Origins Spectral Interpretation Resource Identification Security-Regolith Explorer (OSIRIS-REx) Project

OSIRIS-REx Map Format Software Interface Specification

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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.

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OSIRIS-REx Project
Map Format SIS

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1 Purpose and Scope

The data formats described by this Software Interface Specification (SIS) are the formats used by the OSIRIS-REx "map" data products. "Map" format products are those products that assign a value to an area on the surface of Bennu and/or provide additional information about that area. The OSIRIS-REx Science Processing and Operation Center (SPOC) located at the University of Arizona produces maps in conjunction with the OSIRIS-REX Science Team Working Groups, as well as project systems engineering (safety map) and flight dynamics (deliverability map). The SPOC distributes the data products to both the entire OSIRIS-REx Science Team and in many cases the Planetary Data System.

The purpose of this document is to provide the preparers and users of these data products with a detailed description of the project approved "map" data formats. The document is intended to provide enough information to enable preparers to write the data products and end-users to read and understand the data products. The users for whom this document is intended are the scientists who will produce the data or 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 Format SIS is consistent with the following Planetary Data System Documents:

1. Planetary Data System Standards Reference, Version 1.7.0, September 28, 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 Format 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 26, 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 – J-Asteroid ICD, UA-ICD-9.4.4-102, Rev 2.0, March 2016.
7. OSIRIS-REx Thermal Analysis Derived Data Product Software Interface Specification, UA-SIS-9.4.4-317, Rev. 1.0, June 17, 2015.
8. OSIRIS-REx Spectral Processing Derived Data Product Software Interface Specification, UA-SIS-9.4.4-312, Rev. 1.0, March 2016.
9. OSIRIS-REx Regolith Development Derived Data Product Software Interface Specification, UA-SIS-9.4.4-320, Rev. 1.0, June 15, 2016.

10. OSIRIS-REx Image Processing Derived Data Product Software Interface Specification, UA-SIS-9.4.4-309, Rev. 1.0, March 2016
11. OSIRIS-REx Altimetry & Stereophotoclinometry Derived Data Product Software Interface Specification, UA-SIS-9.4.4-307, Rev 2.0, April 24, 2017.
12. OSIRIS-REx Visual and Infrared Spectrometer (OVIRS) Uncalibrated / Calibrated Data Product Software Interface Specification, UA-SIS-9.4.4-306, Rev 2.0, March 2016.
13. OSIRIS-REx Thermal Emission Spectrometer (OTES) Uncalibrated / Calibrated Data Product Software Interface Specification, UA-SIS-9.4.4-304, Rev. 2.0 March 2016.
14. OSIRIS-REx Camera Suite (OCAMS) Uncalibrated / Calibrated Data Product Software Interface Specification, UA-SIS-9.4.4-300, Rev 3.0, March 2016.
15. OSIRIS-REx Laser Altimeter (OLA) Uncalibrated/Calibrated Data Product Software Interface Specification, UA-SIS-9.4.4-302, Rev 2.0, March 2016.
16. OSIRIS-REx Naming Conventions Document, UA-HBK-9.4.4-905, Rev 4.0, August 3, 2017.
17. OSIRIS-REx Coordinate System Description, Version 2.1, https://sbnarchive.psi.edu/pds4/orex/orex.mission/document/Bennu_Coordinate_System_Description.pdf, August 19 2021

This document is also consistent with the FITS format standard as defined in

18. Definition of the Flexible Image Transport System (FITS), The FITS Standard Version 4.0: 2018 August 13.

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 formats described in this SIS effect or are effected by the following software, products or documents:

Table 1 - Interface Relationships

Name	Type	Owner
SPOC Database Schema	Product	SPOC
Altimetry Map Products	Product	SPOC
Image Processing Map Products	Product	SPOC
Spectral Analysis Map Products	Product	SPOC
Radio Science Map Products	Product	SPOC
Regolith Map Products	Product	SPOC
Thermal Map Products	Product	SPOC
Sample Site Map Products	Product	SPOC

Name	Type	Owner
SPOC-Science Working Group ICDs	Document	SPOC
Altimetry SIS	Document	SPOC
Image Processing SIS	Document	SPOC
Radio Science SIS	Document	SPOC
Regolith SIS	Document	SPOC
Thermal SIS	Document	SPOC
Sample Site SIS	Document	SPOC
J-Asteroid SIS	Document	SPOC
OSIRIS-REx Science Data Management Plan	Document	Project

Please note that for all OSIRIS-REx map data products, the Map Formats SIS is the governing document. Any map product found in another SIS may specify metadata specific to that map, but the map format by definition will be consistent with this document. In the event that another SIS describes a format inconsistent with this document, that SIS will be updated.

4 Data Product Characteristics and Environment

4.1 Map Products Overview

The data formats described in this SIS are applicable to the map products produced by all OSIRIS-REx Science Team Working Groups and others who deliver map products to the SPOC during asteroid proximity operations. "Maps" are produced at various scales during the mission but are generally either Global (80% or better coverage of Bennu's surface) or Site-Specific in nature. We do not use the term "Map" in the strict sense of a two-dimensional representation of a three-dimensional object. "Map" can be thought of, for our purposes, as any data collection that describes the surface of Bennu and can be rendered with the appropriate software. All maps are generated in one of three formats with varying header values that describe the specifics of the particular map.

4.2 Data Format Overview

This SIS describes the format of map products produced for the OSIRIS-REx mission. In general, map data products are produced as PDS4 compliant .OBJ plus ancillary information FITS file, FITS format files, or shape files. Specific details for each format can be found in Section 5. The map formats described in the SIS are used to produce the following types of data products, although other map formatted data products may be produced:

1. **Altimetry Maps** – Topography and Tilt Maps
2. **Image Processing** – Particle Size Frequency Distribution Maps, Image Mosaics
3. **Spectral Analysis Maps** – Mineralogy/Chemistry Maps and Dust Cover Maps
4. **Radio Science** – Slope and Gravity Field Maps

5. **Regolith Development** - Crater, Boulder, Regolith, Linear Features, Geologic, Space Weathering Maps
6. **Thermal** – Temperature and Thermal Inertia Maps
7. **Sample Site** – Safety, Sampleability, Deliverability and Science Value Maps

4.3 Data Processing

Almost all OSIRIS-REx mission science data processing is performed at the SPOC. Map products are derived data products that may contain data acquired from a single observation or may contain data acquired from multiple observations that have been binned, averaged, or processed in some other way. Input data for map products is obtained from the SPOC Data Repository and finished map products are ingested back into the Data Repository through a controlled process to be made available to the entire science team.

4.3.1 Data Processing Level

All map data products are produced from other data products and are considered to be OSIRIS-REx Level 4 data products. Correlation to NASA and CODMAC data processing levels and definitions can be found in Appendix 6.2.

4.3.2 Data Product Generation

As mentioned previously, almost 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 turn-around needed by the science and operations teams to make tactical decisions about sample site selection. Map data products are generated by several different methods described in the following paragraphs.

4.3.2.1 Enhanced Shape Model Data

Data that are acquired or combined at a resolution approximately equal to the project approved shape model for a given mission phase will use the .OBJ + Ancillary File format. The .OBJ file is derived from the project-approved shape model and contains vertices and facets that describe Bennu's shape as a triangular mesh. The .OBJ format is based on a format developed by Wavefront Technologies, but wherever differences between this document and other documents describing the .OBJ format exist, this document shall prevail. Enhanced shape model data assign a single value to each triangular plate in the mesh that can be related to a position on the surface of Bennu. Data that are acquired at the approximate resolution of the shape model and that cover a single facet of the triangular mesh can be assigned to that single facet of the triangular mesh. Combined data can be generated using software developed by the OSIRIS-REx team that allows a user to input observation data, determine where the data was collected on the surface of Bennu, determine which facet or facets of the shape model the observations cover, and assign that observation to the(those) facet(s). Once observations are assigned to facets, data can be averaged, filtered and/or excluded depending on user preferences. The resulting output is either one data value (scalar) and standard deviation per shape model facet (Ancillary 6), three values and standard deviations to support the mapping of a single vector (Ancillary 10), or a 3 vector and standard deviations file (Ancillary 22). This information is saved into the Ancillary File that is formatted to accompany a specific .OBJ file that describes Bennu's shape.

4.3.2.2 Image Data

Many datasets will have higher resolution (many instrumental samples per triangular facet) than the project approved shape model for a given mission phase. In these cases, it will be desirable to fuse the high-resolution data and 3D position information provided by the project-approved shape model and associated SPICE (Digital Shape Kernels). To accomplish this, we will use the FITS image format to capture the high-resolution data. These products are generally image data, image mosaics or maps, where it is desirable to preserve pixel-by-pixel information. These products will be generated by the Image Processing Working Group, typically only for PDS deliverables.

4.3.2.3 "ShapeFile" Data

There are types of map products that delineate or annotate specific points or areas on the surface of Bennu. These products are essentially labels or representations of features on the asteroid's surface. These types of map products are produced using the OSIRIS-REx data visualization tool or other software products that support the standard described in this document. The output product is a "ShapeFile" that contains information about the selected features. "ShapeFiles" can be saved to the SPOC Data Repository, to be made available to all team members.

4.3.3 Labeling and Identification

OSIRIS-REx science data products are named according to the OSIRIS-REx Naming Conventions Document (UA-HBK-9.4.4-905).
The map files shall be named according to the following convention:
Coverage Type + "_" + Ground Sample Distance+ "mm"+ "_" + "_" + SDP Area + "_" + Description + "_" + "*Center Location*"+ "_" + "v" + Version + "." + PDS Type
Coverage Type is either "g" for Global or "l" for Local
Ground Sample Distance is the five-digit spatial resolution in units of mm.
SDP Area is one of the following:

- ALT = Altimetry – OSIRIS- REx Laser Altimeter
- AST = Astronomy
- IP = Image Processing
- RD = Regolith Development
- RS = Radio Science
- SP = Spectral Processing
- SPC = Altimetry – Stereophotoclinometry
- SPO = Altimetry – Stereophotoclinometry and OSIRIS-REx Laser Altimetry
- SS = Sample Site
- TA = Thermal Analysis

Description describes the product type of the file as designated in the SPOC Global Specification.
Center Location is an **optional** name component that describes latitude and longitude in the center location of the data product. The format is “LatitudenLongitude”, where latitude is 4 digits and longitude is 5 digits.
Version is a three-digit version identifier.
PDS Type is either .OBJ or FITS for map products
Several examples of map file names are given below:
l_00300mm_alt_dtm_0000n07500_v100.obj
l_00300mm_alt_elv_0000n07500_v100.fits
g_00850mm_alt_mtl_0000n00000_v100.fits

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 pre-release PDS peer review to ensure compliance with applicable standards.

4.4.2 Time Standard

Time Standards used by the OSIRIS-REx mission conform to PDS time standards. All OSIRIS-REx data products contain both the spacecraft clock time of data acquisition and a conversion to UTC to facilitate comparison of data products. All time formats should be considered to be in UTC unless otherwise indicated.

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 “Bennu Coordinate System Description” (Applicable Document 17). The Bennu coordinate system is deployed in the mission through the creation of SPICE kernels which are used in the creation of mission approved shape models. These shape models are in turn used to create Ancillary FITS map file templates based on the facet construction of the approved shape model. In map products, the way to distinguish the coordinate system used to create the shape model the map is based on is by the DATASRCV and OBJ_FILE attributes. The DATASRCV is the shape model data source version and the OBJ_FILE is the name of the shape file used to produce the map template. The shape model data source version linkage to SPICE kernels can be found in the shape model documentation that resides in the orex.altimetry bundle. However, it can generally be assumed that maps are based on the Benne coordinate system as described in Version 2.1 of the “Bennu Coordinate System Description” document.

4.4.4 Data Storage Conventions

FITS data are stored according to the FITS 3.0 Standard. OBJ files are stored as ASCII Text table extensions. Ancillary files are stored as binary table extensions. Image FITS files are stored as 2- or 3-dimensional arrays. Shape files are stored according to the conventions listed in Section 5.2.1.1.

The binary format of 32-bit and 64-bit floating point numbers shall conform to the IEEE-754 floating point standard, which consists of a sign bit, a biased exponent (8-bit and 11-bit, respectively), and a fraction. "Not a number" or quiet NaN as specified in IEEE-754 is used to represent a value that is not known or is unavailable and is represented as the hexadecimal value of 0x7FC00000 (32-bit) or 0x7FF8000000000000. (64-bit).

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.

In addition to software types of 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.

5 Detailed Data Product Specifications

The following sections provide detailed data product specifications for each of the three types of map formats. These specifications will provide sufficient detail, so that data product users can read and interpret the products.

5.1 Data Product Structure and Organization

The OSIRIS-REx archive is organized into bundles for each detector (OCAMS, OTES, OVIRS, OLA, REXIS), TAGSAM, DSN, SPICE, and higher-order data product bundles. The higher-order data product bundles are Astronomy, Altimetry, Image Processing, Spectral Processing, Derived Radio Science, Thermal Analysis, and Regolith. Map data will be spread among the various higher-order bundle elements but will be identified in the filename in the "Description" field.

5.2 Data Format Descriptions

The following sections give the detailed data format descriptions for the project approved Map Interchange Formats.

5.2.1 Enhanced Shape Model Data - OBJ + Ancillary File

5.2.1.1 OBJ File Format

For all map data products that are tied to the project-approved shape model and have a single value at the scale of the shape model the .OBJ file format with an independent ancillary file shall be used. The .OBJ file is one variant of the standard created by Wavefront Technologies with specifications for the vertex and facets of a triangular mesh that describes the 3-dimensional shape of the asteroid. The ancillary information file assigns a single scalar value and associated error or a triple vector value and errors to each facet of the mesh.

The .OBJ file is stored in ASCII format using the .OBJ file extension. The OSIRIS-REx implementation of the .OBJ standard begins with a required header, although a header is not required in other .OBJ standards. Header or comment lines are declared with the hash (#) symbol. The header is followed by the file data. Each non-blank line of the data portion of the file starts with a keyword followed on the same line by the data for that keyword. Data are stored as specified in the example below and are separated into columns using white space as delimiters. Lines are read and processed sequentially until the end of the file is reached.

A subset of keywords supported by the .OBJ file format used by the OSIRIS-REx project are listed in Table 2.

Table 2. Definitions taken from http://www.martinreddy.net/gfx/3d/OBJ.spec.

Keyword Definition	Keyword	Data	Description
Geometric Vertices	(v)		Specifies a geometric vertex and its x,y,z coordinates. The enumerated position of the vertex in the list is the vertex reference number.
		x	x coordinate of vertex
		y	y coordinate of vertex
		z	z coordinate of vertex
Facet	(f)		Specifies a face element by its three vertex reference numbers.

All elements in an .OBJ file are referenced by number to identify geometric vertices and facets. The vertices are numbered (vertex reference number) sequentially, starting with 1. The first geometric vertex in the file has a vertex reference number of 1, the second is 2, etc. The numbering continues sequentially throughout the entire file.

The preceding paragraphs were summarized from http://www.martinreddy.net/gfx/3d/OBJ.spec, where a complete description of the .OBJ standard can be found.

An example of an .OBJ file format is as follows:

```
#Model of the surface of Bennu. File consists of vertices and facets. Facets are triangular and
#connected by the right hand rule. The x, y, and z components of the vertices precede the
#letter 'v' in the first part of the file. The number of each vertex is defined by the position
#of the vertex in the list defined by the letter 'v', where the first line in this list is the first vertex.
#In the second half of the file, the three numbers following the letter 'f' are the vertex numbers
#that make up each facet.
#PRODVERS = 4.5.0 \ Product version number
#MISSION = OSIRIS-REx
#TARGET = 101955 BENNU
#ORIGIN = OREXSPOC
#SPOC_ID =  \ Unique identifier created by the SPOC on upload to the repository. The template default is
blank.
#MPHASE = SOPIE1
#OBJTYPE = Global \Global or Local
#DATASRC = TRUTH
#DATASRCV = BENNUV4.5i (4.5f plus 5cm maplets)
#SOFTWARE = AltwgPipeline \ Software used to create map data
#SOFT_VER = 1 \ 1
#DATEPRD = 2017-05-01T17:44:01 \ UTC
#PRODNAME = g_0078cm_tru_obj_0000n00000_v450.fits
#PRODVERS = 4.5.0 \ Product version number
#DATASRCV = BENNUV4.5i (4.5f plus 5cm maplets)
#CLON = 180 \ [deg] longitude at center of image
#CLAT = 0.0 \ [deg] latitude at center of image
#Number of Plates          = 3145728
#Number of Vertices        = 1579014
#Number of Edges           = 4718592
#Euler Polyhedron Formula   = 6150
#Surface Area              = 0.7802739656753155    km^2
#Plate Area Mean           = 2.480424136083282e-07 km^2
#Plate Area Min            = 1.690566067297758e-07 km^2
#Plate Area Standard Dev    = 3.539128495633372e-08 km^2
#Edge Length Mean          = 0.0007847788651570420 km
#Edge Length Max           = 0.001284602933854431  km
#Edge Length Variance       = 1.786029767293688e-08 km^2
#Surface Closed?           = Yes
#Volume                    = 0.06257137911397348   km^3
#Centroid:
#  [2.521250024913485E-4, 5.511084611215825E-4, -1.546124972719001E-4] km
#Moment of Inertia Tensor Relative To Origin:
#  [0.0014640440405228848, -1.2318568729703212E-7, 4.7634371477116014E-7]
#  [-1.2318568729703212E-7, 0.0015035669717645707, -6.333000631921742E-8]
#  [4.7634371477116014E-7, -6.333000631921742E-8, 0.0016369856678711077]
#Moment of Inertia Tensor Relative To Centroid:
#  [0.001464023540539748, -1.1449150541271791E-7, 4.7390457752740555E-7]
#  [-1.1449150541271791E-7, 0.0015035614985183193, -6.866160437409918E-8]
#  [4.7390457752740555E-7, -6.866160437409918E-8, 0.0016369626861823976]
#Extent:
#  X: [-0.27035000920295715, 0.27706000208854675] km
#  Y: [-0.2590799927711487, 0.2653200030326843] km
#  Z: [-0.24514999985694885, 0.25745001435279846] km
v  0.000000  0.000000  0.139347
v  0.000000  0.123456  0.789101
v  0.123456  0.789101  0.121314
```

```
v 0.000000 0.000000 0.567890
v 0.456739 0.000000 0.139347
v 0.000000 0.000000 0.139347
v 0.892630 0.617283 0.139347
v 0.000000 0.000000 0.139347
v 0.467820 0.890173 0.139347
v 0.000000 0.000000 0.139347

# Facet Definitions
f 1 2 3
f 1 3 4
f 1 4 5
f 1 5 6
f 1 6 7
f 1 7 2
f 2 8 9
f 1 9 10
```

Each facet is numbered by its ordinal position in the list of Facet Definitions

5.2.1.2 Ancillary FITS File

The Ancillary file is a FITS file that provides all metadata about the .OBJ/Ancillary File pair, and then lists each facet in order, along with its latitude and longitude, and a value and associated error for the facet of regard. The Ancillary file is formatted as a FITS file with a single header data unit. Optional keywords are noted in the "Description" column by the (*Optional) designation.

An example of the Global Map Ancillary File format is as follows:

Table 3. Global Ancillary File

Keyword	Value (Values in regular text are literal values, values in italics are example values)	Description
SIMPLE	T	Conforms to FITS Standard
BITPIX	8	
NAXIS	0	Number of axes; 0 for Binary table. Template Entry
EXTEND	T	Extensions are permitted. Template Entry
COMMENT	Header Information	
HDRVERS	3.0.0	The version number of this FITS header. Value is a string that should match the SIS version. Template Entry
COMMENT	Mission Information	
MISSION	'OSIRIS-REx'	Mission: OSIRIS-REx. Template Entry
HOSTNAME	'OREX'	PDS Terminology. Template Entry
TARGET	*'101955 BENNU'*	Target Object. User Entry defaulted to Bennu.
ORIGIN	'OREXSPOC'	University of Arizona Science Processing and Operations Center. Template Entry
INSTRUME	'OCAMS"	(*Optional) Instrument: OSIRIS-REx Camera Suite
Comment	Identification Information	

Keyword	Value (Values in regular text are literal values, values in italics are example values)	Description
SPOC_ID	*ALT-08:01*	Unique identifier created by the SPOC on upload to the repository. The template default is blank. SPOC upload entry.
SDPAREA	*ALT*	Three letter abbreviation for each of the Science Working Group Data Processing Areas. These abbreviations match SDP Area in Section 4.3.3. SPOC upload entry.
SDPDESC	*DTM*	Matches Description in the filename. SPOC upload entry.
MPHASE	*'detailed survey'*	Mission Phase(s) of the mapped data. User entry
Comment	Shape Data Source	
DATASRC	'*SPC*'	Source of shape model data – whether from SPC, ALT or a combination, SPO. If unknown, UNK. Template entry
DATASRCF	'*ZS1664.MAP*'	Source shape model data filename(s). Useful for traceability or for debugging. Set to 'multiple files' if more than one source file was used to create the product. Value is a string. Template entry
DATASRCV	'*PS30_FINAL_v1.0*'	Name and version of SPC, OLA or SPC/OLA model employed. Value is a string. Template entry
DATASRCS		[m/pix] Shape model plate scale. Template Entry
DATASRCD	*2017-08-29T08:47:00*	Shape model generation date. Template Entry
OBJ_FILE	'*L_005cm_OLA_DTM_1000N21000_v251.OBJ*'	Name of parent OBJ file to which the data in this ancillary file corresponds. Value is a string. Template entry
Comment	Processing Information	
PRODNAME	'*L_005cm_20130122T100443_ALT_NSLP_1000N21000_v001.FITS*'	Product File Name. Value is a string. SPOC upload entry.
DATEPRD	'*2015-10-02T08:12:23.9234*'	UTC date that this MAP product was produced. Value is a string of format: 'YYYY-MM-DDTHH:MM:SS.ssss' in UTC. User entry.
SOFTWARE	'*SDP Software Module*'	Name of software used to create map data. User entry
SOFT_VER	*1*	Version of software. User entry
Comment	Map Specific Information	
MAP_NAME	'*tilt*'	Map data type. User entry per Global Spec
MAP_VER	'*2.5.1*'	Product version number. This will distinguish different generations of the data, on the assumption that models are regenerated with different parameters, different processing sequences). Value is a string. User entry or SPOC upload entry
MAP_TYPE	'*global*'	Global or local map. Template entry
MAP_PROJ		(*Optional) Map Projection name
GSD	*1278.0149562590927*	(*Optional) Ground sample distance. Units are provided in each keyword's associated comment immediately following the forward slash in square brackets. (e.g. [m]). Value is a real floating point number with the format F18.13. Template entry

Keyword	Value (Values in regular text are literal values, values in italics are example values)	Description
GSDI	*1278*	Ground sample distance integer. Units are provided in each keyword's associated comment immediately following the forward slash in square brackets. (e.g. [m]). Value is an integer number. Template entry
Comment	Summary Spatial Information	
CLON		Longitude E of center of regional DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360, units are degrees. Template entry
CLAT		Latitude of center of regional DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90 degrees. Units are degrees. Template entry
Comment	Product Specific Keyword	Any keywords found after this comment are specific to the individual product and are referenced in the product-specific SIS.
END		
Primary Data Unit		None as per FITS Standard
Secondary Header		
XTENSION	'BINTABLE'	This is the Binary Ancillary table of data values per shape model facet
BITPIX	8	Bits per data value
NAXIS	2	Number of axes
NAXIS1	(24)	Number of bytes in a Row (facet)
NAXIS2	(12288)	Number of Rows (facets)
PCOUNT	0	No group data
GCOUNT	1	One group
TFIELDS	(6, 10, or 22)	Number of fields in table
TFORM1	'J'	Format (J is 32-bit integer)
TTYPE1	'FACET_NUM'	Facet Number
TFORM[2,3,4]	('D')	Format (usually double precision floating point)
TTYPE[2,3,4]	('LATITUDE, LONGITUDE, RADIUS')	The type of value stored in the second (for Latitude, third for Longitude, and fourth for Radius) column of the file. This will be the Latitude [or Longitude, Radius] coordinate in the body fixed frame from the center of the body to the center to each facet of the OBJ file defined by the MATCHOBJ record keyword. Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[m]). Value is a string.
TUNIT[2,3]	'DEGREES'	Latitude and Longitude (Columns 2 and 3) are in units of Degrees.
TUNIT[4]	'KILOMETERS'	Radius (Column 4) is in units of kilometers.
TFORM[5 or 5,7,9, or 5,7,9,11,13,15,17,19,21]	('D','E','I','J')	Format (usually a numeric type, if an array, prefix with total number of elements) in standard FITS notation. See AP-18 for possible values.
TTYPE[5 or 5,7,9 or 5,7,9,11,13,15,17,19,21]	'VALUE' FOR VECTOR FILES 'VALUEX', 'VALUEY', 'VALUEZ' or 'VALUEX1', 'VALUEX2', 'VALUEX3' 'VALUEY1',	The facet values stored in the fifth column of this file. In some instances, for single vector quantities, this will include two additional columns for Y and Z values located at columns 7 and 9 respectively, and for three vector quantities the X vector values are stored in columns 5,7,9, Y vector values in 11,13,15, and Z vector values in 17,19,21. The units will be specified The units will be specified in the

Keyword	Value (Values in regular text are literal values, values in italics are example values)	Description
	'VALUEY2', 'VALUEY3', 'VALUEZ1', 'VALUEZ2', 'VALUEZ3'	corresponding TUNITS field. Interpretation of value stored in the columns is defined by the MAP_NAME keyword.
TUNIT[5 or 5,7,9 or 5,7,9,11,13,15,17,19,21]	('D','E','I','J')	(*Optional) Physical units of the VALUE(s) given in standard FITS format (e.g. /[unit].
TFORM[6 or 6,8,10, or 6,8,10,12,14,16,18,20,22]	('D','E','I','J')	Format (same type as value)
TTYPE[6 or 6,8,10 or 6,8,10,12,14,16,18,20,22]	'SIGMA' FOR VECTOR FILES 'SIGMAX', 'SIGMAY', 'SIGMAZ' ('uncertainty')	The type of values stored in sixth (or sixth, eighth and tenth) column of data. This value is an estimate of the uncertainty associated with each value in the column defined by the TTYPE[5 and optionally 7 and 9 or 7,9, 11,13,15,17,19,21 keyword. The units will be specified in the corresponding TUNITS field.
TUNIT[6 or 6,8,10 or 6,8,10,12,14,16,18,20,22]	('D','E','I','J')	(*Optional) units of the SIGMA(s) given in standard FITS format (e.g. /[unit].
END		Required in a FITS compliant header
Secondary Data Unit		Binary Table

The Site-Specific (or local) Ancillary File format is identical to the Global Ancillary File format with additional summary spatial information keywords added according to Table 4.

Table 4. Site Specific Ancillary File

Comment	Summary Spatial Information	
CLON		Longitude E of center of regional DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360, units are degrees. Template entry

CLAT		Latitude of center of regional DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90 degrees. Units are degrees. Template entry
LLCLNG		Longitude E of lower left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360. Units are degrees. Template entry
LLCLAT		Latitude of lower left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90. Units are degrees. Template entry
URCLNG		Longitude E of upper left corner of DTM (deg) . Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360. Units are degrees. Template entry
URCLAT		Latitude of upper left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90. Units are degrees. Template entry
LRCLNG		Longitude E lower right corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360. Units are degrees. Template entry
LRCLAT		Latitude lower right corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90. Units are degrees. Template entry
ULCLNG		Longitude E upper left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360. Units are degrees. Template entry

ULCLAT		Latitude upper left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90. Units are degrees. Template entry
CNTR_V_[XYZ]		(*Optional) The three coordinates of the vector (on three lines for _X, _Y and _Z) from the center of object to the center of the DTM in Bennu Body Fixed coordinates. Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[m]). Value is a real floating-point number. Template entry
UX_[XYZ]		(*Optional) The three components (of the unit vector (on three lines for _X, _Y and _Z) lying on the reference plane along axis 1 of NFT fits file, in Bennu Body Fixed coordinates. . Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[m]). Value is a real floating-point number. Template entry
UY_[XYZ]	-255.0223	(*Optional) The three components of the unit vector (on three lines for _X, _Y and _Z) lying on the reference plane along axis 2 of NFT fits file, in Bennu Body Fixed coordinates. . Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[m]). Value is a real floating-point number. Template entry
UZ_[XYZ]	-19.2322	(*Optional) The three components of the reference plane unit normal vector (on three lines for _X, _Y and _Z). This vector is orthogonal to the reference plane and has a positive dot product with CNTR_V. Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[m]). Value is a real floating-point number. Template entry
CRAD		(*Optional) Radius at center pixel of the map (m)
Comment	Product Specific Keyword	Any keywords found after this comment are specific to the individual product and are referenced in the product specific SIS.
END		
Primary Data Unit		None as per FITS Standard
Secondary HDU		Identical to the "Global" file specification

Latitude, longitude and radius are calculated at center of the triangular facet.

"NaN" (See Section 4.4.4) is used for undefined values.

Note that any "UNITS" FITS keywords are defined using standard SI units, and are translated in the PDS4 labels as either attribute or table column descriptors.

The OBJ/FITS Ancillary file pairs are named identically with the exception of the product type field and file extensions. An .OBJ file may be associated with several ancillary files. The OBJ file has an .OBJ extension and the FITS file has a .FITS extension. For example:

l_0030cm_alt_shp_0000n07500_v100.obj
l_0030cm_alt_elv_0000n07500_v100.fits

The following is a partial list of data products that will use this format:

1. **Altimetry Maps** – Topography and Tilt Maps
2. **Image Processing** – Particle Size Frequency Distribution Maps
3. **Spectral Analysis Maps**– Mineralogy/Chemistry Maps and Dust Cover Maps
4. **Radio Science** – Slope and Gravity Field Maps
5. **Thermal** – Temperature and Thermal Inertia Maps
6. **Sample Site** – Deliverability, Safety, Sampleability and Science Value Maps

5.2.2 FITS Format File

For all map data products that have many values (i.e. pixels) within one element (triangular facet) of the shape model shall use the FITS (Flexible Image Transport System http://fits.gsfc.nasa.gov/fits_home.html) map format file described below.

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
NAXIS3		(*Optional) Plane data axis
EXTEND	T	Indicates if the FITS file is allowed to contain extensions following the primary header
Comment	Header Information	
HDVERS		The version number of this FITS header. Value is a string that should match the SIS version.
Comment	Mission Information	
MISSION	‘OSIRIS-REx’	Mission: OSIRIS-REx
HOSTNAME	‘OREX’	PDS Terminology
TARGET	‘BENNU’	Target Object
ORIGIN	‘SPOC’	University of Arizona Science Processing and Operations Center
INSTRUME	‘OCAMS’	(*Optional) Instrument: OSIRIS-REx Camera Suite
Comment	Identification Information	
SPOC_ID	*ALT-08:01*	Unique identifier created by the SPOC on upload to the repository. The template default is blank. SPOC upload entry

SDPAREA	*ALT*	Three letter abbreviation for each of the Science Working Group Data Processing Areas. These abbreviations match SDP Area in Section 4.3.3. SPOC upload entry.
SDPDESC		Matches Description in the filename. SPOC upload entry.
MPHASE	'*detailed survey*'	Mission Phase
Comment	Shape Data Source	
DATASRC		(*Optional) Source of shape model data – whether from SPC, ALT or a combination, SPO.
DATASRCF		(*Optional) Source shape model data filename(s). Useful for traceability or for debugging. Set to 'multiple files' if more than one source file was used to create the product. Value is a string.
DATASRCV		Name and version of SPC, OLA or SPC/OLA model employed. Value is a string.
DATASRCS		Plate scale of the shape model.
DATASRCD		Shape model generation date.
OBJ_FILE		(*Optional) Name of parent OBJ file for which the data in this ancillary file corresponds to. Value is a string.
Comment	Processing Information	
PRODNAME		Product File Name. Value is a string. SPOC upload entry.
DATEPRD	('2015-10-02T08:12:23.9234)	The date that this MAP product was produced. Value is a string of format: 'YYYY-MM-DDTHH:MM:SS.ssss' in UTC.
SOFTWARE		Name of software used to create map data. User entry
SOFT_VER		Version of software used to create map. User entry
Comment	Map Description	
MAP_NAME	'*Map_Name'*	Map Name
MAP_VER	*1.0*	Map version
MAP_TYPE	'*Global*'	Global' or 'Local' map
MAP_PROJ	'*Simple Cylindrical*'	(*Optional) Name of map projection
GSD	*1278.1234567891123*	(*Optional) Ground sample distance. Units are provided in each keyword's associated comment immediately following the forward slash in square brackets. (e.g. [cm]). Value is a real floating point number with the format F18.13.
GSDI	*1278*	Ground sample distance integer. Units are provided in each keyword's associated comment immediately following the forward slash in square brackets. (e.g. [cm]). Value is an integer number. Template entry
Comment	Summary Spatial Information	
CLON		Longitude E of center of regional DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360, units are degrees. Template entry
CLAT		Latitude of center of regional DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90 degrees. Units are degrees. Template entry

LLCLNG		Longitude E of lower left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360. Units are degrees. Template entry
LLCLAT		Latitude of lower left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90. Units are degrees. Template entry
URCLNG		Longitude E of upper left corner of DTM (deg) . Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360. Units are degrees. Template entry
URCLAT		Latitude of upper left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90. Units are degrees. Template entry
LRCLNG		Longitude E lower right corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360. Units are degrees. Template entry
LRCLAT		Latitude lower right corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90. Units are degrees. Template entry
ULCLNG		Longitude E upper left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is 0 to 360. Units are degrees. Template entry
ULCLAT		Latitude upper left corner of DTM (deg). Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[deg]). Value is a real floating-point number with the format F18.13. Range of values is -90 to 90. Units are degrees. Template entry

CNTR_V_[XYZ]		(*Optional) The three coordinates of the vector (on three lines for _X, _Y and _Z) from the center of object to the center of the DTM in Bennu Body Fixed coordinates. Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[m]). Value is a real floating-point number. Template entry
UX_[XYZ]		(*Optional) The three components (of the unit vector (on three lines for _X, _Y and _Z) lying on the reference plane along axis 1 of NFT fits file, in Bennu Body Fixed coordinates. . Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[m]). Value is a real floating-point number. Template entry
UY_[XYZ]		(*Optional) The three components of the unit vector (on three lines for _X, _Y and _Z) lying on the reference plane along axis 2 of NFT fits file, in Bennu Body Fixed coordinates. . Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[m]). Value is a real floating-point number. Template entry
UZ_[XYZ]		(*Optional) The three components of the reference plane unit normal vector (on three lines for _X, _Y and _Z). This vector is orthogonal to the reference plane and has a positive dot product with CNTR_V. Units are provided in each keyword's associated comment immediately following the forward slash in square brackets (e.g., /[m]). Value is a real floating-point number. Template entry
CRAD		(*Optional) Radius at center pixel of the map (m)
Comment	Plane Information	
PLANE_[n]	'Hazard Mask'	(*Optional) Data Plane description
END		
Primary 2-D array (1024x1024)	**Default**	**Description (32-bit floating point values)**

Note that any "UNITS" FITS keywords are defined using standard SI units, and are translated in the PDS4 labels as either attribute or table column descriptors.

FITS Cube Version

A **cube version** (multiple data planes) of the FITS file described above may also be used for some products. Therefore, the metadata of this data product will map directly to this document, ***except*** for the multiple planes (2D arrays), which will be designated by keywords, such as:

```
PLANE_01  = 'Hazard Mask'
PLANE_02  = 'Latitude'           / Degrees
PLANE_03  = 'Longitude'          / Degrees
```

Data products that will use this format are:

1. **Image Processing** – Hazard/Particle Map, Image Mosaics (only for PDS delivery), and orthoimages (only for PDS delivery).

5.2.3 ShapeFile

For all map data products that specify a location or object on the surface of Bennu, a ShapeFile shall be used. Shapefiles can be used to describe complex shapes that (most frequently) need to be displayed and geospatially registered with other types of maps. These shapes take the form of simple vectors, closed shapes, or polylines defined by a series of coordinates that describe the shape. The following formats are accepted:
CSV File: The CSV file is a standard "Well Known Text" (WKT) file used for describing spatial objects' shape. The header line of the CSV ASCII file specifies 3 columns in this example; a geometry, radius (optional), and the feature string. Additional columns can be added to specify additional attributes of the feature. In this example a point looks like: POINT (347.21875 -1.9374999999999989),,point. There is no radius for a true point so the 2nd column is empty. Circles are special cases of the point type, where the radius IS set. Instead of the "point" string in the 3rd column, it is left blank. So a circle looks like this:

POINT (9.890625000000057, -9.265625000000005),28.669991477800203,circle.

A polygon shape again has the geometry in the first column, no radius and the "polygon" string in the 3rd column:

"POLYGON ((1.0625 3.437500000000009, 2.09375 -1.7187499999999956,
4.812499999999943 1.812499999999982, 1.0625 3.437500000000009))",,polygon.

A polyline is just a series of two or more points with the geometry in the first column, no radius, and "polyline" in the 3rd column:

"LINESTRING (356.0625 -4.90625, 0.6875 -8.250000000000016)",,polyline.

The geometry will be in the first column, but the other column positions can vary as the example below demonstrates.

geometry,Radius:double,Feature:string
POINT (13.46875 -6.843750000000002),36.651665402972505,
"POLYGON ((5 -5.812500000000014, 8.156250000000057 1.156249999999978,
13.5625 -2.8437500000000147, 4.906249999999943 -7.406250000000012, 5 -
5.812500000000014))",,polygon
POINT (350.40625 -0.5937500000000018),,point
"POLYGON ((1.0625 3.437500000000009, 2.09375 -1.7187499999999956,
4.812499999999943 1.812499999999982, 1.0625 3.437500000000009))",,polygon
POINT (3.250000000000057 6.312499999999995),44.393553308901524,
POINT (346.78124999999994 -5.062500000000011),,point

"LINESTRING (348.71875 -8.218749999999998, 355.06250000000006 -6.6562500000000195, 350.15625 -6.374999999999992, 345.78125 -7.593749999999998, 347.65625000000006 -8.093750000000005)",,polyline
POINT (347.21875 -1.937499999999989),,point
"LINESTRING (356.0625 -4.90625, 0.6875 -8.250000000000016)",,polyline
POINT (350.71875000000006 -4.593749999999994),,point
POINT (9.890625000000057 -9.265625000000005),28.669991477800203,

ESRI Shapefile: In addition to the above format, the ESRI open source shapefiles may also be used. These are a set of specification files that describe geographic location and attribute data. The collection of files that specify a particular geographic feature are as follows:

`.shp` — shape format; the feature geometry itself

`.shx` — shape index format; a positional index of the feature geometry to allow seeking forwards and backwards quickly

`.dbf` — attribute format; columnar attributes for each shape, in dBase IV format

A full accounting of the binary format of each of these files can be found at:
http://en.wikipedia.org/wiki/Shapefile
The following list contains a partial list of data products that will use this format:

1. **Regolith Development** - Crater, Boulder, Regolith, Linear Features, Geologic, Space Weathering Maps
2. **Dust and Plume Maps**

6 Appendices

6.1 Acronyms

Phrase/Acronym	Description
ALT	Altimetry
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
AST	Astronomy
CCB	Change Control Board
CCD	Charge Couple Device
CM	Configuration Management
CML	Configuration Management Lead
CODMAC	Committee On Data Management and Computation
CR	Change Request
CSV	Comma Separated Values
DMP	Data Management Plan
DSK	Digital Shape Kernel
DSN	Deep Space Network
DTM	Digital Terrain Model
ECR	Engineering Change Request
ESRI	Environmental Systems Research Institute
EU	Engineering Units
FITS	Flexible Image Transport System
HDU	Header/Data Unit
IAU	International Astronomical Union
IAUFWG	International Astronomical Union Flexible Image Transport System Working Group
ICD	Interface Control Document
ID	Identifier
IEEE	Institute of Electrical and Electronics Engineers
IP	Instrument Processing
IPWG	Image Processing Working Group
IR	Infra-red
ISIS	Integrated Software for Imagers and Spectrometers
ISO	International Standards Organization
LIDAR	Light Detection And Ranging
LM	Lockheed Martin
NASA	National Aeronautics and Space Administration
NFT	Natural Feature Tracking
OBJ	Shape Model Object file format

OCAMS	OSIRIS-REx Camera Suite
OIA	Operational Interface Agreement
OLA	OSIRIS-REx Laser Altimeter
OSIRIS-Rex	Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer
OTES	OSIRIS-REx Thermal Emission Spectrometer
OVIRS	OSIRIS-REx Visible and near-IR Spectrometer
PDS	Planetary Data System
PVL	Parameter Value Language
RD	Regolith Development
RDWG	Regolith Development Working Group
REXIS	Regolith X-ray Imaging Spectrometer
RS	Radio Science
SAWG	Spectral Analysis Working Group
SDP	Science Data Product
SIS	Software Interface Specification
SP	Spectral Processing
SPC	Stereophotoclinometry
SPICE	Spacecraft, Planet, Instrument, Camera, Events kernels
SPO	Stereophotoclinometry and OSIRIS-REx Laser Altimetry
SPOC	Science Processing and Operations Center
SS	Sample Site
ST	Science Team
TA	Thermal Analysis
TAG	Touch-And-Go
TAGSAM	Touch-And-Go Sample Acquisition Mechanism
TBD	To Be Determined/Delivered
TBR	To Be Recorded
UNK	Unknown
UTC	Universal Time Coordinated
WKT	Well Known Text

6.2 Definitions of Data Processing Levels

OSIRIS-REx	NASA	CODMAC	Description
	Packet data	Raw - Level 1	Telemetry data stream as received at the ground station, with science and engineering data embedded.
Level 0 - Raw	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.

Level	*Definition*	
Low-Level Products	Any data product assigned to OSIRIS-REx Level 0 through Level 2	
	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. This data will be archived to the PDS.
	OREx Level 2	*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. This data will be archived to the PDS
High-Level Products	Any product assigned to an OSIRIS-REx data product level above Level 2.	
	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. Data products of this processing level will be archived to the PDS according to DMP-Table 19
	OREx Level 4	*Derived data*. Products created by combining data from more than one source (instrument, observer, etc.). Data products of this processing level will be archived to the PDS according to DMP-Table 19