTMP	Deg C	MapCam Lens Thermistor
mission_area.mapcam_readout_elect_heater	MCROEHTR		State of the heater: 0=off, 1=on
mission_area.mapcam_roe_temp_x	MCROETMP	Deg C	MapCam Read Out Electronics Thermistor
mission_area.polycam_focus_house_heater	PCFOHHTR		State of the heater: 0=off, 1=on
mission_area.polycam_foh_temp_x	PCFOHTMP	Deg C	PolyCam Focus Housing Thermistor
mission_area.polycam_focus_motor_heater	PCFOMHTR		State of the heater: 0=off, 1=on
mission_area.polycam_fom_temp_x	PCFOMTMP	Deg C	PolyCam Focus Motor Thermistor
mission_area.polycam_primary_heater	PCMR1HTR		State of the heater: 0=off, 1=on
mission_area.polycam_mirror_1_temp_x	PCMR1TMP	Deg C	PolyCam Primary Mirror Thermistor
mission_area.polycam_readout_elect_heater	PCROEHTR		State of the heater: 0=off, 1=on
mission_area.polycam_roe_temp_x	PCROETMP	Deg C	PolyCam Read Out Electronics Thermistor
mission_area.samcam_filt_house_heater	SCFWHHTR		State of the heater: 0=off, 1=on
mission_area.samcam_fwh_temp_x	SCFWHTMP	Deg C	SamCam Filter Wheel Housing Thermistor
mission_area.samcam_filt_motor_heater	SCFWMHTR		State of the heater: 0=off, 1=on
mission_area.samcam_fwm_temp_x	SCFWMTMP	Deg C	SamCam filter wheel motor heater, on/off state
mission_area.samcam_lens_heater	SCLENHTR		State of the heater: 0=off, 1=on
mission_area.samcam_len_temp_x	SCLENTMP	Deg C	SamCam Lens Thermistor
mission_area.samcam_readout_elect_heater	SCROEHTR		State of the heater: 0=off, 1=on
mission_area.samcam_roe_temp_x	SCROETMP	Deg C	SamCam Read Out Electronics Thermistor
mission_area.htr_brd_temp_x	HTRBDTMP	Deg C	Heater_BRD_Temp (unbuffered)
mission_area.dpu_brd_temp_x	DPUBDTMP	Deg C	DPU Board Temperature
mission_area.lvps_brd_temp_x	LVPBDTMP	Deg C	LVPS Board Temperature
mission_area.motor_brd_temp_x	MTRBDTMP	Deg C	Motor Board Temperature
mission_area.sdram_csr	SDRAMCSR		SDRAM Memory Control/Status Register: 0=off, 1= 0n
mission_area.pwr_mon_vod_l_override	PMVODLOV		Power monitor high-performance charge couple device (HCCD) drain override. Enable = 1.
mission_area.pwr_mon_vdd_l_override	PMVDDLOV		Power monitor on-chip amplifier drain override. Enable = 1.
mission_area.pwr_mon_wbb_l_override	PMVBBLOV		Power monitor substrate bias override. Enable = 1.
mission_area.ccd_csr_reserved	CCDCSRRV		CCD control status register reserve bit
mission_area.ccd_rst_l_pulse	CCDRSTLP		CCD control status reg left reset pulse indicator. "1" = 25 ns RST_L pulse , "0" = 12.5 ns (Control/Status) Note: if ADC_INCLK = 10 MHz, RST_L is forced to 12.5 ns.
mission_area.ccd_rst_r_pulse	CCDRSTRP		CCD control status reg right reset pulse indicator. "1" = 25 ns RST_R pulse, "0" = 12.5 ns (Control/Status) Note: if ADC_INCLK = 10 MHz, RST_R is forced to 12.5 ns.
mission_area.encode_upper_pixel_bits	ENCUPPIX		Charge couple device control status register "1" = encode upper pixel bits
mission_area.imgs_to_capture	IMGSTCAP		Number of images to capture (Control/Status) Minimum/Default = 1; Maximum = 28
mission_area.storage_flush_block_flag	FLSTRBLK		Charge couple device control status register storage flush block flag. Enable = 1.

Class. Attribute Name	FITS Keyword	Units	Description
mission_area.adc_clamp_enable	ADCCLMPE		Analog to digital converter clamp enable during imaging. Enable = 1.
mission_area.vfreq_csr	VFREQCSR		CCD vertical clock frequency control, i.e., number of system clock cycles for each of the 8 vertical clock periods
mission_area.cx_pattern	CX_PATT		CCD vertical clock pattern. There are 8 bit periods per vertical clock cycle. CX_PATT determines the high to low ratio incremented each VFREQCSR count cycle.
mission_area.storage_flush_cnt	STOFLCNT	ms	Milliseconds between storage portion flushes
mission_area.cs1h_ccd	CS1H_CCD		CCD Storage clock pattern. CCD Storage clock patterns during a storage to horizontal register transfer. There are 8 bit periods per storage clock cycle. The CS1H_CCD determines the high to low ratio incremented each VFREQCSR count cycle.
mission_area.cs2h_ccd	CS2H_CCD		CCD Storage clock pattern. CCD Storage clock patterns during a storage to horizontal register transfer. There are 8 bit periods per storage clock cycle. The CS2H_CCD determines the high to low ratio incremented each VFREQCSR count cycle.
mission_area.cs3h_ccd	CS3H_CCD		CCD Storage clock patterns during a storage to horizontal register transfer. There are 8 bit periods per storage clock cycle. The CS3H_CCD determines the high to low ratio incremented each VFREQCSR count cycle.
mission_area.cs4h_ccd	CS4H_CCD		CCD Storage clock patterns during a storage to horizontal register transfer. There are 8 bit periods per storage clock cycle. The CS4H_CCD determines the high to low ratio incremented each VFREQCSR count cycle.
mission_area.tck_pattern	TCX_PATT		CCD transfer clock pattern. There are 8 bit periods per the clock cycle. TCK_PATTERN determines the high to low ratio.
mission_area.chan1_course_dac_reg_val	CDAC1		Channel 1 coarse DAC register. 0=off, 1=on.
mission_area.chan1_fine_dac_reg_val	FDAC1		Channel 1 fine DAC register. 0=off, 1=on.
mission_area.chan2_course_dac_reg_val	CDAC2		Channel 2 coarse DAC register. 0=off, 1=on.
mission_area.chan2_fine_dac_reg_val	FDAC2		Channel 2 fine DAC register. 0=off, 1=on.
mission_area.pga1_gain_amp	PGA1	DN	Channel 1 Programmable Gain Amplifier Value
mission_area.pga2_gain_amp	PGA2	DN	Channel 2 Programmable Gain Amplifier Value
mission_area.htr_test_pt_x	HTRTSTPT	V	Ground (Analog)
mission_area.ground_x	GROUND	V	Ground (Analog)
mission_area.volt_mon_sc_x	VOLTMNSC	V	Primary Voltage from S/C
mission_area.volt_mon_minus_12_x	VOLMNM12	V	-12 V Monitor
mission_area.volt_mon_plus_5_x	VOLTMNP5	V	+5 V Monitor
mission_area.volt_mon_plus_24_x	VOLMNP24	V	+24 V Monitor
mission_area.vref_mon_plus_5_x	VREFMNP5	V	+5 V Reference Monitor
mission_area.volt_mon_minus_24_x	VMON_M24	V	-24 V Monitor (buffered)
mission_area.volt_mon_plus_12_x	VMON_P12	V	+12 V Monitor
mission_area.volt_4_5_therm_mon_1_x	VMON1_45	V	+4.5 V Thermistor Monitor #1
mission_area.volt_4_5_therm_mon_2_x	VMON2_45	V	+4.5 V Thermistor Monitor #2
mission_area.cur_htr_x	CUR_HTR	mA	Heater Current
mission_area.cur_index_x	CUR_IDX	mA	Index Lamp Current

Class. Attribute Name	FITS Keyword	Units	Description
mission_area.cur_lamp_x	CUR_LAMP	mA	Illumination Lamp Current
mission_area.cur_motor_x	CUR_MTR	mA	Motor Current
mission_area.cur_detector_minus_24_x	IDET_M24	mA	-24 V current detector
mission_area.cur_detector_plus_24_x	IDET_P24	mA	+24 V current detector
mission_area.cur_detector_plus_5_x	IDET_P5	mA	+5 V current detector

5.2.4 Level 2 Calibrated Image Format

The Level 2 calibrated image format contains 1 HDU with a 1024 x 1024 radiometrically corrected image in units of radiance (W $m^{-2}sr^{-1}$), spectral radiance (W $m^{-2}sr^{-1}\mu m^{-1}$), or reflectance (I/F, unitless)" for clarity. Metadata contained in these files are listed in the following table.

Table 12. OCAMS L2 calibrated image metadata

Class.Attribute Name	FITS Keyword	Units	Description
element_array.data_type	BITPIX		number of bits per data pixel (-32 bits, single precision floats)
axes	NAXIS		number of data axes
axis_array.sequence_number	NAXIS1		length of data axis 1
axis_array.sequence_number	NAXIS2		length of data axis 2
n/a - FITS specific	EXTEND		FITS dataset may contain extensions
n/a - FITS specific	DATE		Creation date UTC (CCCC-MM-DD) of FITS header
investigation_area.name	MISSION		Mission: OSIRIS-REx
observing_system.name	HOSTNAME		PDS Terminology
observing_system_component.name	INSTRUME		Instrument: OSIRIS-Rex Camera Suite
target_identification.name	TARGET		Target object of observation
n/a - FITS specific	ORIGIN		University of Arizona Science Processing and Operations Center
mission_identification.mission_phase_name	MPHASE		Mission phase of the OSIRIS REx mission. Mission phase possibilities include outbound cruise, approach, preliminary survey, orbital a, detailed survey, orbital b, reconnaissance, rehearsal, and TAG (Touch-and-go)
primary_results_summary.purpose	ACTIVITY		Equivalent to primary result summary
mission_area.apid	APID		Application Identification Number
mission_area.ground_receipt_time	GRT		Ground Receive Time in UTC (YYYY-MM-DDThh:mm:ss.sss)

Class.Attribute Name	FITS Keyword	Units	Description
mission_area.sclk_string	SCLK_STR		Spacecraft Clock String at start of image observation
mission_area.mid_obs_et	ET	s	The ephemeris time of the instrument clock.
mission_area.date_of_observation	DATE_OBS		Observation start time in UTC (YYYY-MM-DDThh:mm:ss.sss)
mission_area.mid_obs	MIDOBS		Spacecraft mid-obs time, UTC [YYYY-MM-DDThh:mm:ss.sss] (DATE_OBS + .5*EXPTIME).
mission_area.exposure	EXPTIME	ms	Exposure time in milliseconds
mission_area.exposec	EXPOSEC	s	Exposure time in seconds
mission_area.delta_obs	DELTAOBS	s	Delta between mid-observation time and spacecraft clock string (Mid-observation time) - (SCLK_STR timestamp), in seconds used to verify exposure time.
mission_area.meta_ker	META_KER		Metakernel that holds all the spice kernels used for processing
mission_area.ckqual	CKQUAL		Quality of C-Kernel (nominal = 'RECONSTRUCT', contingency = 'PREDICT')
geom.qcos	SC_QA		Spacecraft quaternion in J2000 (q0 = cos(t/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time. SPICE quaternion standard is that Q0 is the scalar value.
geom.qsin1	SC_QX		Spacecraft quaternion in J2000 (q1 = sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time. SPICE quaternion standard is that Q0 is the scalar value.
geom.qsin2	SC_QY		Spacecraft quaternion in J2000 (q2= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame.

Class.Attribute Name	FITS Keyword	Units	Description
			This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qsin3	SC_QZ		Spacecraft quaternion in J2000 (q3= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in spacecraft frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qcos	INST_QA		Instrument quaternion in J2000 (q0 = cos(t/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time. SPICE quaternion standard is that Q0 is the scalar value.
geom.qsin1	INST_QX		Instrument quaternion in J2000 (q1= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qsin2	INST_QY		Instrument quaternion in J2000 (q2= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame. This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
geom.qsin3	INST_QZ		Instrument quaternion in J2000 (q3= sin(theta/2)) obtained from the NAIF provided C kernel. SPICE convention conversion to 3x3 matrix transforms vector in instrument frame to J2000 frame.

Class.Attribute Name	FITS Keyword	Units	Description
			This value is calculated using the SPICE interface and numbers will be accurate to the accuracy of the SPICE kernels. Calculations will be based on the MIDOBS time.
mission_area.object	OBJECT		Object Name
mission_area.ctype1	CTYPE1		Coordinate type for reference pixel, values are either ''RA---TAN'' = gnomic or tangent plane or "SIP" - simple image polynomial.
mission_area.ctype2	CTYPE2		Coordinate type for the reference pixel, values are either ''DEC--TAN'' = gnomic or tangent plane or "SIP" - simple image polynomial.
geom.right_ascension_angle	CRVAL1	Deg	Right ascension of the reference pixel or boresight vector in degrees.
geom.declination_angle	CRVAL2	Deg	Declination of reference pixel or boresight vector in degrees.
mission_area.cunit1	CUNIT1		Units for reference pixel 1 (CRPIX1)
mission_area.cunit2	CUNIT2		Units for reference pixel 2 (CRPIX2)
geom.horizontal_coordinate_pixel	CRPIX1		X coordinate pixel number of the boresight reference point to which the projection and the rotation refer.
geom.verticle_coordinate_pixel	CRPIX2		Y coordinate pixel number of the boresight reference point to which the projection and the rotation refer.
mission_area.cd1_1	CD1_1	Deg	Change in RA per pixel along first axis (sample) evaluated at reference pixel
mission_area.cd1_2	CD1_2	Deg	Change in RA per pixel along second axis (line) evaluated at reference pixel
mission_area.cd2_1	CD2_1	Deg	Change in DEC per pixel along first axis (sample) evaluated at reference pixel
mission_area.cd2_2	CD2_2	Deg	Change in DEC per pixel along second axis (line) evaluated at reference pixel
mission_area.radesys	RADESYS		International Celestial Reference System (ICRS)
mission_area.equinox	EQUINOX		Epoch of mean equator and equinox (J2000)
geom.celestial_north_clock_angle	ORIENTAT	Deg	The angle (in degrees measured East of North) of the y axis of the detector projected on the sky
mission_area.boresight_lat	LAT		Boresight latitude of the imaging location
mission_area.boresight_lon	LON		Boresight longitude of the imaging location

Class.Attribute Name	FITS Keyword	Units	Description
mission_area.bennu_ra	BENNURA	Deg	Right Ascension of the vector, expressed in the Earth Mean Equator of the J2000 Epoch, from the ORX spacecraft toward the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value
mission_area.bennu_dec	BENNUDEC	Deg	Declination of the vector, expressed in the Earth Mean Equator of the J2000 Epoch, from the ORX spacecraft toward the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value
mission_area.bennu_naxis1_offset	BENNUNX1	Pixel	Approximate offset from CRPIX1 pixel in +NAXIS1 direction of the location of the center of the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value; assumes undistorted optics
mission_area.bennu_naxis2_offset	BENNUNX2	Pixel	Approximate offset from CRPIX2 pixel in +NAXIS2 direction of the location of the center of the target named in FITS keyword BENNURDT (typically Bennu); see also BENNURDQ for a statement of the quality of this value; assumes undistorted optics
mission_area.bennana	BENNANA	Deg	Azimuth of the North polar Axis of the target named in FITS keyword BENNURDT (typically Bennu), positive from the +NAXIS2 direction toward the +NAXIS1 direction; see also BENNURDQ for a statement of the quality of this value; assumes undistorted optics; will be -999 if the calculation fails
mission_area.bennu_radec_target	BENNURDT		Target for the BENNURA, BENNUDEC, BENNUNX1 and BENNUNX2 FTIS keywords; typically, BENNU; may be NONE if the calculation failed. Target is not required to be in the field of view.
mission_area.bennu_radec_quality	BENNURDQ		(Quality: provenance) for the BENNURA, BENNUDEC, BENNUNX1, BENNUNX2 FITS keywords. This will be one of three values: (BEST: SPK), meaning the geometry was obtained from SPICE SP-Kernels; (POOR: osculating elements; +/-1E6km), meaning the geometry was obtained from osculating orbital elements of Bennu w.r.t the Sun, and will have uncertainties of order 1E6km; (NONE: FAILURE), meaning both the SPK and elements methods failed; the parentheses, (), are only delimiters

Class.Attribute Name	FITS Keyword	Units	Description
			here and not part of the quality:provenance values.
mission_area.sc2sun_uvx	SUNSCUVX		X component of Cartesian coordinate system unit vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_uvy	SUNSCUVY		Y component of Cartesian coordinate system unit vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_uvz	SUNSCUVZ		Z component of Cartesian coordinate system unit vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_range_km	SUNSCRNG	km	Range component of spherical coordinate system vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_theta_deg	SUNSCTHE	Deg	Theta component (angle around +Z from XZ plane, positive from +X toward +Y) of spherical coordinate system vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.sc2sun_phi_deg	SUNSCPHI	Deg	Phi component (angle from XY plane, positive toward +Z) of spherical coordinate system vector, pointing from the ORX spacecraft toward the Sun, in the ORX_SPACECRAFT frame
mission_area.creator	CREATOR		Creator of this product
mission_area.file_creation	SPOCDATE		Date of creation of this file.
mission_area.spoc_version	SPOCIVER		SPOC Ingest version from GIT repository
mission_area.ocams_pl_ver	OCPLVER		OCAMS Pipeline version from GIT repository.
mission_area.control_file	IN_FILE		Data origin/provenance information
mission_area.dispornt	DISPORNT		Image origin (0,0) is located in the bottom-left corner of the display. This is the standard FITS display orientation.
mission_area.min_pixel_value	MINVAL		Max image pixel value in dynamic range recorded by the instrument.
mission_area.max_pixel_value	MAXVAL		Max image pixel value in dynamic range recorded by the instrument.
mission_area.quality_flag	DQ_FLAG		Data Quality Flag. 0=good. Other flags to be added

Class.Attribute Name	FITS Keyword	Units	Description
mission_area.proc_desc_flag	PROCDES		Processing description flag.
mission_area.misspxla	MISSPXLS		Number of pixels in the 1024x1024 active area that were zero filled as a result of data loss
mission_area.data_source	DATASRC		Origin of image data TEST or FLIGHT
reference_list.bias_file	BIASFILE		Name of Bias file used in correction
reference_list.dark_file	DARKFILE		Name of Dark file used in correction
reference_list.flat_file	FLATFILE		Name of Flat file used in correction
reference_list.rad_file	RAD_FILE		Radiometric Calibration File used in correction
reference_list.cte_file	CTE_FILE		CTE File used in correction (blank if not used)
mission_area.rad_units	UNITS		Radiance (W/m^2/sr) or Spectral Radiance (W/m^2/sr/um).
mission_area.camera_id	CAMERAID		ID of camera in use. 0- Map, 1-Sam, 2-Poly. Note that the numeric values for ACTV_CAM are different, but the named camera will be identical.
mission_area.image_id	IMAGEID		Identifier that is associated with an image
imission_area.image_type_code	IMAGETYP		Type of image commanded. LIGHT (science observation), BIAS (calibration) , DARK (calibration), LAMP (calibration), OTHER
mission_area.seconds_raw	SECOND	s	Camera control module (CCM) seconds for start of exposure
mission_area.subseconds_raw	SUBSEC		Camera control module sub-seconds for start of exposure
mission_area.readout_mode	READOUTM		Readout mode of detector
mission_area.detector_mode	IMG_CMD		Imaging command mode.
mission_area.motor_pos	MTR_POS		Filter wheel or focus position
mission_area.filtname	FILTNAME		Filter name: SS - sun safe, X - 860 nm filter, W - 700 nm filter, V - 550 nm filter, B - 470 nm filter, PAN - panchromatic filter focused at greater than or equal to 125 m, SSCAL - sun safe blocking filter calibration prosition, PAN30 - panchromatic filter focuses at 30 m, PAN1 - panchromatic filter focused at 5 m, PAN4 - panchromatic filter focused at 5 m , PAN5 - panchromatic filter focused at 5 m
mission_area.secondary_ik_num	PCNAIFID		Secondary Instrument-Kernel number for variable optics. See the ORX OCAMS

Class.Attribute Name	FITS Keyword	Units	Description
			Instrument kernel (SPICE collection) for the full definition of this parameter.
mission_area.lut	LUT		Currently selected LUT number: 0=None. The description of this field will be updated as more LUTS are added.
mission_area.mapcam_ccd_temp_x	MCCCDTMP	Deg C	MapCam CCD resistance temperature detector (RTD) temperature
mission_area.polycam_ccd_temp_x	PCCCDTMP	Deg C	PolyCam CCD resistance temperature detector (RTD) temperature
mission_area.samcam_ccd_temp_x	SCCCDTMP	Deg C	SamCam CCD resistance temperature device (RTD) temperature
mission_area.mapcam_fwh_temp_x	MCFWHTMP	Deg C	MapCam Filter Wheel Housing Thermistor
mission_area.mapcam_fwm_temp_x	MCFWMTMP	Deg C	MapCam Filter Wheel Housing Thermistor
mission_area.mapcam_len_temp_x	MCLENTMP	Deg C	MapCam Lens Thermistor
mission_area.mapcam_roe_temp_x	MCROETMP	Deg C	MapCam Read Out Electronics Thermistor
mission_area.polycam_foh_temp_x	PCFOHTMP	Deg C	PolyCam Focus Housing Thermistor
mission_area.polycam_fom_temp_x	PCFOMTMP	Deg C	PolyCam Focus Motor Thermistor
mission_area.polycam_mirror_1_temp_x	PCMR1TMP	Deg C	PolyCam Primary Mirror Thermistor
mission_area.polycam_roe_temp_x	PCROETMP	Deg C	PolyCam Read Out Electronics Thermistor
mission_area.samcam_fwh_temp_x	SCFWHTMP	Deg C	SamCam Filter Wheel Housing Thermistor
mission_area.samcam_fwm_temp_x	SCFWMTMP	Deg C	SamCam filter wheel motor heater, on/off state
mission_area.samcam_len_temp_x	SCLENTMP	Deg C	SamCam Lens Thermistor
mission_area.samcam_roe_temp_x	SCROETMP	Deg C	SamCam Read Out Electronics Thermistor
mission_area.saturation_limit	SATLIM		Saturation Limit.
mission_area.linearity_limit	LINLIM		Linearity Limit.

5.2.5 OCAMS Raw Pixel Values

Non-valid pixels (e.g. missing data, dead pixels etc.) may be present in small numbers within the Reconstructed Telemetry and Uncalibrated image arrays. The SDL detector assembly reads the detector pixels values from the Teledyne DALSA CCD output gate and sends them to the ADC unit to create image data in 14-bit precision. Once created, the data is generally converted to 16-bit numbers by the Command Telemetry Interface and stored as such in the packetized data stream that is downlinked to ground. The image data is converted to unsigned 16-bit numbers. Non-valid pixels are not identified at any of the stages of data acquisition, either within the detector assemblies or within the CCM multiplexers.

The OSIRIS-REx Science Processing and Operations Center OCAMS Ingest process collects a packetized data stream and reassembles the packets into image data, which are stored as Reconstructed Telemetry images. Missing data packets will result in lines of NULL data in the image array. These NULL data values are represented by the value '0' in the image array. An actual DN value of '0' is not expected. The valid maximum DN value in Reconstructed Telemetry image arrays is 16,382.

5.2.6 OCAMS Calibration File Formats

OCAMS has the following calibration files that will be developed from in-flight and/or ground calibration data: bad pixel map, bias, dark, flat, and radiometric calibration. Calibration files will be saved in a format appropriate for their type of calibration, as indicated by the NAXIS1 and NAXIS2 keywords in their respective headers. In-flight and ground calibration file formats are identical within type.

Bad Pixel Map - A map of physical pixels (1080x1044) on the array that have been identified as bad. Bad pixels are classified in three ways: hot pixels (-3) are pixels which are over-responsive; dead pixels (-1) are pixels which are under-responsive; flicker (or Random Telegraph Signal) pixels (-2) are pixels whose responsivity varies over time. The latter can only be identified with multiple images taken over time. As such, the bad pixel map is a historical record of known bad pixels that is delivered periodically by the OCAMS team, and is used for reference only. This map is not used in the instrument calibration pipeline. A bad pixel map is created for each camera.

Bias - A bias calibration image is the average of many individual bias images, which are dark images taken with the minimum possible exposure. A bias image is a measure of read noise in the camera and of the bias level offset. A stand-alone bias calibration image is an 1112x1044 array and may be created for each camera. In the standard pipeline processing, the bias correction is combined with the dark correction processing and is applied as a single operation.

Dark - A dark calibration image is the average of many individual dark images (images taken with the shutter closed). A dark calibration image is provided for a specific exposure time (in general, matching the exposure time of light observations taken before or after). The dark image is a measure of the dark signal in the physical pixels (1112x1044) for an image of that exposure time. A combined BiasDark file contains an 1112(sample) x1044 (line) array.

Bias and dark file subtraction will correct the bulk of the bias and dark signal, but variations at the moment of imaging will not be corrected. These instantaneous variations can be corrected with on-chip data from the overscan and covered columns. To update the bias correction, the median is taken of the 16 overscan columns, on a row-wise basis, and subtracted from their respective rows across the array. The isolation columns are not used. To update the dark correction, the median is taken of the 48 covered columns, on a row-wise basis, and subtracted from their respective rows across the array.

Flat - A flat field calibration image captures the pixel-to-pixel responsivity variation across the active region of the array (1024x1024). The flat calibration image is updated as a result of a calibration campaign. A flat field is created for each camera and filter.

Radiometric - A radiometric calibration image provides a per-pixel factor, across the active region of the array (1024x1024), to convert from digital numbers (as output by the detector) to physical units (radiance, spectral radiance, or reflectance). Calibrated images are created for each camera and filter. Values of reflectance are determined from radiance and spectral radiance images using the following solar model:

> Thuillier, G., F. Linton, T. N. Woods, R. Cebula, E. Hilsenrath, M. Hersé, and D. Labs 2004. Solar Irradiance Reference Spectra. In Solar Variability and its Effect on Climate, AGU monograph 141, eds J. Pap and P. Fox, p. 171. DOI: dx.doi.org/10.1029/141GM13

5.2.6.1 OCAMS Bad Pixel Identification Header Format

Table 13. OCAMS Bad Pixel Map Header Format

Primary Header Key Word	Default or Sample Value	Description
Mandatory Keywords		
SIMPLE	T	Conforms to FITS Standard
BITPIX	-32	8 unsigned integer, 16 & 32 integer, -32 & -64 real
NAXIS	2	Number of axes
NAXIS1	1080	Fastest changing axis
NAXIS2	1044	Next fastest changing axis
EXTEND	T	Indicates if the FITS file is allowed to contain extensions following the primary header
DATE	'2017-01-13'	Creation UTC (CCCC-MM-DD) date of FITS header
Mission Information		
MISSION	'OSIRIS-REx'	Mission: OSIRIS-REx
HOSTNAME	'OREX'	PDS Terminology
INSTRUM	'OCAMS'	Instrument: OSIRIS-REx Camera Suite
TARGET	'BENNU'	Target Object
ORIGIN	'SPOC'	University of Arizona Science Processing and Operations Center
Observation Information		
MPHASE	'Detailed Survey'	Mission Phase
ACTIVITY	'Instrument data collection'	Equivalent to primary result summary

Timing Information		
CALSTART	'2015-03-19T21:22:30.000'	Calibration File UTC Start
CALSTOP	'2015-03-19T21:22:38.000'	Calibration File UTC Stop
DATASRC	TEST	TEST for ground testing, and FLIGHT for observations after launch.
SPOCDATE	'2012-12-23T13:05:40Z'	Product creation time
CALVER	'92 fe f3 c6 97 af fc a5 2e fd 25 63 87 bf 83 a1'	Calibration code version from GIT repository
Correction Files and Information		
IN_FILE	'PCAM_L_ALLF_BadPixelMap_20150430_V001.txt'	Input Files Used
Camera Specifications		
CAMERAID	0	ID of camera in use. 0- MapCam, 1-SamCam, 2-PolyCam
Detector Regions		
RDPXLMAP	'L13H08'	String encoding how pixels read from CCD *One character for read-out direction: 'D' = Dual, 'L' = Left, 'R' = Right' *Two digit mode: 12, 13 *Once character for CTE: 'V' for mode 12 or 'H' for mode 13 *Two digit CTE value: vcte_csr for mode 12 or hcte_csr for mode 13
WRPXLMAP	'R13H08'	String encoding how pixels are written to file
Primary 2-D array (1080 x 1044)	**Default**	**Description**

5.2.6.2 OCAMS Bias Correction File Header Format

This is the format of the standalone Bias correction file.

Table 14. OCAMS Bias Correction File Header Format

Primary Header Key Word	Default or Sample Value	Description
Mandatory Keywords		
SIMPLE	T	Conforms to FITS Standard
BITPIX	-32	8 unsigned integer, 16 & 32 integer, -32 & -64 real

NAXIS	2	Number of axes
NAXIS1	1112	Fastest changing axis
NAXIS2	1044	Next fastest changing axis
EXTEND	T	Indicates if the FITS file is allowed to contain extensions following the primary header
DATE	'2017-01-13'	Creation UTC (CCCC-MM-DD) date of FITS header
Mission Information		
MISSION	'OSIRIS-REx'	Mission: OSIRIS-REx
HOSTNAME	'OREX'	PDS Terminology
INSTRUME	'OCAMS'	Instrument: OSIRIS-REx Camera Suite
TARGET	'BENNU'	Target Object
ORIGIN	'SPOC'	University of Arizona Science Processing and Operations Center
Observation Information		
MPHASE	'Detailed survey'	Mission Phase
ACTIVITY	'Instrument data collection'	Equivalent to primary result summary
Timing Information		
DATE_OBS	'2012-12-23T03:01:35.123'	YYYY-MM-DDThh:mm:ss.sss observation start, UT
CALSTART	'2015-03-19T21:22:30.000'	Calibration File UTC Start
CALSTOP	'2015-03-19T21:22:38.000'	Calibration File UTC Stop
EXPTIME	1.49407500000	[ms] Exposure time in milliseconds
Pipeline Processing Status		
DATASRC	TEST	TEST for ground testing, and FLIGHT for observations after launch.
SPOCDATE	'2012-12-23T13:05:40Z'	Product creation time
CALVER	'bd af bb 3c 59 24 5b 29 c6 33 33 ef c2 e0 24 dc'	Calibration code version from GIT repository
Correction Files and Information		
IN_FILE	'MCAM_L_ALLF_BiasCorrection_20160919_V001.txt'	Input Files Used
Camera Specifications		
CAMERAID	0	ID of camera in use. 0- MapCam, 1-SamCam, 2-PolyCam
IMAGETYP	'BIAS '	Type of image includes BIAS, DARK, FLAT, LIGHT
READOUTM	1	Readout Direction; Mode of the image, derived from CCDCSR
MCCCDTMP	1334	Mean MapCam CCD Temperature
PCCCDTMP	4095	Mean PolyCam CCD Temperature

SCCCDTMP	4095	Mean SamCam CCD Temperature
Detector Regions		
RDPXLMAP	'L13H08'	String encoding how pixels read from CCD *One character for read-out direction: 'D' = Dual, 'L' = Left, 'R' = Right' *Two digit mode: 12, 13 *Once character for CTE: 'V' for mode 12 or 'H' for mode 13 *Two digit CTE value: vcte_csr for mode 12 or hcte_csr for mode 13
WRPXLMAP	'R13H08'	String encoding how pixels are written to file
Primary 2-D array	**Default**	**Description** **(1112 x 1044) array**

5.2.6.3 OCAMS Dark Correction File Header Format

This is the format of the standalone Dark Correction file.

Table 15. OCAMS Dark Correction File Header Format

Primary Header Key Word	Default or Sample Value	Description
Mandatory Keywords		
SIMPLE	T	Conforms to FITS Standard
BITPIX	-32	8 unsigned integer, 16 & 32 integer, -32 & -64 real
NAXIS	2	Number of axes
NAXIS1	1080	Fastest changing axis
NAXIS2	1044	Next fastest changing axis
EXTEND	T	Indicates if the FITS file is allowed to contain extensions following the primary header
DATE	'2016-09-23'	Creation UTC (CCCC-MM-DD) date of FITS header
Mission Information		
MISSION	'OSIRIS-REx'	Mission: OSIRIS-REx
HOSTNAME	'OREX'	PDS Terminology
INSTRUMEN	'OCAMS'	Instrument: OSIRIS-REx Camera Suite
TARGET	'BENNU'	Target Object
ORIGIN	'SPOC'	University of Arizona Science Processing and Operations Center

Observation Information		
MPHASE	'Detailed survey'	Mission Phase
ACTIVITY	'Instrument data collection'	Equivalent to primary result summary
Timing Information		
DATE_OBS	'2012-12-23T03:01:35.123'	YYYY-MM-DDThh:mm:ss.sss observation start, UT
CALSTART	'2015-03-19T21:22:30.000'	Calibration File UTC Start
CALSTOP	'2015-03-19T21:22:38.000'	Calibration File UTC Stop
EXPTIME	100	Exposure time in ms from image integration time
Pipeline Processing Status		
DATASRC	'TEST '	TEST for ground testing, and FLIGHT for observations after launch.
SPOCDATE	'2012-12-23T13:05:40Z'	Product creation time
CALVER	'5f e4 97 be a7 17 fa 65 a1 29 fe 8e 17 0c db 49'	Calibration software version number from GIT repository
Calibration File Information		
IN_FILE	OCAM_L_ALLF_DarkCorrect'.txt	Input Files Used
Keyword Inserted During Processing		
BIASFILE	'MCAM_L_ALLF_BiasCorrection_V001.fits'	Bias Calibration File used for Bias correcton.
Camera Specifications		
CAMERAID	0	ID of camera in use. 0- MapCam, 1-SamCam, 2-PolyCam
IMAGETYP	'DARK '	Type of image includes BIAS, DARK, FLAT, LIGHT, OTHER
READOUTM	1	Readout Direction; Mode of the image, derived from CCDCSR
MCCCDTMP	1334	[DN] Mean MapCam CCD Temperature
PCCCDTMP	4095	[DN] Mean PolyCam CCD Temperature
SCCCDTMP	4095	[DN] Mean SamCam CCD Temperature
Detector Regions		
RDPXLMAP	'L13H08'	String encoding how pixels read from CCD *One character for read-out direction: 'D' = Dual, 'L' = Left, 'R' = Right' *Two digit mode: 12, 13 *Once character for CTE: 'V' for mode 12 or 'H' for mode 13 *Two digit CTE value: vcte_csr for mode 12 or hcte_csr for mode 13

WRPXLMAP	'R13H08'	String encoding how pixels are written to file
Primary 2-D array (1080 x 1044)	**Default**	**Description**

5.2.6.4 OCAMS BiasDark Correction File Header Format

This is the format of the combined Bias and Dark correction file.

Table 16. Combined BiasDark Correction file

Primary Header Key Word	Default or Sample Value	Description
Mandatory Keywords		
SIMPLE	T	Conforms to FITS Standard
BITPIX	-32	8 unsigned integer, 16 & 32 integer, -32 & -64 real
NAXIS	2	Number of axes
NAXIS1	1112	Fastest changing axis
NAXIS2	1044	Next fastest changing axis
EXTEND	T	Indicates if the FITS file is allowed to contain extensions following the primary header
DATE	'2017-01-13'	Creation UTC (CCCC-MM-DD) date of FITS header
Mission Information		
MISSION	'OSIRIS-REx'	Mission: OSIRIS-REx
HOSTNAME	'OREX'	PDS Terminology
INSTRUME	'OCAMS'	Instrument: OSIRIS-REx Camera Suite
TARGET	'BENNU'	Target Object
ORIGIN	'SPOC'	University of Arizona Science Processing and Operations Center
Observation Information		
MPHASE	'Detailed survey'	Mission Phase
ACTIVITY	'Instrument data collection'	Equivalent to primary result summary
Timing Information		
DATE_OBS	'2012-12-23T03:01:35.123'	YYYY-MM-DDThh:mm:ss.sss observation start, UT
CALSTART	'2015-03-19T21:22:30.000'	Calibration File UTC Start
CALSTOP	'2015-03-19T21:22:38.000'	Calibration File UTC Stop
EXPTIME	1.49407500000	[ms] Exposure time in milliseconds
Pipeline Processing Status		
DATASRC	TEST	TEST for ground testing, and FLIGHT for observations after launch.

SPOCDATE	'2012-12-23T13:05:40Z'	Product creation time
CALVER	'bd af bb 3c 59 24 5b 29 c6 33 33 ef c2 e0 24 dc'	Calibration code version from GIT repository
Correction Files and Information		
IN_FILE	'MCAM_L_ALLF_BiasCorrection_20160919_V001.txt'	Input Files Used
BIASFILE		Bias Calfile Used (if blank, bias/dark combined)
Camera Specifications		
CAMERAID	0	ID of camera in use. 0- MapCam, 1-SamCam, 2-PolyCam
IMAGETYP	'BIAS '	Type of image includes BIAS, DARK, FLAT, LIGHT
READOUTM	1	Readout Direction; Mode of the image, derived from CCDCSR
MCCCDTMP	1334	Mean MapCam CCD Temperature
PCCCDTMP	4095	Mean PolyCam CCD Temperature
SCCCDTMP	4095	Mean SamCam CCD Temperature
Detector Regions		
RDPXLMAP	'L13H08'	String encoding how pixels read from CCD *One character for read-out direction: 'D' = Dual, 'L' = Left, 'R' = Right' *Two digit mode: 12, 13 *Once character for CTE: 'V' for mode 12 or 'H' for mode 13 *Two digit CTE value: vcte_csr for mode 12 or hcte_csr for mode 13
WRPXLMAP	'R13H08'	String encoding how pixels are written to file
Primary 2-D array	**Default**	**Description** **(1112 x 1044) array**

5.2.6.5 OCAMS Flat Field File Header Format

Table 17. OCAMS Flat Field File

Primary Header Key Word	Default or Sample Value	Description
Mandatory Keywords		
SIMPLE	T	Conforms to FITS Standard
BITPIX	-32	8 unsigned integer, 16 & 32 integer, -32 & -64 real

NAXIS	2	Number of axes
NAXIS1	1024	Fastest changing axis
NAXIS2	1024	Next fastest changing axis
EXEND	T	Indicates if the FITS file is allowed to contain extensions following the primary header
DATE	'2017-01-13'	Creation UTC (CCCC-MM-DD) date of FITS header
Mission Information		
MISSION	'OSIRIS-REx'	Mission: OSIRIS-REx
HOSTNAME	'OREX'	PDS Terminology
INSTRUMEN	'OCAMS'	Instrument: OSIRIS-REx Camera Suite
TARGET	'BENNU'	Target Object
ORIGIN	'SPOC'	University of Arizona Science Processing and Operations Center
Observation Information		
MPHASE	'Detailed survey'	Mission Phase
ACTIVITY	'Instrument data collection'	Equivalent to primary result summary
Timing Information		
DATE_OBS	'2012-12-23T03:01:35'.123	YYYY-MM-DDThh:mm:ss.sss observation start, UT
CALSTART	'2015-03-19T21:22:30.000'	Calibration File UTC Start
CALSTOP	'2015-03-19T21:22:38.000'	Calibration File UTC Stop
EXPTIME	100	Exposure time in milliseconds
Pipeline Processing Status		
DATASRC	'TEST '	TEST for ground testing, and FLIGHT for observations after launch.
SPOCDATE	'2012-12-23T13:05:40Z'	Product creation time
CALVER	'83 fc fd 7f 09 16 84 39 f9 1b 4f ff 0f 0a a6 0f'	Calibration code version from GIt repository
Correction Files and Information		
IN_FILE	N/A	Input Files Used
BIASFILE	'MCAM_L_ALLF_BiasCorrection_V001.fits'	Bias Calibration File used in corrections.
DARKFILE	'MCAM_L_ALLF_DarkCorrection_V001.fits '	Dark Calibration File used in corrections.
Camera Specifications		
CAMERAID	0	ID of camera in use. 0- MapCam, 1-SamCam, 2-PolyCam
IMAGETYP	'FLAT '	Type of image includes BIAS, DARK, FLAT, LIGHT, OTHER
FILTNAME	'PAN '	Filter name, see Table 10.

LAMP_SEL	0	Bitwise Camera of the active illumination lamp
Detector Regions		
RDPXLMAP	'L13H08'	String encoding how pixels read from CCD *One character for read-out direction: 'D' = Dual, 'L' = Left, 'R' = Right' *Two digit mode: 12, 13 *Once character for CTE: 'V' for mode 12 or 'H' for mode 13 *Two digit CTE value: vcte_csr for mode 12 or hcte_csr for mode 13
WRPXLMAP	'R13H08'	String encoding how pixels are written to file
Primary 2-D array (1024 x 1024)	**Default**	**Description**

5.2.6.6 OCAMS Radiometric Calibration File Header Formats

Table 18. OCAMS Radiometric Calibration File Format

Primary Header Key Word	Default or Sample Value	Description
Mandatory Keywords		
SIMPLE	T	Conforms to FITS Standard
BITPIX	-32	8 unsigned integer, 16 & 32 integer, -32 & -64 real
NAXIS	2	Number of axes
NAXIS1	1024	Fastest changing axis
NAXIS2	1024	Next fastest changing axis
EXTEND	T	Indicates if the FITS file is allowed to contain extensions following the primary header
DATE	'2017-01-13'	Creation UTC (CCCC-MM-DD) date of FITS header
Mission Information		
MISSION	'OSIRIS-REx'	Mission: OSIRIS-REx
HOSTNAME	'OREX'	PDS Terminology
INSTRUMEN	'OCAMS'	Instrument: OSIRIS-REx Camera Suite
TARGET	'BENNU'	Target Object
ORIGIN	'SPOC'	University of Arizona Science Processing and Operations Center
Observation Information		

MPHASE	'Detailed survey'	Mission Phase
ACTIVITY	'Instrument data collection'	Equivalent to primary result summary
Timing Information		
DATE_OBS	'2012-12-23T03:01:35.123'	YYYY-MM-DDThh:mm:ss.sss observation start, UT
CALSTART	'2015-03-19T21:22:30.000'	Calibration File UTC Start
CALSTOP	'2015-03-19T21:22:38.000'	Calibration File UTC Stop
DATASRC	TEST	TEST for ground testing, and FLIGHT for observations after launch.
SPOCDATE	'2012-12-23T13:05:40Z'	Product creation time
CALVER	'6b 41 e1 8e ac 5f 59 a7 5f 93 16 94 99 bf c2 da'	Calibration code version from GIT repository
Camera Specifications		
CAMERAID	0	ID of camera in use. 0- MapCam, 1-SamCam, 2-PolyCam
FILTNAME	'PAN '	Filter name. See Table 10 for a complete list.
Detector Regions		
RDPXLMAP	'L13H08'	String encoding how pixels read from CCD *One character for read-out direction: 'D' = Dual, 'L' = Left, 'R' = Right' *Two digit mode: 12, 13 *Once character for CTE: 'V' for mode 12 or 'H' for mode 13 *Two digit CTE value: vcte_csr for mode 12 or hcte_csr for mode 13
WRPXLMAP	'R13H08'	String encoding how pixels are written to file
Correction Files and Information		
IN_FILE	'MCAM_A_X_RadiometricCorrection_20150120_V001.txt'	Input files used to create the radiometric correction file.
Primary 2-D array (1024 x 1024)	**Default**	**Description**

5.2.7 OCAMS Ancillary Image Information File Formats

The OCAMS Ancillary Image Information Engineering data product is an L0 binary table with 162 fields and 259 bytes per record. The binary table fields are described in the XML label. See Section 7.4 for an example label. It contains information from the CCM and EICD ID packets.

Table 19. OCAMS Ancillary Image Information File Format

Field Number	Field Name	Field Location	Field Length	Data Type	Units	Description
1	data_type	1	1	UnsignedByte		
2	seconds_raw	2	4	UnsignedMSB4	s	CCM seconds for start of exposure
3	subseconds_raw	6	2	UnsignedMSB2		CCM sub-seconds for start of exposure
4	motor_pos	8	2	UnsignedMSB2		Filter wheel or focus position
5	mapcam_fwm_temp	10	2	UnsignedMSB2	DN	MapCam Filter Wheel Motor Thermistor
6	mapcam_len_temp	12	2	UnsignedMSB2	DN	MapCam Lens Thermistor
7	samcam_fwm_temp	14	2	UnsignedMSB2	DN	SamCam Filter Wheel Motor Thermistor
8	samcam_len_temp	16	2	UnsignedMSB2	DN	SamCam Lens Thermistor
9	polycam_fom_temp	18	2	UnsignedMSB2	DN	PolyCam Focus Motor Thermistor
10	polycam_mirror_2_temp	20	2	UnsignedMSB2	DN	PolyCam Secondary Mirror Thermistor
11	polycam_tbd_temp	22	2	UnsignedMSB2	DN	PolyCam TBD Thermistor
12	mapcam_roe_temp	24	2	UnsignedMSB2	DN	MapCam Read Out Electronics Thermistor
13	samcam_fwh_temp	26	2	UnsignedMSB2	DN	SamCam Filter Wheel Housing Thermistor
14	samcam_roe_temp	28	2	UnsignedMSB2	DN	SamCam Read Out Electronics Thermistor
15	mapcam_fwh_temp	30	2	UnsignedMSB2	DN	MapCam Filter Wheel Housing Thermistor
16	polycam_roe_temp	32	2	UnsignedMSB2	DN	PolyCam Read Out Electronics Thermistor

Field Number	Field Name	Field Location	Field Length	Data Type	Units	Description
17	polycam_foh_temp	34	2	UnsignedMSB2	DN	PolyCam Focus Housing Thermistor
18	polycam_mirror_1_temp	36	2	UnsignedMSB2	DN	PolyCam Primary Mirror Thermistor
19	htr_test_pt	38	2	UnsignedMSB2	DN	Ground (Analog)
20	htr_brd_temp	40	2	UnsignedMSB2	DN	Heater_BRD_Temp (unbuffered)
21	dpu_brd_temp	42	2	UnsignedMSB2	DN	DPU Board Temperature
22	lvps_brd_temp	44	2	UnsignedMSB2	DN	LVPS Board Temperature
23	motor_brd_temp	46	2	UnsignedMSB2	DN	Motor Board Temperature
24	cur_detector_minus_24	48	2	UnsignedMSB2	DN	-24 V current detector
25	mapcam_ccd_temp	50	2	UnsignedMSB2	DN	MapCam CCD RTD Temperature
26	samcam_ccd_temp	52	2	UnsignedMSB2	DN	SamCam CCD RTD Temperature
27	cur_detector_plus_24	54	2	UnsignedMSB2	DN	+24 V current detector
28	cur_htr	56	2	UnsignedMSB2	DN	Heater Current
29	cur_motor	58	2	UnsignedMSB2	DN	Motor Current
30	cur_index	60	2	UnsignedMSB2	DN	Index Lamp Current
31	cur_lamp	62	2	UnsignedMSB2	DN	Illumination Lamp Current
32	volt_mon_sc	64	2	UnsignedMSB2	DN	Primary Voltage from S/C
33	polycam_ccd_temp	66	2	UnsignedMSB2	DN	PolyCam CCD RTD Temperature
34	volt_mon_minus_24	68	2	UnsignedMSB2	DN	-24 V Monitor (buffered)
35	volt_mon_minus_12	70	2	UnsignedMSB2	DN	-12 V Monitor
36	volt_mon_plus_24	72	2	UnsignedMSB2	DN	+24 V Monitor
37	volt_4_5_therm_mon_1	74	2	UnsignedMSB2	DN	+4.5 V Thermistor Monitor #1
38	volt_4_5_therm_mon_2	76	2	UnsignedMSB2	DN	+4.5 V Thermistor Monitor #2

Field Number	Field Name	Field Location	Field Length	Data Type	Units	Description
39	volt_mon_plus_12	78	2	UnsignedMSB2	DN	+12 V Monitor
40	volt_mon_plus_5	80	2	UnsignedMSB2	DN	+5 V Monitor
41	vref_mon_plus_5	82	2	UnsignedMSB2	DN	+5 V Reference Monitor
42	ground	84	2	UnsignedMSB2	DN	Ground (Analog)
43	cur_detector_plus_5	86	2	UnsignedMSB2	DN	+5 V current detector
44	adc_mode	88	1	UnsignedByte		ADC readout mode: 1=averaged, 0=instant
45	standby	89	1	UnsignedByte		Bitwise non-Off state of the cameras: 1=MapCam, 2=SamCam, 4=PolyCam
46	lut	90	1	UnsignedByte		Currently selected LUT number: 0=None
47	active	91	1	UnsignedByte		Camera number of active camera (1-Map, 2-Sam, 3-Poly)
48	motor_zone	92	1	UnsignedByte		Width of the last home command index (>31 is 31)
49	reserved11	93	2	UnsignedMSB2		Reserved
50	index_led_read	95	1	UnsignedByte		Bitwise read of the active LED sensors
51	reserved12	96	1	UnsignedByte		Reserved
52	index_led_sel	97	1	UnsignedByte		Camera number of the active motor index LED set
53	motor_select	98	1	UnsignedByte		Camera number of the active motor
54	cal_lamp_sel	99	1	UnsignedByte		Bitwise Camera of the active illumination lamp
55	action_mode	100	1	UnsignedByte		Action sequence enable mode: 0=off, 1=on
56	eeprom_mode	101	1	UnsignedByte		Reserved
57	samcam_lens_heater	102	1	UnsignedByte		State of the heater: 0=off, 1=on
58	samcam_filt_house_heater	103	1	UnsignedByte		State of the heater: 0=off, 1=on

Field Number	Field Name	Field Location	Field Length	Data Type	Units	Description
59	samcam_readout_elect_heater	104	1	UnsignedByte		State of the heater: 0=off, 1=on
60	samcam_ccd_heater	105	1	UnsignedByte		Samcam CCD heater, on/off state
61	mapcam_filt_motor_heater	106	1	UnsignedByte		State of the heater: 0=off, 1=on
62	mapcam_lens_heater	107	1	UnsignedByte		State of the heater: 0=off, 1=on
63	mapcam_filt_house_heater	108	1	UnsignedByte		State of the heater: 0=off, 1=on
64	mapcam_readout_elect_heater	109	1	UnsignedByte		State of the heater: 0=off, 1=on
65	samcam_filt_motor_heater	110	1	UnsignedByte		State of the heater: 0=off, 1=on
66	polycam_ccd_heater	111	1	UnsignedByte		Polycam CCD heater, on/off state
67	polycam_tbd_heater	112	1	UnsignedByte		State of the heater: 0=off, 1=on
68	polycam_secondary_heater	113	1	UnsignedByte		State of the heater: 0=off, 1=on
69	polycam_focus_motor_heater	114	1	UnsignedByte		State of the heater: 0=off, 1=on
70	polycam_primary_heater	115	1	UnsignedByte		State of the heater: 0=off, 1=on
71	polycam_readout_elect_heater	116	1	UnsignedByte		State of the heater: 0=off, 1=on
72	polycam_focus_house_heater	117	1	UnsignedByte		State of the heater: 0=off, 1=on
73	mapcam_ccd_heater	118	1	UnsignedByte		Mapcam CCD heater, on/off state
74	detector_mode	119	1	UnsignedByte		Imaging Command Mode
75	checksum2	120	2	UnsignedMSB2		Checksum of all data in CCM packet
76	sync	122	2	UnsignedMSB2		The sync pattern, always 0xED35
77	packet_id	124	2	UnsignedMSB2		packet identification number
78	packet_len	126	2	UnsignedMSB2	bytes	packet length in bytes
79	image_id	128	2	UnsignedMSB2		ID that is associated with an image
80	board_rev_num	130	1	UnsignedByte		Board revision number

Field Number	Field Name	Field Location	Field Length	Data Type	Units	Description
81	fpga_rev_num	131	1	UnsignedByte		FPGA revision number
82	ccd_rev_num	132	1	UnsignedByte		CCD revision number
83	cam_info_reserved	133	1	UnsignedByte		Reserved
84	camera_id	134	1	UnsignedByte		ID of camera in use. 0- Map, 1-Sam, 2-Poly
85	image_rows	135	2	UnsignedMSB2		number of ccd rows in image
86	image_cols	137	2	UnsignedMSB2		number of ccd columns in image
87	min_cnt	139	2	UnsignedMSB2	min	Number of minutes since reset
88	int_time	141	4	UnsignedMSB4	ms	Commanded exposure time in milliseconds
89	read_start	145	4	UnsignedMSB4		Starting read address for a memory dump.
90	read_end	149	4	UnsignedMSB4		Ending read address for a memory dump
91	sdram_csr	153	2	UnsignedMSB2		SDRAM Memory Control/Status Register
92	flags	155	2	UnsignedMSB2		Interface flags
93	pwr_mon_vod_l_override	157	1	UnsignedByte		Power monitor high-performance charge couple device (HCCD) drain override
94	pwr_mon_vdd_l_override	158	1	UnsignedByte		Power monitor on-chip amplifier drain override
95	pwr_mon_wbb_l_override	159	1	UnsignedByte		Power monitor substrate bias override
96	ccd_csr_reserved	160	1	UnsignedByte		CCD control status register reserve bit
97	ccd_rst_l_pulse	161	1	UnsignedByte		CCD control status reg left reset pulse indicator
98	ccd_rst_r_pulse	162	1	UnsignedByte		CCD control status reg right reset pulse indicator. "1" = 25 ns RST_R pulse, "0" = 12.5 ns (Control/Status) Note: if ADC_INCLK = 10 MHz, RST_R is forced to 12.5 ns.

Field Number	Field Name	Field Location	Field Length	Data Type	Units	Description
99	encode_upper_pixel_bits	163	1	UnsignedByte		Charge couple device control status register "1" = encode upper pixel bits
100	imgs_to_capture	164	1	UnsignedByte		Number of images to capture (Control/Status) Minimum/Default = 1; Maximum = 28
101	storage_flush_block_flag	165	1	UnsignedByte		Charge couple device control status register storage flush block flag
102	adc_clamp_enable	166	1	UnsignedByte		Analog to digital converter clamp enable
103	readout_mode	167	1	UnsignedByte		Readout mode
104	vfreq_csr	168	2	UnsignedMSB2		CCD vertical clock frequency control
105	vcte_csr	170	1	UnsignedByte		CCD vertical clock pattern
106	hcte_csr	171	1	UnsignedByte		Milliseconds between storage portion flushes
107	cx_pattern	172	2	UnsignedMSB2		CCD vertical clock pattern
108	storage_flush_cnt	174	2	UnsignedMSB2	ms	Storage flush count
109	cs1h_ccd	176	2	UnsignedMSB2		CD Storage clock pattern
110	cs2h_ccd	178	2	UnsignedMSB2		CD Storage clock pattern
111	cs3h_ccd	180	2	UnsignedMSB2		CD Storage clock pattern
112	cs4h_ccd	182	2	UnsignedMSB2		CD Storage clock pattern
113	tck_pattern	184	2	UnsignedMSB2		CCD transfer clock pattern
114	main_config	186	1	UnsignedByte		Main configuration Register
115	power_control	187	1	UnsignedByte		Power down control Register
116	pga_power_trim	188	1	UnsignedByte		PGA Power Trimming Register
117	adc_power_trim	189	1	UnsignedByte		ADC Power Trimming Register
118	voltage_control	190	1	UnsignedByte		Voltage Clamp Buffer Control Register

Field Number	Field Name	Field Location	Field Length	Data Type	Units	Description
119	lvds_config	191	1	UnsignedByte		LVDS Output Configuration Register
120	sample_hold	192	1	UnsignedByte		Sample & Hold Mode Register
121	status_reg	193	1	UnsignedByte		Status Register
122	reserved1	194	6	UnsignedBitString		Reserved
123	chan1_course_dac_reg_unused	200	1	UnsignedByte		Unused register
124	chan1_course_dac_reg_val	201	2	UnsignedMSB2		Channel 1 Coarse DAC Register value
125	chan1_fine_dac_reg_unused	203	1	UnsignedByte		Unused register
126	chan1_fine_dac_reg_val	204	2	UnsignedMSB2		Channel 1 Fine DAC Register value
127	reserved2	206	1	UnsignedByte		Reserved
128	pga1_gain_amp	207	1	UnsignedByte	DN	Channel 1 Programmable Gain Amplifier
129	reserved3	208	2	UnsignedMSB2		Reserved
130	chan2_course_dac_reg_unused	210	1	UnsignedByte		Unused
131	chan2_course_dac_reg_val	211	2	UnsignedMSB2		Channel 2 Coarse DAC Register.
132	chan2_fine_dac_reg_unused	213	1	UnsignedByte		Unused
133	chan2_fine_dac_reg_val	214	2	UnsignedMSB2		Channel 2 Fine DAC Register.
134	pga2_gain_amp	216	1	UnsignedByte	DN	Channel 2 Programmable Gain Amplifier Value
135	reserved4	217	3	UnsignedBitString		Reserved
136	clamp_start_reg_unused	220	1	UnsignedByte		Unused
137	clamp_start_reg_val	221	1	UnsignedByte		Clamp Start Register.
138	clamp_end_reg_unused	222	1	UnsignedByte		Unused
139	clamp_end_reg_val	223	1	UnsignedByte		Clamp End Register
140	sample_start_reg_unused	224	1	UnsignedByte		Unused

Field Number	Field Name	Field Location	Field Length	Data Type	Units	Description
141	sample_start_reg_val	225	1	UnsignedByte		Sample Start Register.
142	sample_end_reg_unused	226	1	UnsignedByte		Unused
143	sample_end_reg_val	227	1	UnsignedByte		Sample End Register.
144	reserved5	228	1	UnsignedByte		Reserved
145	inclk_range_register	229	1	UnsignedByte		Internal Clock Range Register
146	reserved6	230	2	UnsignedMSB2		Reserved
147	dll_config_reg	232	1	UnsignedByte		DLL Configuration Register
148	reserved7	233	7	UnsignedBitString		Reserved
149	test_scan_cntrl	240	1	UnsignedByte		Test & Scan Control Register
150	device_id	241	1	UnsignedByte		ADC Device Revision ID
151	reserved8	242	1	UnsignedByte		Reserved
152	clock_mon_reg	243	1	UnsignedByte		Internal Clock Signal Monitor Register
153	test_start	244	2	UnsignedMSB2		Test Pattern start value.
154	test_width	246	2	UnsignedMSB2		Test Pattern Width value.
155	test_pitch	248	1	UnsignedByte		Test Pattern pitch
156	test_step	249	1	UnsignedByte		Test Pattern Step Code.
157	test_ch_offset	250	1	UnsignedByte		Test Pattern Channel Offset Register.
158	digital_config	251	1	UnsignedByte		Serial Communication Configuration Register.
159	test_value	252	2	UnsignedMSB2		Test Pattern Value Register
160	reserved9	254	3	UnsignedBitString		Reserved
161	test_cntrl	257	1	UnsignedByte		Test Pattern Control Register.
162	checksum1	258	2	UnsignedMSB2		Checksum over sum of all data in ID packet

5.2.8 OCAMS L0 Housekeeping File Format

The OCAMS L0 Housekeeping Engineering data product is a binary table with 96 fields per 150-byte record. The binary table fields are described in the XML label. See Section 7.4 for an example label. It contains information from the Housekeeping telemetry packet.

Table 20. OCAMS L0 Housekeeping File Format

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
1	data_type	1	2	UnsignedMSB2		ID for Housekeeping packet
2	seconds_raw	3	4	UnsignedMSB4		CCM seconds at packet creation time
3	subseconds_raw	7	2	UnsignedMSB2		CCM sub-seconds at packet creation time
4	packet_bytes_count	9	2	UnsignedMSB2		Number of bytes in packet, Data_type through Checksum
5	mapcam_fwm_temp	11	2	UnsignedMSB2	DN	MapCam Filter Wheel Housing Thermistor
6	mapcam_len_temp	13	2	UnsignedMSB2	DN	MapCam Lens Thermistor
7	samcam_fwm_temp	15	2	UnsignedMSB2	DN	Samcam filter wheel motor heater, on/off state
8	samcam_len_temp	17	2	UnsignedMSB2	DN	SamCam Lens Thermistor
9	polycam_fom_temp	19	2	UnsignedMSB2	DN	PolyCam Focus Motor Thermistor
10	polycam_mirror_2_temp	21	2	UnsignedMSB2	DN	Polycam Secondary Mirror Thermistor
11	polycam_tbd_temp	23	2	UnsignedMSB2	DN	PolyCam TBD Thermistor (never installed)
12	mapcam_roe_temp	25	2	UnsignedMSB2	DN	MapCam Read Out Electronics Thermistor
13	samcam_fwh_temp	27	2	UnsignedMSB2	DN	SamCam Filter Wheel Housing Thermistor
14	samcam_roe_temp	29	2	UnsignedMSB2	DN	SamCam Read Out Electronics Thermistor
15	mapcam_fwh_temp	31	2	UnsignedMSB2	DN	MapCam Filter Wheel Housing Thermistor

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
16	polycam_roe_temp	33	2	UnsignedMSB2	DN	PolyCam Read Out Electronics Thermistor
17	polycam_foh_temp	35	2	UnsignedMSB2	DN	PolyCam Focus Housing Thermistor
18	polycam_mirror_1_temp	37	2	UnsignedMSB2	DN	PolyCam Primary Mirror Thermistor
19	htr_test_pt	39	2	UnsignedMSB2	DN	Ground (Analog)
20	htr_brd_temp	41	2	UnsignedMSB2	DN	Heater_BRD_Temp (unbuffered)
21	dpu_brd_temp	43	2	UnsignedMSB2	DN	DPU Board Temperature
22	lvps_brd_temp	45	2	UnsignedMSB2	DN	LVPS Board Temperature
23	motor_brd_temp	47	2	UnsignedMSB2	DN	Motor Board Temperature
24	cur_detector_minus_24	49	2	UnsignedMSB2	DN	-24 V current detector
25	mapcam_ccd_temp	51	2	UnsignedMSB2	DN	MapCam CCD RTD Temperature
26	samcam_ccd_temp	53	2	UnsignedMSB2	DN	SamCam CCD RTD Temperature
27	cur_detector_plus_24	55	2	UnsignedMSB2	DN	+24 V current detector
28	cur_htr	57	2	UnsignedMSB2	DN	Heater Current
29	cur_motor	59	2	UnsignedMSB2	DN	Motor Current
30	cur_index	61	2	UnsignedMSB2	DN	Index Lamp Current
31	cur_lamp	63	2	UnsignedMSB2	DN	Illumination Lamp Current
32	volt_mon_sc	65	2	UnsignedMSB2	DN	Primary Voltage from S/C
33	polycam_ccd_temp	67	2	UnsignedMSB2	DN	PolyCam CCD RTD Temperature
34	volt_mon_minus_24	69	2	UnsignedMSB2	DN	-24 V Monitor (buffered)
35	volt_mon_minus_12	71	2	UnsignedMSB2	DN	-12 V Monitor
36	volt_mon_plus_24	73	2	UnsignedMSB2	DN	+24 V Monitor
37	volt_4_5_therm_mon_1	75	2	UnsignedMSB2	DN	+4.5 V Thermistor Monitor #1
38	volt_4_5_therm_mon_2	77	2	UnsignedMSB2	DN	+4.5 V Thermistor Monitor #2
39	volt_mon_plus_12	79	2	UnsignedMSB2	DN	+12 V Monitor
40	volt_mon_plus_5	81	2	UnsignedMSB2	DN	+5 V Monitor
41	vref_mon_plus_5	83	2	UnsignedMSB2	DN	+5 V Reference Monitor
42	ground	85	2	UnsignedMSB2	DN	Ground (Analog)

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
43	cur_detector_plus_5	87	2	UnsignedMSB2	DN	+5 V current detector
44	adc_mode	89	1	UnsignedByte		ADC readout mode: 1=averaged, 0=instant
45	standby	90	1	UnsignedByte		Bitwise non-Off state of the cameras: 1=MapCam, 2=SamCam, 4=PolyCam
46	lut	91	1	UnsignedByte		Currently selected LUT number: 0=None
47	active	92	1	UnsignedByte		Camera number of active camera (1-Map, 2-Sam, 3-Poly)
48	motor_zone	93	1	UnsignedByte		Width of the last home command's index (>31 is 31)
49	reserved1	94	1	UnsignedByte		Reserved bytes
50	index_led_read	95	1	UnsignedByte		Bitwise read of the active LED sensors
51	reserved2	96	1	UnsignedByte		Reserved bytes
52	index_led_sel	97	1	UnsignedByte		Camera number of the active motor index LED set
53	motor_select	98	1	UnsignedByte		Camera number of the active motor
54	cal_lamp_sel	99	1	UnsignedByte		Bitwise Camera of the active illumination lamp
55	action_mode	100	1	UnsignedByte		Action sequence enable mode: 0=off, 1=on
56	eeprom_mode	101	1	UnsignedByte		Reserved
57	samcam_lens_heater	102	1	UnsignedByte		State of the heater: 0=off, 1=on
58	samcam_filt_house_heater	103	1	UnsignedByte		State of the heater: 0=off, 1=on
59	samcam_readout_elect_heater	104	1	UnsignedByte		State of the heater: 0=off, 1=on
60	samcam_ccd_heater	105	1	UnsignedByte		Samcam CCD heater, on/off state
61	mapcam_filt_motor_heater	106	1	UnsignedByte		State of the heater: 0=off, 1=on
62	mapcam_lens_heater	107	1	UnsignedByte		State of the heater: 0=off, 1=on
63	mapcam_filt_house_heater	108	1	UnsignedByte		State of the heater: 0=off, 1=on
64	mapcam_readout_elect_heater	109	1	UnsignedByte		State of the heater: 0=off, 1=on
65	samcam_filt_motor_heater	110	1	UnsignedByte		State of the heater: 0=off, 1=on
66	polycam_ccd_heater	111	1	UnsignedByte		Polycam CCD heater, on/off state
67	polycam_tbd_heater	112	1	UnsignedByte		State of the heater: 0=off, 1=on
68	polycam_secondary_heater	113	1	UnsignedByte		State of the heater: 0=off, 1=on

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
69	polycam_focus_motor_heater	114	1	UnsignedByte		State of the heater: 0=off, 1=on
70	polycam_primary_heater	115	1	UnsignedByte		State of the heater: 0=off, 1=on
71	polycam_readout_elect_heater	116	1	UnsignedByte		State of the heater: 0=off, 1=on
72	polycam_focus_house_heater	117	1	UnsignedByte		State of the heater: 0=off, 1=on
73	mapcam_ccd_heater	118	1	UnsignedByte		Mapcam CCD heater, on/off state
74	map_pos	119	2	UnsignedMSB2		Absolute position of the MapCam filter wheel
75	sam_pos	121	2	UnsignedMSB2		Absolute position of the SamCam filter wheel
76	poly_pos	123	2	UnsignedMSB2		Absolute position of the PolyCam focus wheel
77	time_back_cnt	125	2	UnsignedMSB2		Number of times the instrument value was earlier than the last time read
78	idle_cnt	127	2	UnsignedMSB2		An indicator of the processor utilization or idleness
79	cmd_cnt	129	1	UnsignedByte		Number of OCAMS commands received
80	cmd_reject	130	1	UnsignedByte		Number of rejected OCAMS commands
81	time_cnt	131	1	UnsignedByte		Number of Time Update commands
82	time_missedt	132	1	UnsignedByte		number of consecutive TIME_UPDATE messages not received before the timeout
83	tlm_cnt	133	1	UnsignedByte		Number of telemetry packets sent
84	noop_cnt	134	1	UnsignedByte		Number of no-op packets sent
85	idle_cnt_min	135	2	UnsignedMSB2		Minimum IdleCnt value seen
86	idle_cnt_max	137	2	UnsignedMSB2		Maximum IdleCnt value seen
87	edac_cnt	139	2	UnsignedMSB2		Number of EDAC interrupt signals seen
88	cip_cnt	141	1	UnsignedByte		Number of command transaction CIPs seen
89	cip_reject_cnt	142	1	UnsignedByte		Number of command transaction CIPs rejected
90	one_pps_cnt	143	1	UnsignedByte		Number of 1PPS signals seen
91	one_pps_missed_cnt	144	1	UnsignedByte		Number of 1PPS signal missed interrupts
92	action_seq_state	145	1	UnsignedByte		Current state of the Action Sequence state machine
93	motor_state	146	1	UnsignedByte		Current state of the Motor state machine
94	camera_state	147	1	UnsignedByte		Current state of the Camera state machine

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
95	eeprom_writing_state	148	1	UnsignedByte		Current state of the EEPROM writing state machine
96	checksum	149	1	UnsignedByte		Checksum over entire packet

5.2.9 OCAMS L1 Housekeeping File Format

The OCAMS L1 Housekeeping Engineering data product is a binary table with 94 fields per 226-byte record. The binary table fields are described in the XML label. See Section 7.4 for an example label. It contains information from the Housekeeping telemetry packet. Housekeeping conversion polynomials and coefficients can be found in Applicable Document 8, OCAMS Housekeeping Conversions.

Table 21. OCAMS L1 Housekeeping File Format

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
1	data_type	1	2	UnsignedMSB2		ID for Housekeeping packet
2	seconds_raw	3	4	UnsignedMSB4		CCM seconds at packet creation time
3	subseconds_raw	7	2	UnsignedMSB2		CCM sub-seconds at packet creation time
4	packet_bytes_count	9	2	UnsignedMSB2		Number of bytes in packet, Data_type through Checksum
5	mapcam_fwm_temp_x	11	4	SignedMSB4	Deg C	MapCam Filter Wheel Housing Thermistor
6	mapcam_len_temp_x	15	4	SignedMSB4	Deg C	MapCam Lens Thermistor
7	samcam_fwm_temp_x	19	4	SignedMSB4	Deg C	Samcam filter wheel motor heater, on/off state
8	samcam_len_temp_x	23	4	SignedMSB4	Deg C	SamCam Lens Thermistor
9	polycam_fom_temp_x	27	4	SignedMSB4	Deg C	PolyCam Focus Motor Thermistor
10	polycam_mirror_2_temp_x	31	4	SignedMSB4	Deg C	Polycam Mirror 2 temperature
11	polycam_tbd_temp_x	35	4	SignedMSB4	Deg C	PolyCam TBD Temperature (sensor not installed)

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
12	mapcam_roe_temp_x	39	4	SignedMSB4	Deg C	MapCam Read Out Electronics Thermistor
13	samcam_fwh_temp_x	43	4	SignedMSB4	Deg C	SamCam Filter Wheel Housing Thermistor
14	samcam_roe_temp_x	47	4	SignedMSB4	Deg C	SamCam Read Out Electronics Thermistor
15	mapcam_fwh_temp_x	51	4	SignedMSB4	Deg C	MapCam Filter Wheel Housing Thermistor
16	polycam_roe_temp_x	55	4	SignedMSB4	Deg C	PolyCam Read Out Electronics Thermistor
17	polycam_foh_temp_x	59	4	SignedMSB4	Deg C	PolyCam Focus Housing Thermistor
18	polycam_mirror_1_temp_x	63	4	SignedMSB4	Deg C	PolyCam Primary Mirror Thermistor
19	htr_test_pt_x	67	4	SignedMSB4	Volts	Ground (Analog)
20	htr_brd_temp_x	71	4	SignedMSB4	Deg C	Heater board temperature (unbuffered)
21	dpu_brd_temp_x	75	4	SignedMSB4	Deg C	DPU Board Temperature
22	lvps_brd_temp_x	79	4	SignedMSB4	Deg C	LVPS Board Temperature
23	motor_brd_temp_x	83	4	SignedMSB4	Deg C	Motor Board Temperature
24	cur_detector_minus_24_x	87	4	SignedMSB4	mA	-24 V current detector
25	mapcam_ccd_temp_x	91	4	SignedMSB4	Deg C	MapCam CCD RTD Temperature
26	samcam_ccd_temp_x	95	4	SignedMSB4	Deg C	SamCam CCD RTD Temperature
27	cur_detector_plus_24_x	99	4	SignedMSB4	mA	+24 V current detector
28	cur_htr_x	103	4	SignedMSB4	mA	Heater Current
29	cur_motor_x	107	4	SignedMSB4	mA	Motor Current
30	cur_index_x	111	4	SignedMSB4	mA	Index Lamp Current
31	cur_lamp_x	115	4	SignedMSB4	mA	Illumination Lamp Current
32	volt_mon_sc_x	119	4	SignedMSB4	V	Primary Voltage from S/C
33	polycam_ccd_temp_x	123	4	SignedMSB4	Deg C	PolyCam CCD RTD Temperature
34	volt_mon_minus_24_x	127	4	SignedMSB4	V	-24 V Monitor (buffered)
35	volt_mon_minus_12_x	131	4	SignedMSB4	V	-12 V Monitor
36	volt_mon_plus_24_x	135	4	SignedMSB4	V	+24 V Monitor

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
37	volt_4_5_therm_mon_1_x	139	4	SignedMSB4	V	+4.5 V Thermistor Monitor #1
38	volt_4_5_therm_mon_2_x	143	4	SignedMSB4	V	+4.5 V Thermistor Monitor #2
39	volt_mon_plus_12_x	147	4	SignedMSB4	V	+12 V Monitor
40	volt_mon_plus_5_x	151	4	SignedMSB4	V	+5 V Monitor
41	vref_mon_plus_5_x	155	4	SignedMSB4	V	+5 V Reference Monitor
42	ground_x	159	4	SignedMSB4	V	Ground (Analog)
43	cur_detector_plus_5_x	163	4	SignedMSB4	mA	+5 V current detector
44	adc_mode	167	1	UnsignedByte		ADC readout mode: 1=averaged, 0=instant
45	standby	168	1	UnsignedByte		Bitwise non-Off state of the cameras: 1=MapCam, 2=SamCam, 4=PolyCam
46	lut	169	1	UnsignedByte		Currently selected LUT number: 0=None
47	active	170	1	UnsignedByte		Camera number of active camera (1-Map, 2-Sam, 3-Poly)
48	motor_zone	171	1	UnsignedByte		Width of the last home command's index (>31 is 31)
49	index_led_read	172	1	UnsignedByte		Bitwise read of the active LED sensors
50	index_led_sel	173	1	UnsignedByte		Camera number of the active motor index LED set
51	motor_select	174	1	UnsignedByte		Camera number of the active motor
52	cal_lamp_sel	175	1	UnsignedByte		Bitwise Camera of the active illumination lamp
53	action_mode	176	1	UnsignedByte		Action sequence enable mode: 0=off, 1=on
54	eeprom_mode	177	1	UnsignedByte		Reserved
55	samcam_lens_heater	178	1	UnsignedByte		State of the heater: 0=off, 1=on
56	samcam_filt_house_heater	179	1	UnsignedByte		State of the heater: 0=off, 1=on
57	samcam_readout_elect_heater	180	1	UnsignedByte		State of the heater: 0=off, 1=on
58	samcam_ccd_heater	181	1	UnsignedByte		Samcam CCD heater, on/off state
59	mapcam_filt_motor_heater	182	1	UnsignedByte		State of the heater: 0=off, 1=on

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
60	mapcam_lens_heater	183	1	UnsignedByte		State of the heater: 0=off, 1=on
61	mapcam_filt_house_heater	184	1	UnsignedByte		State of the heater: 0=off, 1=on
62	mapcam_readout_elect_heater	185	1	UnsignedByte		State of the heater: 0=off, 1=on
63	samcam_filt_motor_heater	186	1	UnsignedByte		State of the heater: 0=off, 1=on
64	polycam_ccd_heater	187	1	UnsignedByte		Polycam CCD heater, on/off state
65	polycam_tbd_heater	188	1	UnsignedByte		State of the heater: 0=off, 1=on
66	polycam_secondary_heater	189	1	UnsignedByte		State of the heater: 0=off, 1=on
67	polycam_focus_motor_heater	190	1	UnsignedByte		State of the heater: 0=off, 1=on
68	polycam_primary_heater	191	1	UnsignedByte		State of the heater: 0=off, 1=on
69	polycam_readout_elect_heater	192	1	UnsignedByte		State of the heater: 0=off, 1=on
70	polycam_focus_house_heater	193	1	UnsignedByte		State of the heater: 0=off, 1=on
71	mapcam_ccd_heater	194	1	UnsignedByte		Mapcam CCD heater, on/off state
72	map_pos	195	2	UnsignedMSB2		Absolute position of the MapCam filter wheel
73	sam_pos	197	2	UnsignedMSB2		Absolute position of the SamCam filter wheel
74	poly_pos	199	2	UnsignedMSB2		Absolute position of the PolyCam focus wheel
75	time_back_cnt	201	2	UnsignedMSB2		Number of times the instrument value was earlier than the last time read
76	idle_cnt	203	2	UnsignedMSB2		An indicator of the processor utilization or idleness
77	cmd_cnt	205	1	UnsignedByte		Number of OCAMS commands received
78	cmd_reject	206	1	UnsignedByte		Number of rejected OCAMS commands
79	time_cnt	207	1	UnsignedByte		Number of Time Update commands
80	time_missed	208	1	UnsignedByte		number of consecutive TIME_UPDATE messages not received before the timeout.
81	tlm_cnt	209	1	UnsignedByte		Number of telemetry packets sent
82	noop_cnt	210	1	UnsignedByte		Number of no-op packets sent
83	idle_cnt_min	211	2	UnsignedMSB2		Minimum IdleCnt value seen

Field Number	Name	Field Location	Field Length	Data Type	Units	Description
84	idle_cnt_max	213	2	UnsignedMSB2		Maximum IdleCnt value seen
85	edac_cnt	215	2	UnsignedMSB2		Number of EDAC interrupt signals seen
86	cip_cnt	217	1	UnsignedByte		Number of command transaction CIPs seen
87	cip_reject_cnt	218	1	UnsignedByte		Number of command transaction CIPs rejected
88	one_pps_cnt	219	1	UnsignedByte		Number of 1PPS signals seen
89	one_pps_missed_cnt	220	1	UnsignedByte		Number of 1PPS signal missed interrupts
90	action_seq_state	221	1	UnsignedByte		Current state of the Action Sequence state machine
91	motor_state	222	1	UnsignedByte		Current state of the Motor state machine
92	camera_state	223	1	UnsignedByte		Current state of the Camera state machine
93	eeprom_writing_state	224	1	UnsignedByte		Current state of the EEPROM writing state machine
94	checksum	225	2	UnsignedMSB2		Checksum over entire packet

5.2.10 OCAMS Message Packet File Formats

The OCAMS Message Packet Engineering data product is a binary table with 9 fields per record. The product is a record of messages sent from the instrument, reporting on instrument status. This product will be released at the conclusion of the asteroid encounter. The binary table fields are described in the XML label. See Section 7.4 for an example label.

Table 22. OCAMS Message Packet Engineering Data Record Format

Name	Fields Number	Fields Locations (Start Byte)	Data Type	Field Length (bits)	Field Length (bytes)	Field Format	Unit	Description
Data_type	1	0	UnsignedMSB2	16	2			Start byte which indicates the type of data packet, =12 for Message

Name	Fields Number	Fields Locations (Start Byte)	Data Type	Field Length (bits)	Field Length (bytes)	Field Format	Unit	Description
Seconds	2	2	UnsignedMSB4	32	4		Seconds	Spacecraft seconds at packet creation time
Subsec	3	6	UnsignedMSB2	16	2			Spacecraft sub-seconds at packet creation time
NumMsgs	4	8	UnsignedMSB2	16	2			Number, N, of messages in packet where N≤100
Msg1				80	10			First message, N=1
MsgID	5	10	UnsignedMSB2	16	2			Message identifier
Subsec	6	12	UnsignedMSB2	16	2			Milliseconds since packet creation time.
MsgData1	7	14	unknown	16	2			Message Information , these 16 bits can be arranged in various configurations as bytes or words
MsgData2	8	16	unknown	16	2			Message Information , these 16 bits can be arranged in various configurations as bytes or words
MsgData3	9	18	unknown	16	2			Message Information , these 16 bits can be arranged in various configurations as bytes or words
…								
MsgN								
…								
Msg100				80	10			Last Possible Message, N=100
MsgID	500	1000	UnsignedMSB2	16	2			First message
Subsec	501	1002	UnsignedMSB2	16	2			Milliseconds since packet creation time.
MsgData1	502	1004	UnsignedMSB2	16	2			Subseconds since packet creation time , Send packet before the subsec rolls over
MsgData2	503	1006	unknown	16	2			Message Information , these 16 bits can be arranged in various configurations as bytes or words
MsgData3	504	1008	unknown	16	2			Message Information , these 16 bits can be arranged in various configurations as bytes or words
Checksum	505	1010	unknown	16	2			Message Information , these 16 bits can be arranged in various configurations as bytes or words

5.2.11 OCAMS Memory Dump Packet File Formats

The OCAMS Memory Dump Packet Engineering data product is a binary table with 9 fields per record. The binary table fields are described in the XML label. This product is a record of the memory dumps provided by the instrument to the ground for

analysis by instrument engineers. This product will be released at the conclusion of the asteroid encounter. See Section 7.4 for an example label.

Table 23. OCAMS Memory Dump File Format

Field Name	Fields Number	Fields Locations (Start Byte)	Data Type	Field Length bits	Field Length bytes	Field Format	Unit	Description
Data_type	1	0	UnsignedMSB2	16	2			Start byte which indicates the type of data packet, =12 for Message
Seconds	2	2	UnsignedMSB4	32	4		Seconds	Spacecraft seconds at packet creation time
Subsec	3	6	UnsignedMSB2	16	2			Spacecraft sub-seconds at packet creation time
DumpType	4	8	UnsignedMSB2	16	2			Number, N, of messages in packet where N≤100
StartAddress	5	10	UnsignedMSB2	16	2			Address at start of dump
Length	6	12	UnsignedMSB2	16	2			Length of dump data , which may be odd
Data byte 0	7	14…	UnsignedMSB2	8	1			The data bytes being dumped (i.e. 8 bits x Length(+1 if Length is odd)) , Pad with 0 if needed to force even number of bytes
Data byte 1			UnsignedMSB2	8	1			
Data byte 2			UnsignedMSB2	8	1			
Data byte 3			UnsignedMSB2	8	1			
Data byte 4			UnsignedMSB2	8	1			
Data byte 5			UnsignedMSB2	8	1			
Data byte 6			UnsignedMSB2	8	1			
Data byte 7			UnsignedMSB2	8	1			
Checksum	8	30	UnsignedMSB2	16	2			Checksum over entire packet

5.3 Label and Header Descriptions

All OCAMS science and ancillary data products contain date and time information that can be used to sort and correlate data products.

See Section 7.4 for examples of the OCAMS L0 through L2 data product labels. Data product labels are in XML format and are PDS4 compliant.

6 APPLICABLE SOFTWARE

6.1 Utility Programs

At the current time, the OSIRIS-REX project has no plans to release any mission specific utility programs.

6.2 Applicable PDS Software Tools

Data products found in the OSIRIS-REx archive can be viewed with any PDS4 compatible software utility. OSIRIS-REx image data and portions of the spectrometer data are formatted as FITS data files, which can be read by any FITS compatible viewer or library function.

6.3 Software Distribution and Update Procedures

As no OSIRIS-REx specific software will be released to the public, this section is not applicable.

7 APPENDICES

7.1 Acronyms

Acronym	Definition
A	ampere
A & P	astrometry and photometry
A/D	analog to digital
ACS	attitude control system
ADC	analog-to-digital converter
ANSI	American National Standards Institute
ASIC	application specific integrated circuit
az	azimuth
bps	bits per second
BRDF	bi-directional reflectance distribution function
C	Celsius
CCM	camera control module
CCSDS	Consultative Committee for Space Data Systems
CDH	command and data handling
CK	pointing NAIF SPICE kernel
Cl	chlorine
cm	centimeter
CM	configuration management
CPU	Central Processing Unit
D/A	Digital to Analog
DAWG	Data and Archive Working Group
DB	database
DN	digital numbers
DPU	digital processing unit
DRAM	dynamic random access memory
E	east
EDAC	Expandable Digital to Analog Converter
EEPROM	electrically erasable programmable read only memory
EGA	Earth gravity assist
eV	electron volt
FD	Flight Dynamics
FDS	flight dynamics subsystem
FEDS	front end data system
FK	frame NAIF SPICE kernel
FOV	field of view
FPA	focal plane array
FPGA	field-programmable gate arrays
FSW	flight software
FWHM	full width at half maximum
g	gram

Acronym	Definition
GB	Gigabytes
Gb	Gigabytes
Gbit	gigabit
Gbits	gigabits
GSFC	NASA Goddard Space Flight Center
HK	Housekeeping
HKPS	housekeeping power supply
HLP	higher-level data products
htr	heater
IAU	International Astronomical Union
I/f	(radiance/solar irradiance)
IFOV	instantaneous field of view
IK	instrument NAIF SPICE kernel
ISO	International Standards Organization
J-Asteroid	java asteroid mission-planning and analysis for remote sensing
J2000	Julian date 2451545.0 TT
K	kelvin
kbit	kilobit
kbps	kilobits per second
keV	kiloelectron volt
keV	Thousand electron volts
kg	kilogram
kHz	Thousand hertz
km	kilometer
LUT	lookup-table
LVDS	low voltage differential signal
LVPS	low voltage power supply
m	meta
m	meter
Mb	megabits
MB	megabytes
Mbps	megabits per second
Mbyte	megabyte
MEB	main electronics box
min	minute
mm	millimeter
MOU	Memorandum of Understanding
mrad	milliradian
MRD	mission requirements document
ms	millisecond
N/A	non-applicable
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NavCam	navigation camera

Acronym	Definition
NSSDC	National Space Science Data Center
O-Rex	OSIRIS-REx
O-REx	OSIRIS-REx
OCAMS	OSIRIS-REx Camera Suite
OLA	OSIRIS-REx Laser Altimeter
OpNav	optical navigation
OREX	OSIRIS-REx
OSIRIS-REx	Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer
OTES	OSIRIS-REx Thermal Emission Spectrometer
OVIRS	OSIRIS-REx Visible and Infrared Spectrometer
PCK	planetary constants NAIF SPICE kernel
PDS	Planetary Data System
px	pixel
RDR	Reduced Data Record
REXIS	Regolith X-ray Imaging Spectrometer
RMS	root mean square
RQ36	Asteroid (101955) Bennu
s	second
S	south
S/A	solar array
S/C	spacecraft
S/N	signal to noise ratio
S/W	software
SBN	Small Bodies Node
SCLK	Spacecraft Clock
SDA	science data analysis
SDP	science data processing
SDRAM	synchronous dynamic random-access memory
SE	system engineering
SIS	software interface specification
SPICE	Spacecraft, Planet, Instrument, Constants, and Events
SPK	ephemerides NAIF SPICE kernel
SPOC	science processing and operations center
sr	steradian
SRAM	static random access memory
STI	science team interface
StowCam	stow camera
SW	software
T	temperature
TAG	touch and go
TAGCAM	touch and go camera system
TAGSAM	touch-and-go sample acquisition mechanism
TBD	to be determined
TBR	to be resolved

Acronym	Definition
tlm	telemetry
TLM	telemetry
UA	University of Arizona
UTC	coordinated universal time
V	volt
W	watt
W	west
yr	year
λ	wavelength

7.2 References

Peter H. Smith, Bashar Rizk, Ellyne Kinney-Spano , Charles Fellows, Christian d'Aubigny and Catherine Merrill, The OSIRIS-REx Camera Suite (OCAMS), 1690, 44th Lunar and Planetary Science Conference, Woodlands, TX, 2013.

Tholen, D. J. (1989) Asteroids II, Tucson, UA Press, 1139-1150.

7.3 Definitions of Data Processing Levels

Table 24 shows the comparison of OSIRIS-REx, NASA and CODMAC data processing levels. The OSIRIS-REx team generally uses descriptions when classifying data rather than data levels.

Table 24. OSIRIS-REx, NASA and CODMAC data processing levels

OSIRIS-REx	NASA	CODMAC	NASA Description
	Packet data	Raw - Level 1	Telemetry data stream as received at the ground station, with science and engineering data embedded.
Level 0 - Reconstructed Telemetry	Level 0	Edited - Level 2	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed.
Level 1- Uncalibrated	Level 1A	Calibrated - Level 3	NASA Level 0 data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied).
Level 2 - Calibrated	Level 1B	Resampled - Level 4	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength).
Level 3 - Processed	Level 1C	Derived - Level 5	NASA Level 1A or 1B data that have been resampled and mapped onto uniform space-time grids. The data are calibrated (i.e., radiometrically corrected) and may have additional corrections applied (e.g., terrain correction).
Level 4 - Derived	Level 2	Derived - Level 5	Geophysical parameters, generally derived from Level 1 data, and located in space and time commensurate with instrument location, pointing, and sampling.
Level 4 - Derived	Level 3	Derived - Level 5	Geophysical parameters mapped onto uniform space-time grids.

OSIRIS-REx Data Product Level Definitions	
Level	**OSIRIS-REx Description**

OREx Level 0	Telemetry. Raw instrument data reconstructed from telemetry with header and ancillary information appended. Appended header and ancillary data is data necessary for further processing.
OREx Level 1	Uncalibrated. Data in one of the fundamental structures.
OREx Level 2	Reversibly calibrated. Data in units proportional to physical units. Since PDS allows offsets and scaling factors in its array and table structures, this would be the minimum level capable of satisfying the “in physical units” requirement.
OREx Level 3	Irreversibly processed. Higher-level products from a single source that cannot be losslessly converted back to the lower-level products from which they were derived. These might also satisfy the “in physical units” requirement.
OREx Level 4	Derived data. Products created by combining data from more than one source (instrument, observer, etc.).

7.4 Example PDS Labels

Example labels can be found in the OCAMS bundle document collection in a sub-directory named “example_labels”. There are example labels for each type of OCAMS data product.