Lucy
SOFTWARE INTERFACE SPECIFICATION
L'Ralph/LEISA Data Products

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Contract NNM16AA08C

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REVISION NOTICE

Revision Number	Change Number	Sections Affected	Change Description	Release Date
0	0	All	(DRAFT, R0)	12/10/2020
0	0	All	Draft, R0	3/31/2021
0	0	All	Draft, R0	09/08/2023
0	0	2.3.4.1	File naming convention updates per PR-0313 and TCR 2311	06/01/2024
0	0	All	Initial Release	7/2024

TBD/TBS RESOLUTION SCHEDULE

Location	Description	Resolution Date
Table 1-1	L'Ralph Instrument Paper	12/31/2023
All	2023 PDS Peer Review updates	6/1/2024

1. INTRODUCTION

1.1 Purpose and Scope

The purpose of this Software Interface Specification (SIS) is to provide the consumers of the *Lucy* L'Ralph/LEISA raw and calibrated data products with a detailed description of the data products, and how they were 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. Raw data products described in this SIS are uncalibrated, uncorrected data products reassembled from spacecraft telemetry as acquired by the instrument. Calibrated data products described in the SIS are corrected and calibrated data products with values given in physically meaningful data units. The *Lucy* Science Operations Center located at the Southwest Research Institute, Boulder, Colorado produces these data products and distributes them to both the *Lucy* Science Team and the Planetary Data System (PDS). This SIS describes how the L'Ralph/LEISA data products are acquired by the instrument, processed, formatted, labeled, and uniquely identified. The document discusses standards used in generating the product and software that may be used to access the products.

1.1 Contents

This Data Product SIS describes how the raw data products are acquired by the L'Ralph/LEISA and how the products are processed, formatted, labeled, and uniquely identified. This SIS also describes how the calibrated data products are derived from the raw data or other calibrated data products. The document discusses standards used in generating the products, and software that may be used to access the products. The raw and calibrated data product structure and organization is described in sufficient detail to enable a user to read the product. Processing is described at a high level, and full definitions of all metadata attributes are provided.

1.2 Applicable Documents

This SIS is meant to be consistent with the contract negotiated between the *Lucy* Project, the L'Ralph Instrument Principal Investigator, and the *Lucy* Science Operations Center (SOC). Product label keywords/attributes may be added to future revisions of this SIS. Therefore, it is recommended that software designed to process products specified by this SIS should be robust to (new) unrecognized keywords. Similarly, entirely new products may be added over time.

This Data Product SIS is responsive to the following documents:

Table 1-1. List of Applicable Documents

Document ID	Title	Release Date	Revision
JPL D-7669, Part 2	Planetary Data System Standards Reference	June, 2023	1.20
n/a	Data Provider's Handbook, Archiving Guide to the PDS4 Data Standards	June, 2023	1.20
n/a	Planetary Data System Common Dictionary Document	June, 2023	1.20
22702-DMAP-01	*Lucy* Data Management and Archive Plan		current revision unless revision is specified
22668.07-ST-ICD-01	*Lucy* Science Operations Center to Science Team ICD		current revision unless revision is specified
s11214-023-01009-2	L'Ralph: A Visible/Infrared Spectral Imager for the Lucy Mission to the Trojans	October, 2023	https://doi.org/10.1007/s11214-023-01009-2

1.3 Relationship with Other Interfaces

This SIS could be affected by changes to the *Lucy* Data Management and Archive Plan (DMAP) or the *Lucy*-SBN Interface Control Document (ICD). Where possible, references are made to the DMAP or ICD rather than duplicating information in this document. This SIS may be revised by consent of the signatories. The following table is a list of other interfaces where changes may affect the contents of this SIS. The SIS will be updated when necessary.

Table 1-2. List of Interface Relationships

Name	Type	Owner
Lucy SOC Database Schema	Product	SOC
LEISA Uncalibrated Data	Product	SOC
LEISA Calibrated Data	Product	SOC
LEISA Pipeline Software	Software	SOC
Lucy SOC-SBN Configuration Control Plan	Document	SOC
Lucy SOC-SBN ICD	Document	SOC
Lucy DMAP	Document	Project

2. DATA PRODUCT CHARACTERISTICS AND ENVIRONMENT

2.1 Instrument Overview

L'Ralph is a combined multi-band visible imager and wedge-filter IR spectrometer. It follows in line from similar instruments on EO-1, New Horizons, and OSIRIS-REx. L'Ralph was developed by NASA GSFC.

The flight instrument operates as two instruments in one with a shared optical path. The visible wavelength multicolor imager (MVIC) acts as a multi-band push-broom camera. Five bands include color filters, and one band is panchromatic. Each of the six bands is an independent rectangular CCD operating in a time-delay integration (TDI) mode. The infrared mapping spectroscopy facility (LEISA) is a square IR HgCdTe array with a linear wedge filter. The filter and detector are arranged so that the cross-track direction and the direction of changing wavelength are orthogonal. The resulting system operates as a push-broom spectrometer. A common set of reflective optics allow the MVIC and LEISA to share the same field of view, with a dichroic optic splitting the incoming energy between the two separate focal planes. A scan mirror mechanism (SMM) attached to the first fold-flat mirror allows the scene to be mapped without having to move the entire spacecraft or integrated payload platform. Note that preferred operation is to scan one pixel per integration time, but other rates are allowed.

LEISA is an IR imaging spectrometer an operates from ~0.95 to 4 microns with a 40.75 microrad/pixel iFOV. LEISA can view science targets, the sun (through the solar calibration) port, or instrument-internal blackbody and filament sources. The full LEISA readout capability is 2048 cross track pixels, but the filters cover from pixel 192 to 1215. In the along-track direction, the filters cover output channels 4 through 26. Each output channel corresponds to 64 pixels.

LEISA can be commanded to readout any consecutive subarray across the wired outputs, and in raw (LEISA_RAW) or Correlated Double Sampled (LEISA_CDS) mode, where the reset value is subtracted. All science data is in CDS. On playback, the data may be further 2x2 superpixeled (values summed, LEISA_SUPER) after applying a bad pixel map, to reduce data volume.

Table 2-1. LEISA Properties

FOV	Cross-Track Window Start	Cross-Track Window End
Reference Pixels (may be used for detector troubleshooting)	0	3
Optimal Science FOV	448	959
Total FOV through the filters	192	1215
Along-Track Channel	**Along-Track Pixel #**	**Center Wavelength Range (micron)**
3	0-255	N/A, obscured
4	256-319	3.949-3.796
5	320-383	3.793-3.640
6	384-447	3.638-3.485
7	448-511	3.482-3.329
8	512-575	3.327-3.174
9	576-639	3.171-3.018
10	640-703	3.016-2.863
11	704-767	2.860-2.707
12	768-831	2.705-2.552
13	832-842	bond gap
13	843-895	2.627-2.497
14	896-959	2.495-2.337
15	960-1023	2.334-2.177
16	1024-1087	2.174-2.017
17	1088-1151	2.014-1.857
18	1152-1215	1.854-1.697
19	1216-1278	1.694-1.539
19 /20	1279-1295	bond gap
20	1296-1343	1.641-1.568
21	1344-1407	1.566-1.468
22	1408-1471	1.466-1.367
23	1472-1535	1.366-1.267
24	1536-1599	1.266-1.167
25	1600-1663	1.166-1.067
26	1664-1717	1.065-0.967

2.1.1 Observation Profile and Data Acquisition

The Lucy mission consists of five flybys of Trojan asteroids to investigate the differences in their surface and internal properties across the population of Trojan asteroids. From these five encounters we will be able to observe seven Trojan asteroids: Eurybates and its small satellite Queta, Polymele, Leucus, Orus, Patroclus and Menoetius. Two of the flybys will encounter multiple Trojan asteroids. The first Lucy Trojan flyby will be of Eurybates and its recently discovered small moon (Noll et al. 2020) and the last encounter is of the near-equal size binary system: Patroclus and Menoetius. Lucy will also fly by a Main Belt asteroid target of opportunity, Dinkinesh, and possible a second target, (52246) Donaldjohanson, prior to reaching the Trojans; these encounters will test operations.

During the flybys, the spacecraft is moving relative to the Trojan asteroids with a velocity of 6-9 km/s making time a critical resource. The mission is designed to maximize the data collected around closest approach which requires efficiency in observing the Trojan asteroids.

L'Ralph is a visible/NIR camera and shortwave infrared spectral mapper. The instrument's primary purpose is to measure surface characteristics, including geological processes, geomorphology, photometric properties, and surface composition (Reuter et al. 2023). L'Ralph will also be used to measure the properties of any tenuous atmospheres and to obtain compositional measurements of serendipitously discovered rings and small satellites.

Most observations and actions on the spacecraft are commanded to execute at a given time. However, during the close-approach subphase most science observations will be initiated based on the range of the spacecraft to the Trojan asteroid target. At the beginning of this time period, the range is estimated based on an on-board ephemeris. As the spacecraft approaches the target and the image of the target is resolved in the Terminal Tracking Cameras, the on-board terminal-tracking state estimation begins to provide an estimate of the Trojan's location relative to the spacecraft. This terminal tracking allows the Lucy spacecraft to have updated knowledge of the target which allows for a more efficient observing strategy. The large uncertainty in the target location (relative to its size) is collapsed by the on-board terminal tracking system. L'Ralph uses an internal scan mirror to scan the target across LEISA or MVIC. Scan rate is set by the desired LEISA integration time, or to match the TDI rate of MVIC, and scans can be commanded in either direction (Short to long wavelength or long to short wavelength) for LEISA.

2.2 Data Product Overview

Instrument data are natively stored as binary Flexible Image Transport System (FITS) files. Images with associated meta-data are also stored in database tables in the Lucy SOC Data Repository for further processing by the SOC systems. Calibration files necessary to process image data are stored as FITS files and are made available to the processing pipeline.

The specific data products described by this SIS are:

1. L'Ralph/LEISA Raw Science Data – Raw instrument science data. Each raw datafile represents a single scan of the target, including information from all commanded spectral channels and cross track pixels. Image data are stored in units of DN.

2. L'Ralph/LEISA Calibration Data – Data used by the pipeline to transform instrument data to science values. Calibration data files are provided by the L'Ralph/LEISA calibration team to the SOC. The SOC software provides the proper calibration data files to the automated pipeline.

   These calibration files will be provided to the SOC by the L'Ralph/LEISA instrument team in the FITS file format. The first delivery was based on ground calibration and assumes the instrument is at notional operational detector temperature (~103 K). Updates were made as necessary based on performance after launch and include the temperature-dependent long wavelength response; the first column in the files corresponds to cross track readout column 192 in the full detector.

   a. Bad Pixel Map – Map of bad pixels across the full array (1472x1024). 0 = good pixel, 1=bad pixel.
   b. Radiometric calibration coefficients – 1472x1024 array of derived calibration coefficients (W/cm2/sr/um)/(counts/sec)
   c. Background file – a default array for the background subtraction (set to all zero)
   d. Wavelength map – 1472x1024 array of derived wavelengths

3. L'Ralph/LEISA Calibrated Science Data– Instrument data that has been calibrated to radiance units. These data are stored as a 5-extension FITS file that includes calibrated instrument data, wavelength array, dark subtraction data, radiometric coefficients, and geometry back plane that contains a timestamp for each frame with range and phase angle of the observation.

A complete description of the various files is given in Section 3.

2.3 Data Processing

The Lucy Science Operations Center (SOC) is responsible for all Lucy science data processing. L'Ralph/LEISA science and engineering telemetry are received by the SOC via the Mission Operations Center (MOC). L'Ralph/LEISA raw telemetry data are reconstructed, sorted, and stored in the SOC data repository. L'Ralph/LEISA science data (along with its associated engineering and housekeeping data) are retrieved from the data repository and fed into the L'Ralph/LEISA-specific data processing pipeline. The pipeline produces the L'Ralph/LEISA uncalibrated and calibrated science and engineering data products. Generally, data are stored in FITS file format, and are delivered to the PDS in that format. Production rates of calibrated data vary over the course of the mission and are dependent on observing campaigns during specific mission phases. Individual file sizes based on the current operational plan are as follows: L'Ralph/LEISA Uncalibrated science data files are dependent on the number of cross track pixels (XT), wavelength channels (AT) = XT*AT*64*16 bits per frame; and Calibrated science data files are approximately 4 times larger than the uncalibrated data, as they contain additional extensions. Specific file sizes will vary dependent on the number of records in each sequence, which is driven by the mission operations plan.

2.3.1 Data Processing Level

The L'Ralph/LEISA data products comply with NASA processing level standards as shown in Table 2-2 Data Processing Levels. L'Ralph/LEISA data products are derived from the previous level product. Calibration file data processing levels are not discussed, as calibration files require special production techniques.

Table 2-2. Data Processing Levels

Lucy Archive Data Product	PDS4 Processing Level	Description
N/A	Telemetry	An encoded byte stream used to transfer data from one or more instruments to temporary storage where the raw instrument data will be extracted. PDS does not archive telemetry data.
Uncalibrated Data Product	Raw	Original data from an instrument. If compression, reformatting, packetization, or other translation has been applied to facilitate data transmission or storage, those processes will be reversed so that the archived data are in a PDS approved archive format. Lucy L'Ralph/LEISA uncalibrated products are the raw science images in units of DN.
	Partially Processed	Data that have been processed beyond the raw stage, but which have not yet reached calibrated status. Lucy L'Ralph/LEISA does not archive partially processed data
Calibrated Data Product	Calibrated	Data converted to physical units, which makes values independent of the instrument. Lucy L'Ralph/LEISA calibrated products are science images in physical units
	Derived	Results that have been distilled from one or more calibrated data products (for example, maps, gravity or magnetic fields, or ring particle size distributions). Supplementary data, such as calibration tables or tables of viewing geometry, used to interpret observational data should also be classified as "derived" data if not easily matched to one of the other three categories.

2.3.2 Data Product Generation

The L'Ralph/LEISA uncalibrated files will be generated by the SOC from the downlinked L'Ralph spacecraft telemetry. The uncalibrated products will contain raw, uncalibrated data, formatted according to the Raw science and housekeeping data formats defined in this SIS. New versions of the products will be identified using a version identifier in the filename, as indicated in Section 2.3.4.1 and by the version_id field in the PDS label. On successful completion through the L'Ralph data processing pipeline software, the SOC will be responsible for inserting the output file data into the SOC Data Repository. In case of errors, any messages produced as well as the error file will be saved for further diagnosis by the L'Ralph/LEISA engineers.

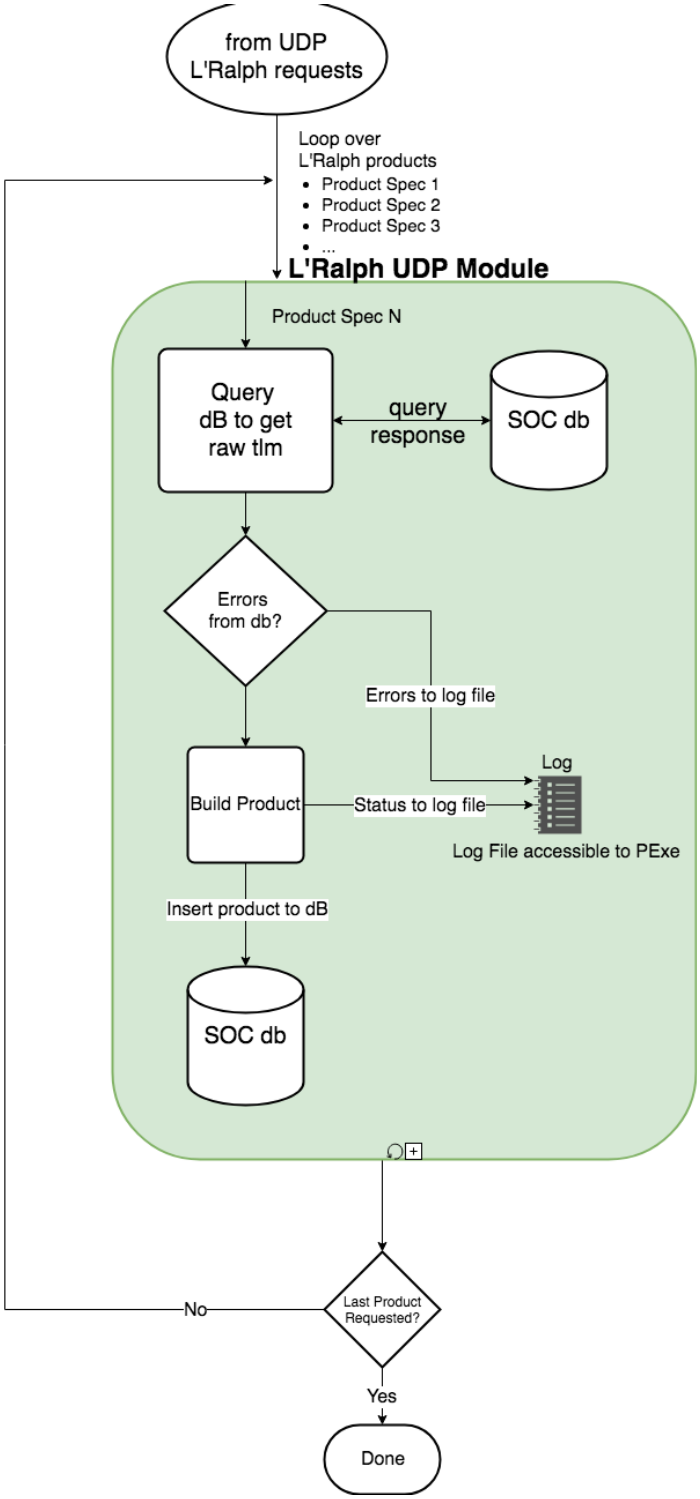
Calibrated data products will be automatically produced by the data processing software from the uncalibrated data files. New versions of Calibrated data will be generated should the raw data, the instrument/spacecraft geometry, the calibration algorithm, or the calibration software components change. Changes to the calibration algorithm and software components will be rare events. It is more likely that an update to geometry will cause re-processing. New versions of the Calibrated data will be identified by incrementing the version identifiers (filename version and PDS label version_id) in the data. All versions of the data products are retained in the SOC repository for reference, however only certified valid products are released to the PDS. Should products need to be updated in the archive, the new certified valid products will replace the older (deprecated) versions.

The SOC will monitor the records being downlinked and correlate them with the uplinked commands to ensure that all commanded data have been accounted for.

2.3.2.1 Uncalibrated Data Product Generation

L'Ralph science, engineering, and ancillary packet telemetry are received from the Mission Operations Center (MOC) via a dedicated connection. The packet data are ingested into the SOC data repository using the Database Downlink Ingestion Tool (DDIT) which is responsible for decompression, database communication, parsing, data insertion, and querying. Once L'Ralph packet data are sorted, parsed, and inserted in the SOC data repository, they are ready for instrument specific processing. DDIT processing splits the L'Ralph packet data into two holding tables, one for LEISA and one for MVIC. Further processing starts from the holding tables. The Pipeline Executive (PExe) process controls the SOC data processing environment by managing and initiating all pipeline functions. Using either scheduled or manual jobs, PExe calls the main Unprocessed Data Processing (UDP) module that manages the setup and execution of the individual instrument pipeline functions. The L'Ralph UDP module has sub-tasks specific to LEISA and MVIC. The tasks build the uncalibrated data products, in FITS format, by appending packet data that holds a single line of pixel data. The data packets included within a given FITS product file are determined by the row counter for LEISA and the CCD for MVIC. FITS header information is also populated at this time. The L'Ralph UDP module returns all UDP products and logfile information to the SOC data repository.

Figure 2-1. L'Ralph UDP Module



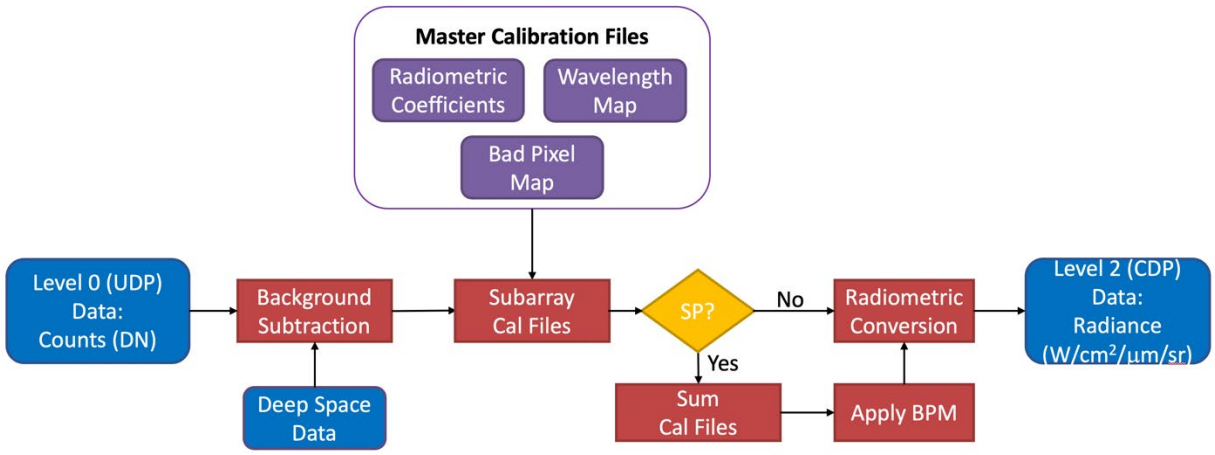
2.3.2.2 Calibrated Data Product Generation

The LEISA calibration pipeline converts data from raw counts to physical units (radiance in $W/cm^2/sr/\mu m$). The output file is a floating-point array with the same dimensions as the input data file, with extensions added that contain the wavelengths, the subtracted dark current counts, and the radiometric conversion coefficients for each pixel.

The pipeline is dependent on accurate header information and on using frames before/after the observation to calculate an average space block, acquired with the same settings, for dark current level subtraction. The exact timing of the creation and the duration of the space block is dependent on the specific observation sequence. However, the SOC will receive the calibration space block prior to running the final calibration pipeline. The integration time is calculated on the fly, as it is possible to command the instrument to non-physical integration times: the commanded time is converted by the LEISA focal plane electronics to truncated LEISA "drop frames" (DF) and is dependent on the number of cross-track pixels that are commanded (XTNUM); if a shorter than allowable integration time is commanded, DF is set to 0. The calibration steps are as follows:

1. Conduct error checks: if it fails any of these, report in logfile and exit
    a. Make sure file is within bounds for the calibration file (outputs 4 through 26, and cross-track pixels 192 to 1215)
    b. Check for an appropriate data type: LEISA_CDS (leisa_mode = true) or LEISA_SUPER (leisa_mode = false).
2. Compare space block file parameters (see calibrated data product reference list for space file used) to ensure they match the science file. If not, use 0 for the background, report in log file, and continue
    a. Subtract average space frame from data to produce background-subtracted counts
3. Subarray the radiometric calibration and bad pixel map files to match the science file readout area (i.e., same cross track and along track readout areas)
4. If LEISA_SUPER, sum the calibration files, apply the bad pixel map to the science file
5. Calculate the actual integration time the instrument used:
    LEIINT = (XTNUM + 3 + (2048 - XTNUM) / 144 + DF) * 0.72 ms where:
    LEIINT FITS header keyword = lucy:leisa_integration_time in PDS xml label.
    XTNUM FITS header keyword = lucy:leisa_xtrack_num_rows
    DF is FITS header keyword M4DROPF = lucy:fpe_drop_frames
6. Divide the background subtracted science file by the integration time, in seconds, and multiply by the (summed or subarrayed, as appropriate) calibration file.

Figure 2-2. LEISA Calibration Data Processing (CDP)



2.3.3 Data Flow

L'Ralph/LEISA uncalibrated 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 SOC data repository system. The L'Ralph/LEISA calibration pipeline queries the SOC date repository for the raw telemetry, science, and ancillary data. Figure 2-3 illustrates the SOC L'Ralph/LEISA data processing pipeline data flow. The Lucy Instrument and Science Teams access data products in the data repository through a query tool.

Figure 2-3. SOC Data Processing Flow

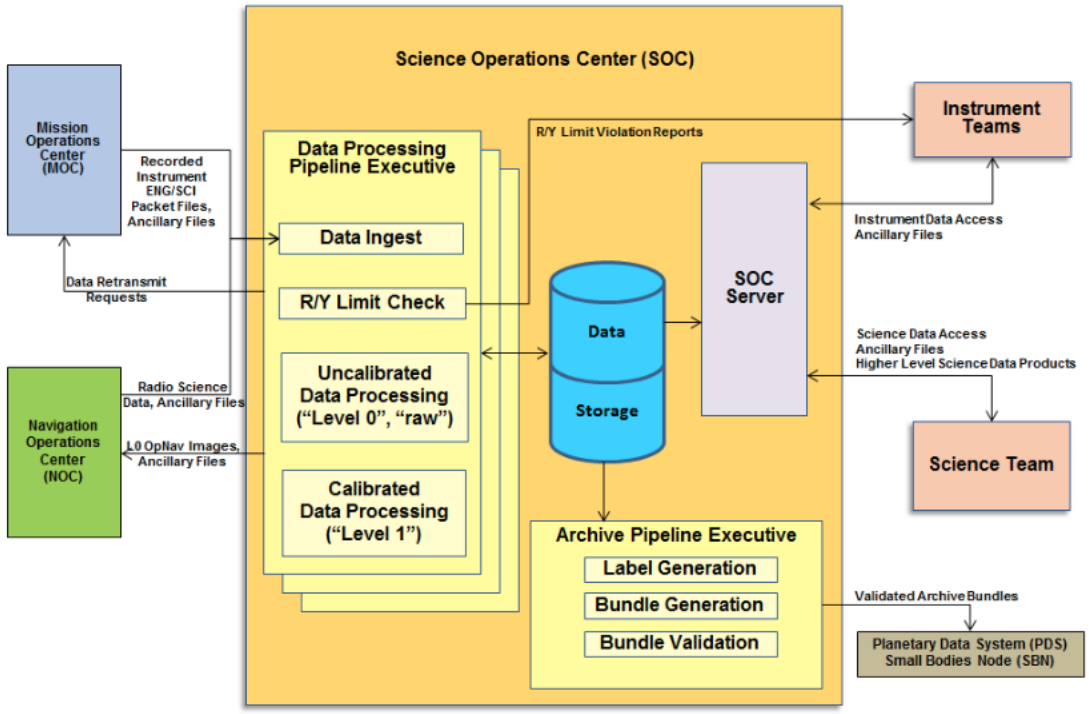


Figure 3-1: Science Operations Center Downlink Overview

2.3.4 Labeling and Identification

All L'Ralph/LEISA products consist of a PDS4-compliant detached XML label that describes the content and format of the associated data files. 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 a representative LEISA Product_Observational is presented below. Note that some classes and attributes may or may not appear in the actual data product label. Classes are indicated by title case and attributes by lower case.

Product_Observational

Identification_Area – class that contains attributes that identify and name an object.

logical_identifier - name/location of file

version_id - version of product

title - Name of file

information_model_version - version of PDS4 information model used to create product.

product_class - attribute provides the name of the product class (Product_Observational)

Citation_Information – attributes that provide specific information for citing data products in journal articles, abstract services, or other reference contexts.
Modification_History - attributes describing changes in data product.
Observation_Area – Classes and attributes that provide information about the circumstances under which the data were collected
Time_Coordinates – class that contains time attributes of data product.
Primary_Results_Summary – class that contains high-level description of the types of products included in the collection or bundle.
Investigation_Area – class that contains mission, observing campaign or other coordinated, large-scale data collection attributes.
Observing_System – class that contains observing system (instrument) attributes.
Target_Identification – class that contains observation target attributes.
Mission_Area - mission specific attributes needed to describe data product.
Lucy_Observation_Planning – class that contains attributes describing the planned *Lucy* observations, and instrument status.
Lucy_Observation_Time_Information – class that contains attributes describing the various times associated with the observation.
Lucy_Target_List – class that contains attributes describing target within the observation field of view.
Lucy_Product_Information – class containing attributes that give additional information about the data product.
Discipline_Area – discipline specific attributes collected by specific discipline areas.
Display_Settings – discipline dictionary class that contains product display information.
Geometry - discipline dictionary class that contains geometric information about the data product.
Mission_Information - discipline dictionary class that contains general mission information values.
Processing_Information - discipline dictionary class that contains attributes describing the data processing used to create the data product.
Reference_List – class that provides references to products or documentation relevant to the data product.
File_Area_Observational - describes a primary data file and one or more tagged_data_objects contained within.
File - identifies the file that contains one or more data objects as described below.
Header* – contains any attached file header information.
Array_2D_Image* - contains classes that describe a 2D array, typically an image.

*Header and image array classes are repeated for each Header Data Unit (HDU) present in a .FITS file.

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.

2.3.4.1 Product Naming

All L'Ralph/LEISA data products are named using the following naming conventions:

<inst>_<acqtime>_<obsid>_<level>_<version>.<ext>

where
inst = 3-letter instrument ID: lei (LEISA)
acqtime = 10-digit SCLK value (seconds) at the start of the acquisition
obsid = 5-digit integer observation ID
level = 3-letter data processing level ("eng" for raw/uncalibrated data, "sci" for calibrated data)
version = 2-digit integer product version number
ext = 3-letter file type extension: fit (Flexible Image Transport System)

L'Ralph/LEISA science data products are FITS file type so therefore have suffixes of ".fit". All L'Ralph/LEISA files are created with detached PDS labels, indicated by the ".xml" file extension. The labels are PDS4 compliant XML format.

2.4 Standards Used in Generating Data Products

2.4.1 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.

2.4.2 Time Standards

Time Standards used by the Lucy mission conform to PDS time standards.

2.4.3 Coordinate Systems

All coordinate systems used by the *Lucy* 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 "***Lucy* Mission Coordinate System Plan"** found in the mission bundle documents collection .

A summary of the Lucy Mission coordinate system process is as follows. The Lucy project will establish a task force to define coordinate systems for each target. The coordinate systems will be reviewed and validated by PDS prior to data delivery, as outlined in the PDS Policy on Acceptable Body-Fixed Coordinate Systems (PDS Mission Proposer's Archiving Guide v4-r5, 21 Sept. 2016). In parallel, the Lucy team will engage the International Astronomical Union (IAU) Working Group on Cartographic Coordinates and Rotational Elements (WGCCRE) coordinate system standards for an official approval of the proposed coordinate systems. Based on our experience, IAU may take several months to approve a coordinate system, and therefore the Lucy team will proceed with PDS delivery using the coordinate systems agreed upon by the project and the PDS. Once final approval by IAU is achieved, the Lucy project will redeliver georeferenced data to PDS, as needed. Upon PDS validation of all the coordinate systems for each Trojan asteroid, all archive instrument products will be updated with the accepted coordinate system for delivery to the PDS 4.5 months after last data downlink for each flyby (with the exception of Eurybates and Polymele). PDS will also review the science content of flyby deliverables. Derived products will be produced with the approved coordinate system or updated with this information when it becomes available.

2.4.4 Data Storage Conventions

L'Ralph/LEISA data products are stored as FITS files. These files conform to the FITS 4.0 standard, https://fits.gsfc.nasa.gov/fits_standard.html.

2.5 Data Validation

The SOC has a comprehensive Verification and Validation (V&V) Plan for all software used at or developed by the SOC. All software is configuration controlled and any changes made follow the SOC Configuration Control Plan, which includes substantive testing of changes. During day-to-day production of raw 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 *Lucy* 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 SOC – SBN Configuration Control Plan governs any changes, should they be needed.

When data are prepared for submission to the PDS, both the L'Ralph/LEISA and SOC Teams will use PDS / mission-provided automated validation tools for conformance to the PDS4 standards.

Validation of the science data contained within the L'Ralph/LEISA data products will, however, occur as a manual inspection by the L'Ralph/LEISA team and the *Lucy* science team.

3. DETAILED DATA PRODUCT SPECIFICATIONS

3.1 Data Products Structure and Organization

The *Lucy* archive is organized into bundles for each instrument/detector, bundles for each discipline-specific set of higher-order data products, and a mission bundle with mission-wide documentation, context, and schema information. Each bundle contains data collections for each mission phase and data processing level of each data type. Each PDS bundle also contains a document collection, to provide the appropriate ancillary information to properly interpret and use the data. L'Ralph/LEISA data products are structured as Flexible Image Transfer System (FITS) files. L'Ralph/LEISA data products are organized by mission phase and data processing level.

The L'Ralph/LEISA bundle structure is as follows:

Table 3-1. LEISA bundle/collection structure.

Bundle	*Collection*	*LID*
LEISA		
	data_cruise1_raw	urn:nasa:pds:lucy.leisa:data_cruise1_raw
	data_cruise1_calibrated	urn:nasa:pds:lucy.leisa:data_cruise1_calibrated
	data_ega1_raw	urn:nasa:pds:lucy.leisa:data_ega1_raw
	data_ega1_calibrated	urn:nasa:pds:lucy.leisa:data_ega1_calibrated
	data_didymos_raw	urn:nasa:pds:lucy.leisa:data_didymos_raw
	data_didymos_calibrated	urn:nasa:pds:lucy.leisa:data_didymos_calibrated
	data_cruise2_raw	urn:nasa:pds:lucy.leisa:data_cruise2_raw
	data_cruise2_calibrated	urn:nasa:pds:lucy.leisa:data_cruise2_calibrated
	data_dinkinesh_raw	urn:nasa:pds:lucy.leisa:data_dinkinesh_raw
	data_dinkinesh_calibrated	urn:nasa:pds:lucy.leisa:data_dinkinesh_calibrated
	data_cruise3_raw	urn:nasa:pds:lucy.leisa:data_cruise3_raw
	data_cruise3_calibrated	urn:nasa:pds:lucy.leisa:data_cruise3_calibrated
	data_donaldjohanson_raw	urn:nasa:pds:lucy.leisa:data_donaldjohanson_raw
	data_donaldjohanson_calibrated	urn:nasa:pds:lucy.leisa:data_donaldjohanson_calibrated
	data_cruise4_raw	urn:nasa:pds:lucy.leisa:data_cruise4_raw
	data_cruise4_calibrated	urn:nasa:pds:lucy.leisa:data_cruise4_calibrated
	data_eurybates-polymele_raw	urn:nasa:pds:lucy.leisa:data_eurybates-polymele_raw
	data_eurybates-polymele_calibrated	urn:nasa:pds:lucy.leisa:data_eurybates-polymele_caibrated
	data_cruise5_raw	urn:nasa:pds:lucy.leisa:data_cruise5_raw
	data_cruise5_calibrated	urn:nasa:pds:lucy.leisa:data_cruise5_calibrated
	data_leucus_raw	urn:nasa:pds:lucy.leisa:data_leucus_raw
	data_leucus_calibrated	urn:nasa:pds:lucy.leisa:data_leucus_calibrated
	data_cruise6_raw	urn:nasa:pds:lucy.leisa:data_cruise6_raw

Bundle	*Collection*	*LID*
	data_cruise6_calibrated	urn:nasa:pds:lucy.leisa:data_cruise6_calibrated
	data_orus_raw	urn:nasa:pds:lucy.leisa:data_orus_raw
	data_orus_calibrated	urn:nasa:pds:lucy.leisa:data_orus_calibrated
	data_cruise7_raw	urn:nasa:pds:lucy.leisa:data_cruise7_raw
	data_cruise7_calibrated	urn:nasa:pds:lucy.leisa:data_cruise7_calibrated
	data_patroclus-menoetius_raw	urn:nasa:pds:lucy.leisa:data_patroclus-menoetius_raw
	data_patroclus-menoetius_calibrated	urn:nasa:pds:lucy.leisa:data_patroclus-menoetius_calibrated
	calibration	urn:nasa:pds:lucy.leisa:calibration
	document	urn:nasa:pds:lucy.leisa:document

3.2 Data Format Descriptions

The following sections describe in detail the formats of L'Ralph/LEISA raw through calibrated data products.

3.2.1 Raw Science Data Product Format

The raw LEISA science product consists of a two extension FITS file that contains the data collected in a single observation set, or 'scan'. The first FITS HDU (Header Data Unit) is the raw LEISA observation data. The number of frames (NAXIS3) is the number of discrete measurements taken in the scan. Data contained in this HDU is in units of DN. The second HDU is the geometry table that contains a timestamp for each data frame, with the associated range to target and phase angle.

Table 3-2 Uncalibrated Data Product Format

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SIMPLE	n/a	FITS specific keyword
BITPIX	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Element_Array[1]/data_type[1]	number of bits per data pixel
NAXIS	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/axes[1]	number of data axes (always 3)
NAXIS1	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Axis_Array[2]/axis_name[1]	length of axis 1 (cross track pixels)
NAXIS2	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Axis_Array[3]/axis_name[1]/node()[1]	length of axis 2 (along track pixels of one exposure)
NAXIS3	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Axis_Array[1]/axis_name[1]/node()[1]	length of axis 3 (number of frames)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
EXTEND	n/a	FITS specific keyword indicating HDU extensions are possible
BZERO	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Element_Array[1]/value_offset[1]	Scaling zero-point
BSCALE	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Element_Array[1]/scaling_factor[1]	Scaling factor
MISSION	/Product_Observational[1]/Observation_Area[1]/Investigation_Area[1]/name[1]/node()[1]	mission name (Lucy)
HOSTNAME	/Product_Observational[1]/Observation_Area[1]/Observing_System[1]/Observing_System_Component[1]	instrument host name (Lucy)
HOSTID	/Product_Observational[1]/Observation_Area[1]/Observing_System[1]/Observing_System_Component[1]	instrument host ID (Lucy)
INSTRUME	/Product_Observational[1]/Observation_Area[1]/Observing_System[1]/Observing_System_Component[2]	name of instrument (LEISA)
OBSID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:observation_id[1]	observation ID
STRTSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:start_sclk[1]	observation start time (SCLK seconds)
MIDSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_sclk[1]	observation midpoint (SCLK seconds)
STOPSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:stop_sclk[1]	observation stop time (SCLK seconds)
STARTUTC	/Product_Observational[1]/Observation_Area[1]/Time_Coordinates[1]/start_date_time[1]	observation start time (UTC, ISOT format)
MIDUTC	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_utc[1]	observation midpoint (UTC, ISOT format)
STOPUTC	/Product_Observational[1]/Observation_Area[1]/Time_Coordinates[1]/stop_date_time[1]	observation stop time (UTC, ISOT format)
MIDSCLKS	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_sclk_string[1]	observation midpoint (full SCLK string)
MIDUTCID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_utc_doy[1]	observation midpoint (UTC, ISO DOY format)
MIDUTCJD	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_utc_jd[1]	observation midpoint (Julian date)
MIDET	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_ephemeris_time[1]	observation midpoint (ET, seconds past J2000)
EXPTIME	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/sp:Spectral_Characteristics[1]/sp:Observation_Parameters[1]/sp:net_integration_time[1]	[s] Exposure time (sec)
FILENAME	/Product_Observational[1]/File_Area_Observational[1]/File[1]/file_name[1]/node()[1]	product file name
DATE	/Product_Observational[1]/File_Area_Observational[1]/File[1]/creation_date_time[1]	product creation time (UTC, ISOT format)
ORIGIN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]	organization responsible for product
LOCATION	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[1]/proc:process_owner_institution_name[1]	location where product was generated
CCSDSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:ccsds_sclk_time[1]	CCSDS timestamp, playback time (SCLK seconds)
PRODLVL	n/a	Lucy internal processing level

FITS Header Keyword	PDS XML Label Class/Attribute	Description
PRODVER	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Product_Information[1]/lucy:internal_product_version_id[1]	Lucy internal data processing product version
UDPVER	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:software_version_id[1]/node()[1]	UDP software version
CDPVER	n/a	CDP software version
APID	n/a	packet application ID of source data
OBSCOMPL	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:observation_complete[1]	observation complete, yes or no
MISSPKT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:observation_missing_packets[1]	number of missing packets
UDPFILE	n/a in uncalibrated file	input UDP filename
CALFILE	n/a in uncalibrated product	radiometric calibration file used in calibration processing
SPCFILE	n/a in uncalibrated product	space block calibration file used in calibration processing
LOADID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:load_identifier[1]	command sequence load ID
MSNSEG	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:mission_segment[1]	mission segment
SAPID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:sap_identifier[1]	science activity plan identifier
VISITNAM	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:visit_name[1]	visit name
SIDE	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:instrument_side[1]/node()[1]	instrument side requested
LORSTAT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:llorri_status[1]	LORRI instrument status
RLPSTAT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:lralph_status[1]	Ralph instrument status
TESSTAT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:ltes_status[1]	TES instrument status
TTCSTAT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:ttcam_status[1]	TTCam instrument status
TARGET	/Product_Observational[1]/Observation_Area[1]/Target_Identification[1]/name[1]	name of intended primary target
TARGETID	/Product_Observational[1]/Observation_Area[1]/Target_Identification[1]/alternate_identification[1]	SPICE ID of intended primary target
SPCINSQA	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[1]	cos(theta/2), instr. -> J2000 SPICE quat.
SPCINSQX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[1]	sin(theta/2)*X, instr. -> J2000 SPICE quat.
SPCINSQY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[1]	sin(theta/2)*Y, instr. -> J2000 SPICE quat.

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SPCINSQZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[1]	sin(theta/2)*Z, instr. -> J2000 SPICE quat.
SPCSCQA	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[2]	cos(theta/2), S/C -> J2000 SPICE quat.
SPCSCQX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[2]	sin(theta/2)*X, S/C -> J2000 SPICE quat.
SPCSCQY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[2]	sin(theta/2)*Y, S/C -> J2000 SPICE quat.
SPCSCQZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[2]	sin(theta/2)*Z, S/C -> J2000 SPICE quat.
RATEX	n/a	angular rate about inst. frame +X axis (urad/s)
RATEY	n/a	angular rate about inst. frame +Y axis (urad/s)
RATEZ	n/a	angular rate about inst. frame +Z axis (urad/s)
RATEXY	n/a	magnitude of [RATEX,RATEY] pair (urad/s)
RATEYZ	n/a	magnitude of [RATEY,RATEZ] pair (urad/s)
RATEXZ	n/a	magnitude of [RATEX,RATEZ] pair (urad/s)
RATEMAG	n/a	magnitude of [RATEX,RATEY,RATEZ] vec. (urad/s)
IPIGANG	n/a	IPP inner gimbal angle (deg)
IPIGRATE	n/a	IPP inner gimbal angle rate (deg/sec)
IPOGANG	n/a	IPP outer gimbal angle (deg)
IPOGRATE	n/a	IPP outer gimbal angle rate (deg/sec)
BSRASTRT	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Object_Orientation_RA_Dec[1]/geom:right_ascension_angle[1]	Boresight RA at obs start (deg)
BSDCSTRT	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Object_Orientation_RA_Dec[1]/geom:declination_angle[1]	Boresight Dec at obs start (deg)
BSRAMID	n/a	Boresight RA at mid-obs time (deg)
BSDCMID	n/a	Boresight Dec at mid-obs time (deg)
BSRASTOP	n/a	Boresight RA at obs end (deg)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
BSDCSTOP	n/a	Boresight Dec at obs end (deg)
TRGFOV1	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Target_List[1]/lucy:target_fov_name[1]/node()[1]	The primary target in the Field of View (FOV)
TRGFOVN	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Target_List[1]/lucy:target_fov_count[1]	number of possible targets in FOV (SPICE-derived)
PA_XINST	n/a	pos. ang. +X axis, E of proj. EMEJ2K N (deg)
PA_YINST	n/a	pos. ang. +Y axis, E of proj. EMEJ2K N (deg)
PA_ZINST	n/a	pos. ang. +Z axis, E of proj. EMEJ2K N (deg)
PA_SUN	n/a	pos. ang. proj. Sun, E of proj. EMEJ2K N (deg)
PA_SUN_X	n/a	pos. ang. proj. Sun, E of inst. +X axis (deg)
PA_SUN_Y	n/a	pos. ang. proj. Sun, E of inst. +Y axis (deg)
PA_SUN_Z	n/a	pos. ang. proj. Sun, E of inst. +Z axis (deg)
TGT_ELON	n/a	ang. betw. target and inst. boresight (deg)
SOL_ELON	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]	ang. betw. Sun and inst. boresight (deg)
EAR_ELON	n/a	ang. betw. Earth and inst. boresight (deg)
SPCQUAL	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[1]/geom:kernel_provenance[1]	SPICE quality
SPCSTAT	n/a	SPICE status
SPCSCNM	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Object_Orientation_RA_Dec[1]/geom:Reference_Frame_Identification[1]/geom:frame_spice_name[1]	SPICE spacecraft bus frame name
SPCSCID	n/a	SPICE spacecraft bus frame ID
SPCINSNM	n/a	SPICE instrument frame name
SPCINSID	n/a	SPICE instrument frame ID
SPCTSCX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Spacecraft_To_Target[1]/geom:x_position[1]	S/C pos vec wrt target, X, EMEJ2000 (km)
SPCTSCY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Spacecraft_To_Target[1]/geom:y_position[1]	S/C pos vec wrt target, Y, EMEJ2000 (km)
SPCTSCZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Target[1]/geom:z_velocity[1]	S/C pos vec wrt target, Z, EMEJ2000 (km)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SPCTSCVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Target[1]/geom:x_velocity[1]	S/C vel vec wrt target, X, EMEJ2000 (km/s)
SPCTSCVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Target[1]/geom:y_velocity[1]	S/C vel vec wrt target, Y, EMEJ2000 (km/s)
SPCTSCVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Target[1]/geom:z_velocity[1]	S/C vel vec wrt target, Z, EMEJ2000 (km/s)
SPCTRANG	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:spacecraft_target_center_distance[1]	S/C range to target center (km)
SPCTPHAS	n/a	Sun-target-S/C angle (deg)
SPCTSOX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:x_position[1]	Sun pos vec wrt target, X, EMEJ2000 (km)
SPCTSOY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:y_position[1]	Sun pos vec wrt target, Y, EMEJ2000 (km)
SPCTSOZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:z_position[1]	Sun pos vec wrt target, Z, EMEJ2000 (km)
SPCTSOVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Sun[1]/geom:x_velocity[1]	Sun vel vec wrt target, X, EMEJ2000 (km/s)
SPCTSOVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Sun[1]/geom:y_velocity[1]	Sun vel vec wrt target, Y, EMEJ2000 (km/s)
SPCTSOVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Sun[1]/geom:z_velocity[1]	Sun vel vec wrt target, Z, EMEJ2000 (km/s)
SPCTSORN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:target_heliocentric_distance[1]	Sun center range to target center (km)
SPCTEOX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Target[1]/geom:x_position[1]	Earth pos vec wrt target, X, EMEJ2000 (km)
SPCTEOY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Target[1]/geom:y_position[1]	Earth pos vec wrt target, Y, EMEJ2000 (km)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SPCTEOZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Target[1]/geom:z_position[1]	Earth pos vec wrt target, Z, EMEJ2000 (km)
SPCTEOVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Earth[1]/geom:x_velocity[1]	Earth vel vec wrt target, X, EMEJ2000 (km/s)
SPCTEOVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Earth[1]/geom:y_velocity[1]	Earth vel vec wrt target, Y, EMEJ2000 (km/s)
SPCTEOVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Earth[1]/geom:z_velocity[1]	Earth vel vec wrt target, Z, EMEJ2000 (km/s)
SPCTEORN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:target_geocentric_distance[1]	Earth center range to target center (km)
SPCSCSX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:x_position[1]	Sun pos vec wrt S/C, X, EMEJ2000 (km)
SPCSCSY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:y_position[1]	Sun pos vec wrt S/C, Y, EMEJ2000 (km)
SPCSCSZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:z_position[1]	Sun pos vec wrt S/C, Z, EMEJ2000 (km)
SPCSCSVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Sun[1]/geom:x_velocity[1]	Sun vel vec wrt S/C, X, EMEJ2000 (km/s)
SPCSCSVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Sun[1]/geom:y_velocity[1]	Sun vel vec wrt S/C, Y, EMEJ2000 (km/s)
SPCSCSVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Sun[1]/geom:z_velocity[1]	Sun vel vec wrt S/C, Z, EMEJ2000 (km/s)
SPCSCSRN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:spacecraft_heliocentric_distance[1]	Sun center range to S/C (km)
SPCESCX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Spacecraft[1]/geom:x_position[1]	S/C pos vec wrt Earth, X, EMEJ2000 (km)
SPCESCY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Spacecraft[1]/geom:y_position[1]	S/C pos vec wrt Earth, Y, EMEJ2000 (km)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SPCESCZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Spacecraft[1]/geom:z_position[1]	S/C pos vec wrt Earth, Z, EMEJ2000 (km)
SPCESCVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Earth[1]/geom:x_velocity[1]	S/C vel vec wrt Earth, X, EMEJ2000 (km/s)
SPCESCVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Earth[1]/geom:y_velocity[1]	S/C vel vec wrt Earth, Y, EMEJ2000 (km/s)
SPCESCVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Earth[1]/geom:z_velocity[1]	S/C vel vec wrt Earth, Z, EMEJ2000 (km/s)
SPCESCRN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:spacecraft_geocentric_distance[1]	S/C range to Earth center (km)
SPCKMK	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[1]/geom:kernel_type[1]/node()[1]	SPICE meta kernel
SPCKNUM	n/a	count of loaded SPICE kernels
SPCKn	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[number]	SPICE kernel [n] (repeats for each kernel used)
PBSTART	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_start[1]	[SCLK s] timestamp of first M4 packet used
PBEND	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_end[1]	[SCLK s] timestamp of last M4 packet used
PBBADPX	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_bad_pixel_mask_status[1]	bad pixel mask enabled (T/F)
PBTRUN	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_truncation_status[1]	truncation enabled in playback (T/F)
PBTYPE	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_header_type[1]	playback header type
M4OBSID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:observation_id[1]	observation ID
M4TEST	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:test_pattern_setting[1]	test pattern setting: 0 = science, 1= test patter
M4XTST	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:hs_xtrack_start_row[1]	cross track start row
M4PXROW	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:scan_row_pixels[1]/node()[1]	number of pixels in a scan row
M4FPECRC	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:fpecrc_error_flag[1]	FPE CRC error flag (T/F)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
M4CAL	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:m4_calibration_state[1]	calibration state
M4BB	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:m4_blackbody_setting[1]	blackbody setting
M4FIL	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:m4_filament_setting[1]	filament setting
M4DROPF	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:fpe_drop_frames[1]	FPE drop frames
M4SCAN	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:mce_scan_rate[1]	[urad/s] MCE scan rate
M4STTS	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:first_packet_timestamp[1]	[SCLK s] timestamp of first packet recorded
M4ENDTS	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:last_packet_timestamp[1]	[SCLK s] timestamp of last packet found
M4XSERR	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:xsum_error_flag_status[1]	xsum flag if errors with stored data packet (T
ACQSTBLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:lr_acquisition_start_block[1]	acquisition start block
MCESTRT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:mce_start_postion[1]	[urad] MCE start position
MCEEND	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:mce_end_postion[1]	[urad] MCE end position
BOARD	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:board_selection[1]	instrument side
ALLOCBLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:blocks_allocated[1]	[blocks] allocation
LEIMODE	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_mode[1]	LEISA mode: true = TCDS, false = FNONCDS
LEIDUR	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_observation_allocation[1]	[s] LEISA observation allocated duration
LEIINT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_integration_time[1]	[ms] LEISA integration time
LEIATST	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_atrack_start_channel[1]	LEISA along track start channel
LEIATNUM	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_atrack_num_channels[1]	LEISA along track number of channels
LEIXTST	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_xtrack_start_row[1]	LEISA cross track start row
LEIXTNUM	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_xtrack_num_rows[1]	LEISA cross track number of rows

FITS Header Keyword	PDS XML Label Class/Attribute	Description
M4LEIOFF	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_offset[1]	[counts] LEISA offset
IRTEMP	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_fpe_ir_temperature[1]	[deg C] FPE IR temperature
SCTLMTIM	n/a - new spacecraft telemetry header additions	[ISO cal] SCET time of s/c telemetry (RLP
MEBST1	n/a - new spacecraft telemetry header additions	[deg C] MEB survival temperature 1
TDAST1	n/a - new spacecraft telemetry header additions	[deg C] TDA survival temperature 1
TDADT1	n/a - new spacecraft telemetry header additions	[deg C] TDA decontamination temperature 1
IPPDT1	n/a - new spacecraft telemetry header additions	[deg C] IPP deck temperature 1
MEBST2	n/a - new spacecraft telemetry header additions	[deg C] MEB survival temperature 2
TDAST2	n/a - new spacecraft telemetry header additions	[deg C] TDA survival temperature 2
TDADT2	n/a - new spacecraft telemetry header additions	[deg C] TDA decontamination temperature 2
IPPDT2	n/a - new spacecraft telemetry header additions	[deg C] IPP deck temperature 2
SIDE1PWR	n/a - new spacecraft telemetry header additions	side 1 power
SIDE2PWR	n/a - new spacecraft telemetry header additions	side 2 power
MEBPHPWR	n/a - new spacecraft telemetry header additions	MEB primary heater power
DECPHPWR	n/a - new spacecraft telemetry header additions	TDA decontamination primary heater power
TDAPHPWR	n/a - new spacecraft telemetry header additions	TDA survival primary heater power
USM3D1V	n/a - new spacecraft telemetry header additions	[volts] USM 3 DPC 1 voltage
USM3D1C	n/a - new spacecraft telemetry header additions	[A] USM 3 DPC 1 current
USM4D1V	n/a - new spacecraft telemetry header additions	[volts] USM 4 DPC 1 voltage
USM4D1C	n/a - new spacecraft telemetry header additions	[A] USM 4 DPC 1 current
SETPTMS	n/a - new spacecraft telemetry header additions	MEB survival heater set point status
SETPTTD	n/a - new spacecraft telemetry header additions	TDA decontamination heater set point status
SETPTTS	n/a - new spacecraft telemetry header additions	TDA survival heater set point status
LORDPUT1	n/a - new spacecraft telemetry header additions	[deg C] LLORRI DPU temp. 1
LORCCDT1	n/a - new spacecraft telemetry header additions	[deg C] LLORRI det. temp. 1, CCD carrier plate
LORFPET1	n/a - new spacecraft telemetry header additions	[deg C] LLORRI FPE temp. 1

FITS Header Keyword	PDS XML Label Class/Attribute	Description
LORM2T	n/a - new spacecraft telemetry header additions	[deg C] LLORRI OTA M2 temp.
TESBPT1	n/a - new spacecraft telemetry header additions	[deg C] LTES baseplate temperature 1
TMODEMS	n/a - new spacecraft telemetry header additions	MEB survival heater control mode
TMODETD	n/a - new spacecraft telemetry header additions	TDA decontamination heater control mode
TMODETS	n/a - new spacecraft telemetry header additions	TDA survival heater control mode
CHECKSUM	n/a FITS specific	HDU checksum updated 2023-08-10T18:51:51
DATASUM	n/a FITS specific	data unit checksum updated 2023-08-10T18:51:51
END	n/a FITS specific	FITS END keyword
HDU[0]	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]	LEISA raw 3d data array: Number of along track pixels x number of cross track pixels x number of frames LEISA data array in units of DN.
HDU[1]	/Product_Observational[1]/File_Area_Observational[1]/Table_Binary[1]	LEISA raw binary table: Frame timing and geometric information including timings, range and phase angle.

Note that vector information in the FITS headers may be reversed in the from/to direction from the PDS4 .xml label. These vectors have been translated between the header and the label.

3.2.2 Calibrated Data Product Format

The LEISA science calibrated data product is a FITS file containing five data arrays (FITS HDUs). The primary data array is the calibrated radiance array of size number along track pixels x number of cross track pixels x number of frames in units of $W/cm^2/sr/\mu m$. The next data array is a floating-point wavelength map in units of microns, followed by the subtracted dark frame array in units of counts, followed by the radiometric coefficient array in units of $(W/cm^2/sr/\mu m)$ / (counts/s). The final HDU is the geometry table that contains a timestamp for each data frame, with the associated range to target and phase angle. The final HDU is directly copied from the raw data product. To translate this data structure to be compliant with PDS4 standards, the FITS HDUs are labeled as a 3d spectral array of calibrated radiance values, a 2d array of wavelengths, a 2d array of the subtracted background, a 2d array of calibration coefficients, and finally a binary table of per frame geometry.

Table 3-3 Calibrated Data Product Format

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SIMPLE	n/a	FITS specific keyword
BITPIX	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Element_Array[1]/data_type[1]	number of bits per data pixel
NAXIS	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/axes[1]	number of data axes (always 3)
NAXIS1	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Axis_Array[2]/axis_name[1]	length of axis 1 (cross track pixels)
NAXIS2	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Axis_Array[3]/axis_name[1]/node()[1]	length of axis 2 (along track pixels of one exposure)
NAXIS3	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Axis_Array[1]/axis_name[1]/node()[1]	length of axis 3 (number of frames)
EXTEND	n/a	FITS specific keyword indicating HDU extensions are possible
BZERO	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Element_Array[1]/value_offset[1]	Scaling zero-point
BSCALE	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]/Element_Array[1]/scaling_factor[1]	Scaling factor
MISSION	/Product_Observational[1]/Observation_Area[1]/Investigation_Area[1]/name[1]/node()[1]	mission name (Lucy)
HOSTNAME	/Product_Observational[1]/Observation_Area[1]/Observing_System[1]/Observing_System_Component[1]	instrument host name (Lucy)
HOSTID	/Product_Observational[1]/Observation_Area[1]/Observing_System[1]/Observing_System_Component[1]	instrument host ID (Lucy)
INSTRUME	/Product_Observational[1]/Observation_Area[1]/Observing_System[1]/Observing_System_Component[2]	name of instrument (LEISA)
OBSID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:observation_id[1]	observation ID
STRTSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:start_sclk[1]	observation start time (SCLK seconds)
MIDSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_sclk[1]	observation midpoint (SCLK seconds)
STOPSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:stop_sclk[1]	observation stop time (SCLK seconds)
STARTUTC	/Product_Observational[1]/Observation_Area[1]/Time_Coordinates[1]/start_date_time[1]	observation start time (UTC, ISOT format)
MIDUTC	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_utc[1]	observation midpoint (UTC, ISOT format)
STOPUTC	/Product_Observational[1]/Observation_Area[1]/Time_Coordinates[1]/stop_date_time[1]	observation stop time (UTC, ISOT format)
MIDSCLKS	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_sclk_string[1]	observation midpoint (full SCLK string)
MIDUTCID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_utc_doy[1]	observation midpoint (UTC, ISO DOY format)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
MIDUTCJD	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_utc_jd[1]	observation midpoint (Julian date)
MIDET	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_ephemeris_time[1]	observation midpoint (ET, seconds past J2000)
EXPTIME	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/sp:Spectral_Characteristics[1]/sp:Observation_Parameters[1]/sp:net_integration_time[1]	[s] Exposure time (sec)
FILENAME	/Product_Observational[1]/File_Area_Observational[1]/File[1]/file_name[1]/node()[1]	product file name
DATE	/Product_Observational[1]/File_Area_Observational[1]/File[1]/creation_date_time[1]	product creation time (UTC, ISOT format)
ORIGIN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]	organization responsible for product
LOCATION	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[1]/proc:process_owner_institution_name[1]	location where product was generated
CCSDSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:ccsds_sclk_time[1]	CCSDS timestamp, playback time (SCLK seconds)
PRODLVL	n/a	Lucy internal processing level
PRODVER	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Product_Information[1]/lucy:internal_product_version_id[1]	Lucy internal data processing product version
UDPVER	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:software_version_id[1]/node()[1]	UDP software version
CDPVER	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[1]/proc:Software[2]/proc:software_version_id[1]	CDP software version
APID	n/a	packet application ID of source data
OBSCOMPL	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:observation_complete[1]	observation complete, yes or no
MISSPKT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:observation_missing_packets[1]	number of missing packets
UDPFILE	/Product_Observational[1]/Reference_List[1]/Internal_Reference[1]/lid_reference[1]	input UDP filename
CALFILE	/Product_Observational[1]/Reference_List[1]/Internal_Reference[2]/lid_reference[1]	radiometric calibration file used in calibration processing
SPCFILE	/Product_Observational[1]/Reference_List[1]/Internal_Reference[3]/lid_reference[1]	space block calibration file used in calibration processing
LOADID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:load_identifier[1]	command sequence load ID
MSNSEG	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:mission_segment[1]	mission segment
SAPID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:sap_identifier[1]	science activity plan identifier

FITS Header Keyword	PDS XML Label Class/Attribute	Description
VISITNAM	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:visit_name[1]	visit name
SIDE	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:instrument_side[1]/node()[1]	instrument side requested
LORSTAT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:llorri_status[1]	LORRI instrument status
RLPSTAT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:lralph_status[1]	Ralph instrument status
TESSTAT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:ltes_status[1]	TES instrument status
TTCSTAT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:ttcam_status[1]	TTCam instrument status
TARGET	/Product_Observational[1]/Observation_Area[1]/Target_Identification[1]/name[1]	name of intended primary target
TARGETID	/Product_Observational[1]/Observation_Area[1]/Target_Identification[1]/alternate_identification[1]	SPICE ID of intended primary target
SPCINSQA	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[1]	cos(theta/2), instr. -> J2000 SPICE quat.
SPCINSQX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[1]	sin(theta/2)*X, instr. -> J2000 SPICE quat.
SPCINSQY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[1]	sin(theta/2)*Y, instr. -> J2000 SPICE quat.
SPCINSQZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[1]	sin(theta/2)*Z, instr. -> J2000 SPICE quat.
SPCSCQA	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[2]	cos(theta/2), S/C -> J2000 SPICE quat.
SPCSCQX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[2]	sin(theta/2)*X, S/C -> J2000 SPICE quat.
SPCSCQY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[2]	sin(theta/2)*Y, S/C -> J2000 SPICE quat.
SPCSCQZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Quaternion_Plus_To_From[2]	sin(theta/2)*Z, S/C -> J2000 SPICE quat.
RATEX	n/a	angular rate about inst. frame +X axis (urad/s)
RATEY	n/a	angular rate about inst. frame +Y axis (urad/s)
RATEZ	n/a	angular rate about inst. frame +Z axis (urad/s)
RATEXY	n/a	magnitude of [RATEX,RATEY] pair (urad/s)
RATEYZ	n/a	magnitude of [RATEY,RATEZ] pair (urad/s)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
RATEXZ	n/a	magnitude of [RATEX,RATEZ] pair (urad/s)
RATEMAG	n/a	magnitude of [RATEX,RATEY,RATEZ] vec. (urad/s)
IPIGANG	n/a	IPP inner gimbal angle (deg)
IPIGRATE	n/a	IPP inner gimbal angle rate (deg/sec)
IPOGANG	n/a	IPP outer gimbal angle (deg)
IPOGRATE	n/a	IPP outer gimbal angle rate (deg/sec)
BSRASTRT	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Object_Orientation_RA_Dec[1]/geom:right_ascension_angle[1]	Boresight RA at obs start (deg)
BSDCSTRT	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Object_Orientation_RA_Dec[1]/geom:declination_angle[1]	Boresight Dec at obs start (deg)
BSRAMID	n/a	Boresight RA at mid-obs time (deg)
BSDCMID	n/a	Boresight Dec at mid-obs time (deg)
BSRASTOP	n/a	Boresight RA at obs end (deg)
BSDCSTOP	n/a	Boresight Dec at obs end (deg)
TRGFOV1	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Target_List[1]/lucy:target_fov_name[1]/node()[1]	The primary target in the Field of View (FOV)
TRGFOVN	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Target_List[1]/lucy:target_fov_count[1]	number of possible targets in FOV (SPICE-derived)
PA_XINST	n/a	pos. ang. +X axis, E of proj. EMEJ2K N (deg)
PA_YINST	n/a	pos. ang. +Y axis, E of proj. EMEJ2K N (deg)
PA_ZINST	n/a	pos. ang. +Z axis, E of proj. EMEJ2K N (deg)
PA_SUN	n/a	pos. ang. proj. Sun, E of proj. EMEJ2K N (deg)
PA_SUN_X	n/a	pos. ang. proj. Sun, E of inst. +X axis (deg)
PA_SUN_Y	n/a	pos. ang. proj. Sun, E of inst. +Y axis (deg)
PA_SUN_Z	n/a	pos. ang. proj. Sun, E of inst. +Z axis (deg)
TGT_ELON	n/a	ang. betw. target and inst. boresight (deg)
SOL_ELON	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]	ang. betw. Sun and inst. boresight (deg)
EAR_ELON	n/a	ang. betw. Earth and inst. boresight (deg)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SPCQUAL	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[1]/geom:kernel_provenance[1]	SPICE quality
SPCSTAT	n/a	SPICE status
SPCSCNM	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Image_Display_Geometry[1]/geom:Object_Orientation_RA_Dec[1]/geom:Reference_Frame_Identification[1]/geom:frame_spice_name[1]	SPICE spacecraft bus frame name
SPCSCID	n/a	SPICE spacecraft bus frame ID
SPCINSNM	n/a	SPICE instrument frame name
SPCINSID	n/a	SPICE instrument frame ID
SPCTSCX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Spacecraft_To_Target[1]/geom:x_position[1]	S/C pos vec wrt target, X, EMEJ2000 (km)
SPCTSCY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Spacecraft_To_Target[1]/geom:y_position[1]	S/C pos vec wrt target, Y, EMEJ2000 (km)
SPCTSCZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Target[1]/geom:z_velocity[1]	S/C pos vec wrt target, Z, EMEJ2000 (km)
SPCTSCVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Target[1]/geom:x_velocity[1]	S/C vel vec wrt target, X, EMEJ2000 (km/s)
SPCTSCVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Target[1]/geom:y_velocity[1]	S/C vel vec wrt target, Y, EMEJ2000 (km/s)
SPCTSCVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Target[1]/geom:z_velocity[1]	S/C vel vec wrt target, Z, EMEJ2000 (km/s)
SPCTRANG	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:spacecraft_target_center_distance[1]	S/C range to target center (km)
SPCTPHAS	n/a	Sun-target-S/C angle (deg)
SPCTSOX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:x_position[1]	Sun pos vec wrt target, X, EMEJ2000 (km)
SPCTSOY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:y_position[1]	Sun pos vec wrt target, Y, EMEJ2000 (km)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SPCTSOZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:z_position[1]	Sun pos vec wrt target, Z, EMEJ2000 (km)
SPCTSOVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Sun[1]/geom:x_velocity[1]	Sun vel vec wrt target, X, EMEJ2000 (km/s)
SPCTSOVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Sun[1]/geom:y_velocity[1]	Sun vel vec wrt target, Y, EMEJ2000 (km/s)
SPCTSOVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Sun[1]/geom:z_velocity[1]	Sun vel vec wrt target, Z, EMEJ2000 (km/s)
SPCTSORN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:target_heliocentric_distance[1]	Sun center range to target center (km)
SPCTEOX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Target[1]/geom:x_position[1]	Earth pos vec wrt target, X, EMEJ2000 (km)
SPCTEOY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Target[1]/geom:y_position[1]	Earth pos vec wrt target, Y, EMEJ2000 (km)
SPCTEOZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Target[1]/geom:z_position[1]	Earth pos vec wrt target, Z, EMEJ2000 (km)
SPCTEOVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Earth[1]/geom:x_velocity[1]	Earth vel vec wrt target, X, EMEJ2000 (km/s)
SPCTEOVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Earth[1]/geom:y_velocity[1]	Earth vel vec wrt target, Y, EMEJ2000 (km/s)
SPCTEOVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Target_Relative_To_Earth[1]/geom:z_velocity[1]	Earth vel vec wrt target, Z, EMEJ2000 (km/s)
SPCTEORN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:target_geocentric_distance[1]	Earth center range to target center (km)
SPCSCSX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:x_position[1]	Sun pos vec wrt S/C, X, EMEJ2000 (km)
SPCSCSY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:y_position[1]	Sun pos vec wrt S/C, Y, EMEJ2000 (km)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SPCSCSZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Sun_To_Spacecraft[1]/geom:z_position[1]	Sun pos vec wrt S/C, Z, EMEJ2000 (km)
SPCSCSVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Sun[1]/geom:x_velocity[1]	Sun vel vec wrt S/C, X, EMEJ2000 (km/s)
SPCSCSVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Sun[1]/geom:y_velocity[1]	Sun vel vec wrt S/C, Y, EMEJ2000 (km/s)
SPCSCSVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Sun[1]/geom:z_velocity[1]	Sun vel vec wrt S/C, Z, EMEJ2000 (km/s)
SPCSCSRN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:spacecraft_heliocentric_distance[1]	Sun center range to S/C (km)
SPCESCX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Spacecraft[1]/geom:x_position[1]	S/C pos vec wrt Earth, X, EMEJ2000 (km)
SPCESCY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Spacecraft[1]/geom:y_position[1]	S/C pos vec wrt Earth, Y, EMEJ2000 (km)
SPCESCZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Position_Earth_To_Spacecraft[1]/geom:z_position[1]	S/C pos vec wrt Earth, Z, EMEJ2000 (km)
SPCESCVX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Earth[1]/geom:x_velocity[1]	S/C vel vec wrt Earth, X, EMEJ2000 (km/s)
SPCESCVY	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Earth[1]/geom:y_velocity[1]	S/C vel vec wrt Earth, Y, EMEJ2000 (km/s)
SPCESCVZ	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Vectors[1]/geom:Vectors_Cartesian_Specific[1]/geom:Vector_Cartesian_Velocity_Spacecraft_Relative_To_Earth[1]/geom:z_velocity[1]	S/C vel vec wrt Earth, Z, EMEJ2000 (km/s)
SPCESCRN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Distances[1]/geom:Distances_Specific[1]/geom:spacecraft_geocentric_distance[1]	S/C range to Earth center (km)
SPCKMK	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[1]/geom:kernel_type[1]/node()[1]	SPICE meta kernel
SPCKNUM	n/a	count of loaded SPICE kernels
SPCKn	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[number]	SPICE kernel [n] (repeats for each kernel used)

FITS Header Keyword	PDS XML Label Class/Attribute	Description
PBSTART	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_start[1]	[SCLK s] timestamp of first M4 packet used
PBEND	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_end[1]	[SCLK s] timestamp of last M4 packet used
PBBADPX	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_bad_pixel_mask_status[1]	bad pixel mask enabled (T/F)
PBTRUN	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_truncation_status[1]	truncation enabled in playback (T/F)
PBTYPE	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:playback_header_type[1]	playback header type
M4OBSID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:observation_id[1]	observation ID
M4TEST	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:test_pattern_setting[1]	test pattern setting: 0 = science, 1= test patter
M4XTST	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:hs_xtrack_start_row[1]	cross track start row
M4PXROW	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:scan_row_pixels[1]/node()[1]	number of pixels in a scan row
M4FPECRC	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:fpecrc_error_flag[1]	FPE CRC error flag (T/F)
M4CAL	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:m4_calibration_state[1]	calibration state
M4BB	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:m4_blackbody_setting[1]	blackbody setting
M4FIL	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:m4_filament_setting[1]	filament setting
M4DROPF	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:fpe_drop_frames[1]	FPE drop frames
M4SCAN	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:mce_scan_rate[1]	[urad/s] MCE scan rate
M4STTS	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:first_packet_timestamp[1]	[SCLK s] timestamp of first packet recorded
M4ENDTS	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:last_packet_timestamp[1]	[SCLK s] timestamp of last packet found
M4XSERR	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:xsum_error_flag_status[1]	xsum flag if errors with stored data packet (T
ACQSTBLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:lr_acquisition_start_block[1]	acquisition start block
MCESTRT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:mce_start_postion[1]	[urad] MCE start position

FITS Header Keyword	PDS XML Label Class/Attribute	Description
MCEEND	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:mce_end_postion[1]	[urad] MCE end position
BOARD	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:board_selection[1]	instrument side
ALLOCBLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LRalph_Instrument_Common_Parameters[1]/lucy:blocks_allocated[1]	[blocks] allocation
LEIMODE	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_mode[1]	LEISA mode: true = TCDS, false = FNONCDS
LEIDUR	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_observation_allocation[1]	[s] LEISA observation allocated duration
LEIINT	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_integration_time[1]	[ms] LEISA integration time
LEIATST	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_atrack_start_channel[1]	LEISA along track start channel
LEIATNUM	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_atrack_num_channels[1]	LEISA along track number of channels
LEIXTST	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_xtrack_start_row[1]	LEISA cross track start row
LEIXTNUM	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_xtrack_num_rows[1]	LEISA cross track number of rows
M4LEIOFF	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_offset[1]	[counts] LEISA offset
IRTEMP	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:LEISA_Instrument_Parameters[1]/lucy:leisa_fpe_ir_temperature[1]	[deg C] FPE IR temperature
SCTLMTIM	n/a - new spacecraft telemetry header additions	[ISO cal] SCET time of s/c telemetry (RLP
MEBST1	n/a - new spacecraft telemetry header additions	[deg C] MEB survival temperature 1
TDAST1	n/a - new spacecraft telemetry header additions	[deg C] TDA survival temperature 1
TDADT1	n/a - new spacecraft telemetry header additions	[deg C] TDA decontamination temperature 1
IPPDT1	n/a - new spacecraft telemetry header additions	[deg C] IPP deck temperature 1
MEBST2	n/a - new spacecraft telemetry header additions	[deg C] MEB survival temperature 2
TDAST2	n/a - new spacecraft telemetry header additions	[deg C] TDA survival temperature 2
TDADT2	n/a - new spacecraft telemetry header additions	[deg C] TDA decontamination temperature 2
IPPDT2	n/a - new spacecraft telemetry header additions	[deg C] IPP deck temperature 2
SIDE1PWR	n/a - new spacecraft telemetry header additions	side 1 power

FITS Header Keyword	PDS XML Label Class/Attribute	Description
SIDE2PWR	n/a - new spacecraft telemetry header additions	side 2 power
MEBPHPWR	n/a - new spacecraft telemetry header additions	MEB primary heater power
DECPHPWR	n/a - new spacecraft telemetry header additions	TDA decontamination primary heater power
TDAPHPWR	n/a - new spacecraft telemetry header additions	TDA survival primary heater power
USM3D1V	n/a - new spacecraft telemetry header additions	[volts] USM 3 DPC 1 voltage
USM3D1C	n/a - new spacecraft telemetry header additions	[A] USM 3 DPC 1 current
USM4D1V	n/a - new spacecraft telemetry header additions	[volts] USM 4 DPC 1 voltage
USM4D1C	n/a - new spacecraft telemetry header additions	[A] USM 4 DPC 1 current
SETPTMS	n/a - new spacecraft telemetry header additions	MEB survival heater set point status
SETPTTD	n/a - new spacecraft telemetry header additions	TDA decontamination heater set point status
SETPTTS	n/a - new spacecraft telemetry header additions	TDA survival heater set point status
LORDPUT1	n/a - new spacecraft telemetry header additions	[deg C] LLORRI DPU temp. 1
LORCCDT1	n/a - new spacecraft telemetry header additions	[deg C] LLORRI det. temp. 1, CCD carrier plate
LORFPET1	n/a - new spacecraft telemetry header additions	[deg C] LLORRI FPE temp. 1
LORM2T	n/a - new spacecraft telemetry header additions	[deg C] LLORRI OTA M2 temp.
TESBPT1	n/a - new spacecraft telemetry header additions	[deg C] LTES baseplate temperature 1
TMODEMS	n/a - new spacecraft telemetry header additions	MEB survival heater control mode
TMODETD	n/a - new spacecraft telemetry header additions	TDA decontamination heater control mode
TMODETS	n/a - new spacecraft telemetry header additions	TDA survival heater control mode
CHECKSUM	n/a FITS specific	HDU checksum updated 2023-08-10T18:51:51
DATASUM	n/a FITS specific	data unit checksum updated 2023-08-10T18:51:51
END	n/a FITS specific	FITS END keyword
HDU[0]	/Product_Observational[1]/File_Area_Observational[1]/Array_3D_Image[1]	LEISA Calibrated Radiance 3d data array in units of W/cm2/sr/mm.: Line: number of along track pixels Sample: number of cross track pixels Band: number of observation frames

FITS Header Keyword	PDS XML Label Class/Attribute	Description
HDU[1]	/Product_Observational[1]/File_Area_Observational[1]/Array_2D[1]	LEISA wavelength map 2d array in units of microns
HDU[2]	/Product_Observational[1]/File_Area_Observational[1]/Array_2D[2]	LEISA subtracted dark frame 2d array in units of counts
HDU[3]	/Product_Observational[1]/File_Area_Observational[1]/Array_2D[3]	LEISA radiometric coefficients 2d array in units of (W/cm2/sr/um) / (counts/s)
HDU[4]	/Product_Observational[1]/File_Area_Observational[1]/Table_Binary[1]	LEISA binary table: Frame timing and geometric information including timings, range and phase angle.

3.3 Label and Header Descriptions

All L'Ralph/LEISA data products are produced with PDS4 compliant detached XML labels. Examples of these labels can be found in the mission bundle, document collection.

4. APPLICABLE SOFTWARE

Any software that can read and parse FITS-format files, including those with extensions, will enable a user read or use the FITS data products.

PDS4 XML labels can be opened using most XML aware text editors.

PDS4 utility programs such as the PDS4 Viewer and other IDL- and Python based PDS4 readers are available through the PDS Tool Registry (https://pds.jpl.nasa.gov/tools/toolregistry/)

4.1 Utility Programs

L'Ralph/LEISA is not planning to deliver any specific utility programs. Since all LEISA archival data products are formatted at FITS files, general utility programs can be found at the FITS Support Office at Goddard Space Flight Center (https://fits.gsfc.nasa.gov/).

4.2 Applicable PDS Software Tools

The PDS supplies a number of software tools that can be used in conjunction with PDS data products. Please refer to the PDS4 software website https://pds.nasa.gov/tools/about/ or additional information on these tools.

4.3 Software Distribution and Update Procedures

The LEISA team will not distribute any instrument specific software.

5. APPENDICES

5.1 ACRONYM LIST

Table 5-1: Acronym List

Acronym	Definition
AT	Along Track
DF	Drop frame – integer number of "rows" skipped in electronics to match commanded integration time to within 0.72 ms
DMAP	Data Management and Archive Plan
DPI	Deputy Principal Investigator
HDU	Header Data Unit
ICD	Interface Control Document
LDAT	*Lucy* Data Archive Team
LEISA	Linear Etalon Imaging Spectral Array
L'LORRI	*Lucy* Long Range Reconnaissance Imager
L'Ralph	Instrument comprised of LEISA and MVIC
L'TES	*Lucy* Thermal Emission Spectrometer
MGSS	Multi-Mission Ground System and Services
MOC	Mission Operations Center
MVIC	Multi-spectral Visible Imaging Camera
NAIF	Navigation and Ancillary Information Facility
NAV	Navigation
NOC	Navigation Operations Center
NSSDCA	National Space Science Data Coordinated Archive
OPS	Operations
PDS	Planetary Data System
PI	Principal Investigator
SBN	Small Bodies Node
SC	Spacecraft

SIS	Software Interface Specification
SMM	Scan Mirror Mechanism
SOC	Science Operations Center
SP	Superpixel – sum of 2x2 pixels
SPICE	Data sets that are called kernel files and stand for: • **S**pacecraft trajectory, given as a function of time (SPK kernels). • **P**lanet, satellite, comet, asteroid, associated physical, and cartographic constants (PCK kernels). • **I**nstrument information, including internal timing and other geometric information (IK kernels). • **C** matrix, time-tagged orientation data of mounted structures and instruments (CK kernels). • **E**vents for the spacecraft and ground data system, both planned and unplanned (EK kernels).
ST	Science Team
SwRI	Southwest Research Institute
TBD	To Be Determined
TDI	Time Delayed Integration
TTCAM	Terminal Tracking Camera
XT	Cross Track