Lucy
SOFTWARE INTERFACE SPECIFICATION
Terminal Tracking Camera Data Products

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REVISION NOTICE

Revision Number	Change Number	Sections Affected	Change Description	Release Date
0	0	All	(DRAFT, R0)	02/20/2021
0	0	All	(DRAFT, R1)	06/27/2021
0	0	All	(DRAFT, R2)	08/23/2023
0	0	2.3.4.1	File naming convention updates per PR-0313 and TCR 2311	06/01/2024
0	0	All	PDS Pipeline Review Lien Resolution	06/30/2024
0	0	All	INITIAL RELEASE	08/2024

TBD/TBS RESOLUTION SCHEDULE

Location	Description	Resolution Date
Table 1-1	Instrument Paper Publication Dates and DOIs	12/15/2023
All	2023 PDS Peer Review updates	6/30/2024

1. INTRODUCTION

1.1 Purpose and Scope

The purpose of this Software Interface Specification (SIS) is to provide the consumers of the *Lucy* Terminal Tracking Camera (TTCam) 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 products. 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 TTCam 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 TTCams 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 products. 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 TTCam Instrument Scientist 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
unassigned	ASU TTCam Calibrated Data Product Pipeline Software User's Guide	12 Dec. 2020	1.0
unassigned	Bell, J.F., Zhao, Y., Cisneros, E. *et al.* The Terminal Tracking Camera System on the NASA *Lucy* Trojan Asteroid Discovery Mission. *Space Sci Rev* **219**, 86 (2023).	13 Dec. 2023	*https://doi.org/10.1007/s11214-023-01030-5*
unassigned	*Zhao et al. TTCam calibration paper*	Summer, 2024	

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
TTCam Uncalibrated Data	Product	SOC
TTCam Calibrated Data	Product	SOC
TTCam 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

Lucy has two Terminal Tracking Cameras (TTCams) on board to provide autonomous pointing of the instrument pointing platform to each Trojan near closest approach. This system is part of the spacecraft's guidance and control system and will also collect single-filter panchromatic (425 - 675 nm bandpass) images that address our science objective to determine the shape of the Trojan asteroids. The wide field of view of the TTCams (11.0°x8.2°) allows imaging of the entire sunlit fraction of each of the Trojan asteroids during the entire flyby, unlike the high-resolution imager L'LORRI. One of the Lucy shape objectives to derive stereo imaging requires observations separated by ~10° of phase angle. While L'Ralph MVIC has higher spatial resolution, the use of TTCam images is preferred instead of L'Ralph because L'Ralph MVIC TDI imaging results in each line of the scan being a separate image to reconstruct the shape. Both L'Ralph MVIC and TTCam will be used to provide redundancy in the observing sequence.

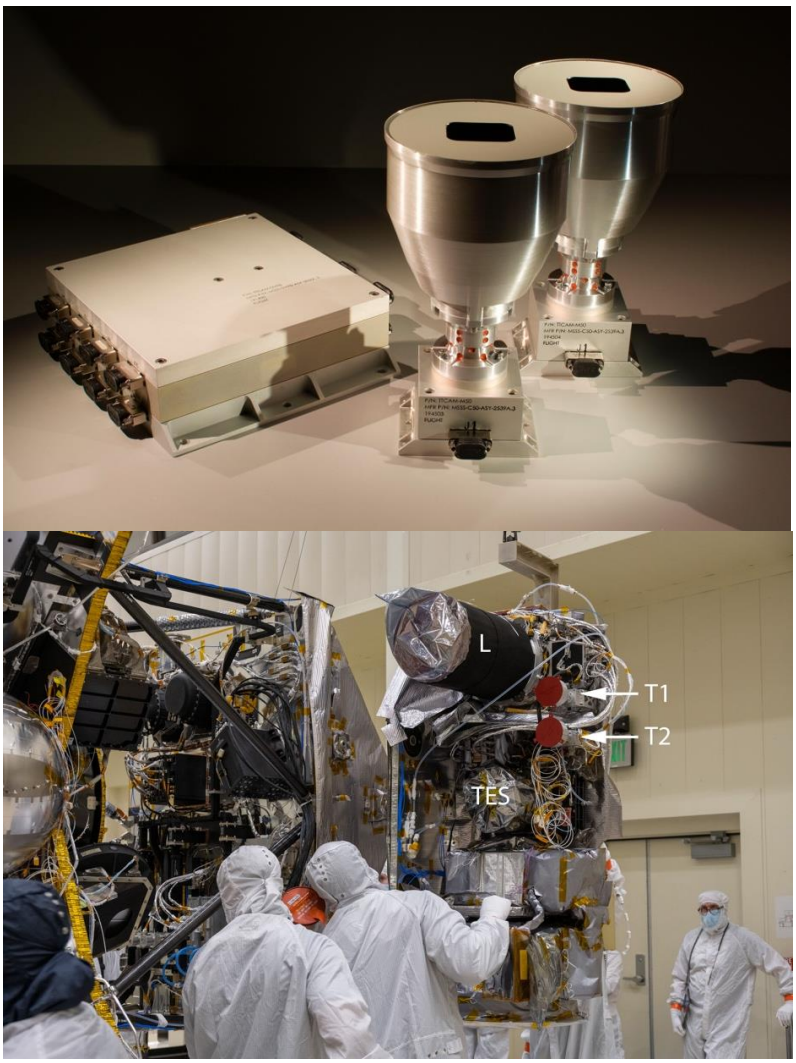

Figure 2-1: (Top) Two Flight Model and one Flight Spare TTCam instruments, as delivered to Lockheed Martin by Malin Space Science Systems, Inc., in April 2020. For scale, each camera and its sunshade/baffle are 22 cm tall. (Bottom) The Flight TTCam instruments (red covers) mounted on the Lucy spacecraft's Instrument Pointing Platform during ATLO testing in Feb. 2021.

TTCam was built by Malin Space Science Systems, Inc. and Dr. James Bell of Arizona State University is the Instrument Scientist. The instrument design (Bell *et al.*, 2023) is derived from the OSIRIS-REx Touch-And-Go Camera Suite (Bos *et al.*, 2020). The sensor is a CMOS device with 2592x1944 active 2.2 μm pixels, or 2752 x 2004 pixels including masked dark pixels. The optical system has a focal length of 29.7 mm and an entrance aperture of 9.9 mm. Each pixel subtends 74.1 μrad. There are two terminal tracking cameras for redundancy. TTCam acquires 12-bit images that are companded onboard to 8-bits using a square-root-like lookup table to preserve signal to noise and image dynamic range (e.g., Malin *et al.*, 2017; Bell *et al.*, 2023; Zhao *et al.*, 2024). Images are then losslessly compressed onboard the spacecraft for downlink using the PPMd

algorithm (Bell *et al.*, 2023). The primary imaging modes of TTCam are acquisition of in-flight calibration images with active and dark pixels, acquisition of high cadence tracking images for IPP pointing, and acquisition of moderate cadence images for science (shape modeling) within a few minutes around closest approach.

Table 2-1. List of Lucy TTCam Instrument Properties (Bell *et al.*, 2023)

***Lucy* Mission Terminal Tracking Camera (TTCam) Specifications**	
Optics	*Description*
Focal length	29.7 mm (all-refractive; fixed focus)
Focal ratio	*f*/2.95
Depth of Field	≈200 m to ∞ (hyperfocal: 133.7 m; near-focus: 66.8 m)
entrance pupil aperture	9.9 mm
aperture area	77 mm^2
exit pupil diameter	7.1 mm
t/#	< 3.36
pixel solid angle	5.5 × 10^{-9} sr
throughput ($A_0 \bullet \Omega$)	4.22 × 10^{-7} mm^2 sr
IFOV	74.1 µrad/pixel (74.1 m/pixel @ 1000 km)
FOV	11.0° × 8.2° (13.7° diagonal) (193×143 km @ 1000 km)
Filters	1
Filter bandpass	Panchromatic: 425-675 nm
Effective Wavelength	Avg. Red Trojan: 537.8 nm (FWHM: 246.7 nm)
(Filter × QE × Sun × Trojan)	Avg. Less-Red Trojan: 534.1 nm (FWHM: 245.2 nm)
Optics Transmission	> 80%
Optics Distortion	0.12% average in corners of field of view
MTF	0.19 (optics+filter+sensor) at Nyquist = 227 l.p./mm
Detector & Electronics	*Description*
Sensor	CMOS: ON Semi Model MT9P031; Electronic Rolling Shutter mode
Clock Rate	10 MHz in 8-bit mode
Exposure Durations	~0.0 to 30.7675 sec; commanded in units of 0.1 msec
Electronic Rolling Shutter	Min. exp.: 121 or 60.4 µsec (8-bit or 12-bit); Frame time ~680 msec
Array size	2592 × 1944 active pixels (2752 × 2004 total)
Preferred Dark Pixels (*cf.* Fig. 2)	rows 1966-1989, cols 16-2607 (region 4 of Fig. 6 in Bos *et al.,* 2020)
Pixel size	2.2 µm (square pixels)
Gain, Read Noise, Full Well	1.8 e^-/DN; 7 e^-; 5400 e^-
Quantum Efficiency	> 50% at 550 nm
Digitization	12 bits/pixel; single gain, no offset states
DVR to Camera data interface	SpaceWire, 100 Mbit/sec
DVR-S/C Cmd/Housekeeping interface	RS-422, 57.6 Kbit/sec Asynchronous Serial
DVR-S/C video telemetry interface	RS-422, 8.33 Mbit/sec Synchronous Serial
Memory	8 GB non-volatile RAM (≈1600 8-bit images) per camera
Camera Head Power	1.5 W standby and 2.0 W imaging, per camera head
DVR Power	6.0 W standby and 8.0 W imaging, per camera board
Image Compression Options	*Description*
Uncompressed	12-bit data (0-4095 DN); No compression
Lossless	In DVR: First-difference, Huffman; In spacecraft: PPMd
Lossy	In DVR: JPEG, commandable compression quality (1–100)
Companding	In DVR: 12-bit to 8-bit square-root encoding (lookup table)
Physical	*Description*
Data Volume: full raw image	2752×2004×12 bits = 8.27 MBytes/image
Data Volume: 8-bit companded	2752×2004×8 bits = 5.52 MBytes/image
Data Vol: 8-bit then lossless comp.	2.76 MBytes/image, assuming 2:1 lossless compression
Dimensions: CMOS Sensor	5.7 × 4.3 mm (7.1 mm diagonal)
Dimensions: Camera Head	8 × 8 × 22 cm (each camera)
Dimensions: DVR	19 × 16 × 7 cm
Mass: Camera Head	0.53 kg, CBE (each camera)
Mass: DVR	1.90 kg, CBE

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 eight Trojan asteroids: Eurybates and its small satellite Queta, Polymele and its small satellite (informally known as “Shaun”), Leucus, Orus, Patroclus and Menoetius (Fig. 1). Three of the flybys will encounter multiple Trojan asteroids. The first Lucy Trojan flyby in 2027 will be of Eurybates and its recently discovered small moon and the last encounter in 2033 is of the near-equal size binary system: Patroclus and Menoetius. Lucy will also fly by two Main Belt asteroid targets of opportunity: (152830) Dinkinesh, successfully encountered in November 2023, and (52246) Donaldjohanson in 2025, prior to reaching the Trojans, and will use these encounters to test terminal tracking and other aspects of mission 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.

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 on the basis of an on-board ephemeris. As the spacecraft approaches the target and the image of the target is resolved by TTCam, the on-board terminal-tracking state estimation begins to use TTCam images to provide an estimate of the Trojan's location relative to the spacecraft. This terminal tracking mode 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. Images acquired during the terminal tracking phase of each encounter are stored in the TTCam Digital Video Recorder (DVR), which can store more than 1600 8-bit images per camera.

Once the terminal tracking function is complete (several minutes prior to closest approach), the TTCam acquisition sequence switches to "science mode", acquiring a continuous series of time-lapse images of each target asteroid over the full range of encounter phase angles, thus providing unique constraints on the shape and volume of each target as well as additional coverage of each target for geologic characterization and mapping. Because of the wide field of view of the TTCam, the entire sunlit portion of each target asteroid is expected to fit within the field of view of each asteroid over the entire encounter. After closest approach, TTCam will continue to acquire science mode images for at least several minutes during departure. The expectation, depending on the final observation sequence at each target asteroid, is that TTCam could acquire between 30 to 50 science mode images over the course of each flyby. Later downlink of the terminal tracking mode images stored on the DVR can also be used for science analysis.

2.2 Data Product Overview

This SIS describes image and instrument status (engineering) data acquired by the TTCams. Terminal Tracking images are stored as binary Flexible Image Transport System (FITS) files for both operational and archival purposes.

The data products described by this SIS are:

1. TTCam Raw Images (Uncalibrated Data Products, or UDPs) – These images are reconstructed science packet telemetry with associated timing and spatial information in a FITS format. Data values are in units of Digital Number (DN). These images are found in the data_*_raw collections.
2. TTCam Calibrated Images (Calibrated Data Products, or CDPs) – These images are calibrated images with associated timing and spatial information and extensions in a FITS format. CDP data values in the main FITS image are in units of radiance ($\mu W/cm^2/sr/nm$). CDPs also have up to four FITS extension images, however, that include a bad pixel map (flagging saturated or nonlinear pixels in the UDP), uncertainties associated with the radiance image (in $\mu W/cm^2/sr/nm$), and, if the images include an asteroid target (as opposed to just a sky/star field), extension images of radiance factor (unitless I/F, where I is the incident radiance on sensor, and π*F is the irradiance of the incident sunlight on the target body at the time of the encounter) and radiance factor uncertainty (also in unitless I/F). These images are found in the data_*_calibrated collection.

Section 3 provides a detailed specification of each product.

2.3 Data Processing

All *Lucy* mission science data processing is performed at the Southwest Research Institute Science Operations Center (SOC) located in Boulder, Colorado. In addition to science processing, the SOC stores, and processes spacecraft engineering camera suite images to standard outputs for further processing by the engineering and science team.

TTCam image and status telemetry are received by the SOC via the Lockheed Martin Mission Support Area (MSA) and the DSN. TTCam data are reconstructed from telemetry frames (packets) and stored in the SOC data repository as raw image or status data products. Raw data products are fed through the TTCam data processing pipeline. Raw status data are processed to convert digital number values to engineering units, resulting in calibrated status data product. This product is then stored in the SOC data repository. Raw image data files during encounters are assumed to be approximately 10 MB in size (8-bit companded raw pixel values are decompanded to 12-bit values, which are then stored as 16-bit values in the FITS.). Calibrated image data files are approximately 18 times that size, assuming a main 16-bit radiance image, three 16-bit extension images (radiance error, I/F, and I/F error), and one 8-bit image extension (bad pixel map), as described below. Spacecraft orientation information (SPICE S/C C-kernels) taken concurrently with the images are processed to provide timing and attitude data that is attached to the image data file headers.

2.3.1 Data Processing Level

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. For Lucy TTCam, these are the uncalibrated image products.
	Partially Processed	Data that have been processed beyond the raw stage, but which have not yet reached calibrated status. Lucy TTCam does not archive any partially processed products.
Calibrated Data Product	Calibrated	Data converted to physical units, which makes values independent of the instrument. For Lucy TTCam, these are the calibrated image products.
	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 TTCam UDPs will be generated by the SOC from the downlinked TTCam spacecraft telemetry. The UDPs will contain raw, uncalibrated data formatted according to the Raw format defined in this SIS. New versions of the products will be identified using a version identifier in the filename and FITS label, as indicated in Section 2.3.4 and by the Version_ID field in the PDS label. On successful completion through the TTCam 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 TTCam engineers and scientists.

CDPs will be automatically produced by the data processing pipeline software as soon as all image packets have been received and processed. The values of SPICE-related keywords will be populated using the best-available information at the time of processing. Initial processing will likely use predicted ephemerides and pointings. Reprocessing will be done when definitive ephemerides and pointings become available.

New versions of CDPs 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 CDPs will be identified by incrementing the version identifiers (filename version, FITS header label keywords, and PDS label version_id and internal_product_version_id attributes) 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 supersede the older (deprecated) versions. Note that the PDS label version_id indicates the number of times the product has been delivered to PDS, whereas the internal_product_version_id indicates the number of times the Lucy team has processed the image.

2.3.2.1 Raw Data Product Generation

TTCam science, status (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 TTCam packet data are sorted, parsed, and inserted in the SOC data repository, they are ready for instrument specific processing. The Pipeline Executive (PExe) process controls the SOC data processing environment by managing and initiating all pipeline functions. Through the use of either scheduled or manual jobs, PExe calls the main UDP module that manages the setup and execution of the individual instrument pipeline functions. The TTCam UDP module performs 8- to 12-bit decompanding and builds uncalibrated image data products in FITS format, containing both image data and ancillary header information. The TTCam UDP module returns both UDP products and logfile information.

The pixel readout order from the TTCam sensor causes the image to be inverted from a normal "sky view" orientation in most FITS viewers (where the first pixel read out is placed at lower left, and subsequent pixels are read out one row at a time with column numbers increasing to the right and row numbers increasing upward). To correct this, the TTCam UDP software inverts the rows top to bottom before writing the output FITS file. This causes line 1 of the image to correspond to the highest row number in the FITS file, line 2 to the next highest, and so on. This has relevance to the image exposure start, mid, and stop times reported in the FITS header, as these times all refer to line 1 of the image as read out of the TTCam sensor. Finally, we note that there is a small, measured difference (i.e., delay), on average, between the line 1 exposure start time as reported in the image mini-header and the actual exposure start time. This average delay has a value of 12.8 msec, and is reflected in all the image exposure start, mid, and stop times reported in the observation section of the FITS header and in the PDS4 xml labels.

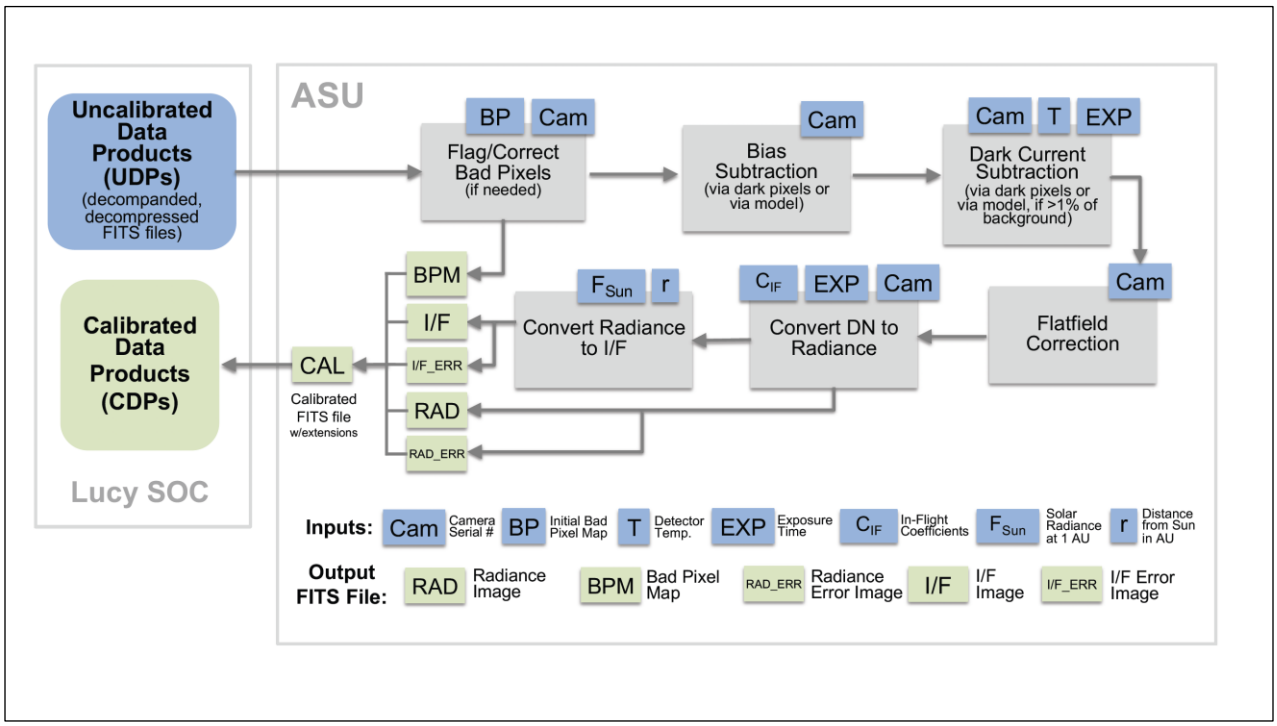

Figure 2-2: TTCam Calibration Flow Chart (*Zhou et al.*, 2024)

2.3.2.2 Calibrated Data Product Generation

Once the UDP module has returned UDP products and logfile information the PExe, and completed operations, the CDP module can be called to create calibrated data products from the uncalibrated data files. The CDP module is based on a data processing pipeline developed at Arizona State University (ASU) and delivered to the SOC for the SOC to run locally. CDP is initialized with an input file containing the calibrated file specification and other parameterized information needed to process the data products. The uncalibrated TTCam images are calibrated by performing a series of calibration steps (Figure 2.3-1) resulting in a FITS 2-dimensional array data product in radiance units with the upper bound size of 2752x2004 pixels for full frame dark pixels on images, with an active area of 2592x1944. Because of a limit on the image size that can be transferred into the spacecraft's terminal tracking algorithm, however, only the pixels in the 2592x1944 active area are read out during each asteroid encounter. When typical 2592x2000 pixel calibration images are read out, the gray areas are ignored in processing. All images have four additional FITS extensions as described below. The calibration steps are described in Zhao *et al*. (2024) and the following paragraphs:

2.3.2.2.1 Bad Pixel Map

The TTCam sensors have a small number of bad (extra low or high responsivity, or nonlinearly responsive) pixels that were determined from pre-flight calibration. In addition, raw TTCam images from flight might also have additional bad pixels because of cosmic rays, image saturation, or post-launch performance changes. The TTCam calibration pipeline identifies these bad pixels and flags them in a Bad Pixel Map extension to the calibrated FITS file, so that end users can

choose to ignore or replace them, if desired. The Bad Pixel Map image is the same size as the main (radiance) image but is an 8-bit array where 0=good pixel, 1=bad pixel (non-responsive or always saturated), 2=saturated pixel for this scene, 3=nonlinear pixel for this scene, and 4=a pixel that was set to zero by the automatic subtraction of bias signal (a so-called "under bias" pixel) when using square-root companding. The input parameter for the Bad Pixel Map in the calibration pipeline is the camera ID, and details about the bad pixels identified from pre-flight calibration are provided in Bell *et al.* (2023) and Zhao *et al.* (2024).

2.3.2.2.2 Bias/Dark Current Correction

Raw TTCam images include a constant level of background (bias) signal as well as a temperature-dependent (dark current) signal. The TTCam calibration pipeline removes these background components from the raw images using dark pixel information, if available, or a model of the background bias/dark current signal levels based on pre-flight instrument calibration (Zhao *et al.*, 2024), if dark pixels are not available. The input parameters of the model bias and dark current for the calibration pipeline are the camera ID, CCD temperature, companding mode, and exposure time. If dark pixels are available in the image, the average and standard deviation of the dark values are extracted from rows 1966:1989 and columns 16:2607. The model and methods are described in Bell *et al.* (2023) and Zhao *et al.* (2024) section 3.2.3.

2.3.2.2.3 Flat Field

Pixel-to-pixel nonuniformities in raw TTCam images can result from imperfections or contaminants (dust) on the camera optics and/or sensor, or simply from intrinsic pixel-to-pixel variations in responsivity. These nonuniformities were characterized during pre-flight calibration by imaging a perfectly uniform source ("flat field") and then creating a normalized correction array that is divided out of the raw data to remove these nonuniformities. The input parameter for the flat field correction in the calibration pipeline is the camera ID. Those correction arrays, one per TTCam camera, are described in Zhao *et al.* (2024) and are available to external users as supplementary archived data associated with that publication. In this step of correction, the normalized flat field array is divided out of the bias and dark current subtracted image.

2.3.2.2.4 Radiance Conversion

During pre-flight calibration, TTCam images were taken of a NIST-calibrated radiance source. These observations were processed and used to derive initial radiance calibration coefficients [(μW/cm^2/sr/nm)/(DN/msec)], subsequently refined by Zhao *et al.* (2024) based on Oct. 2022 TTCam lunar flyby images. These coefficients are input constants for each camera in the calibration pipeline. The input parameters for the radiance conversion for the calibration pipeline are the camera ID, pre-flight calibration coefficient, and exposure time. The coefficients for each TTCam camera and their values were derived using the procedures described in Bell *et al.* (2023) and Zhao *et al.* (2024) section 3.2.5. The result of the radiometric calibration is a calibrated image the same size as the uncalibrated image, represented in physical radiance units (μW/cm^2*sr*nm) instead of DN, and an associated extension image of the same size with the radiance error on each pixel in the same radiometric units as the calibrated image.

2.3.2.2.5 Radiance Factor Conversion

Finally, TTCam images are also calibrated to radiance factor, or I/F, where I is the incident radiance on sensor derived in the previous step, and π*F is the irradiance of the incident sunlight

on the target body at the time of the encounter). The input parameters for the radiance factor conversion for the calibration pipeline are the solar spectral irradiance at 1 AU convolved through the TTCam bandpass, and the heliocentric distance (in AU) of the spacecraft at the time of the observation (the heliocentric distance of the targets during each flyby is essentially the same as the heliocentric distance of the spacecraft, to within the uncertainties of this calibration process). Details on the derivation of I/F values are described in Zhao *et al.* (2024). I/F image extensions are created for all calibrated TTCam images, although the applicability of I/F data to scientific analysis is only valid for images of target bodies in the images that are reflecting incident sunlight.

2.3.3 Data Flow

TTCam 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 TTCam calibration pipeline queries the SOC data repository for the raw telemetry, science, and ancillary data. Figure 2-2: TTCam Calibration Flow Chart (*Zhou et al.,* 2024) illustrates the SOC TTCam data processing pipeline data flow. The Lucy Instrument and Science Teams access data products in the data repository through local file sharing mechanisms (SSH/SCP/RSYNC).

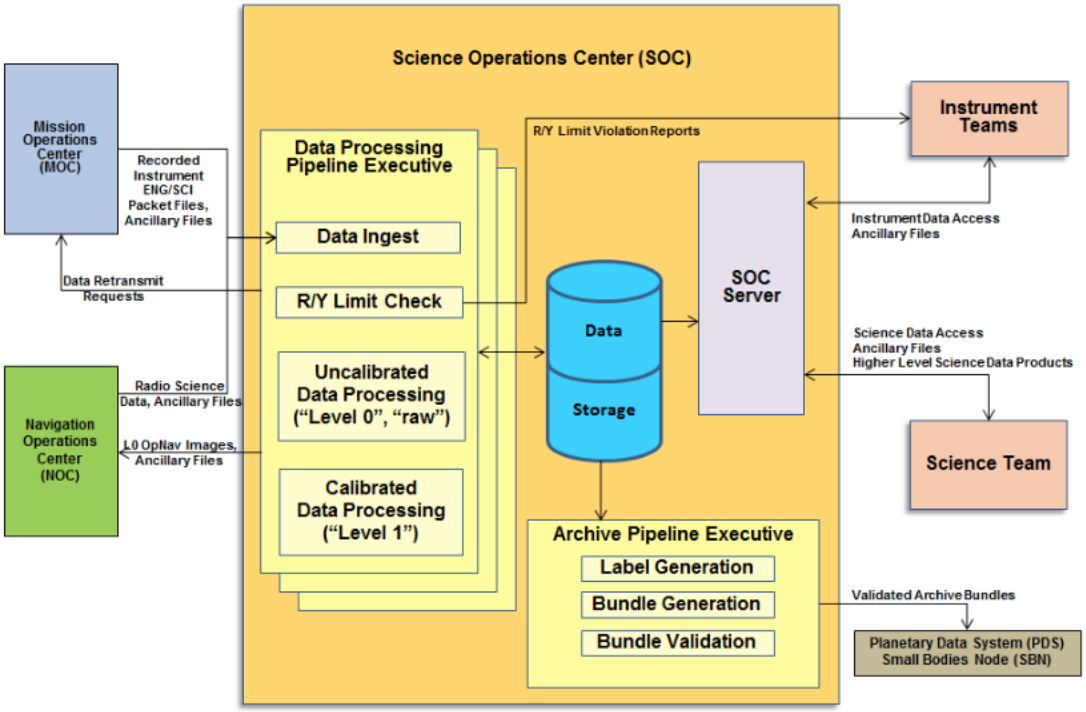

Figure 3-1: Science Operations Center Downlink Overview

Figure 2-3: SOC Data Flow

2.3.4 Labeling and Identification

All TTCam products consist of a PDS4-compliant detached XML label that describes 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 TTCam 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 – class that contains 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.
    - MSSS_Camera_Mini_Header - discipline dictionary class that contains the Malin Space Science Systems camera mini-header attributes and values.
    - 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.
    - Earth_Based_Telescope_Parameters – discipline dictionary class that contains World Coordinate System attributes.
- 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 TTCam data products are named using the following naming conventions:

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

where

inst = 3-letter instrument ID: tt1 or tt2 for TTCam DVR1 and TTCam DVR2
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 and "sci" for calibrated.
version = 2-digit integer product version number
ext = 3-letter file type extension: fit (Flexible Image Transport System)

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

(NOTE: TTCam images don't have a commanded observation ID associated with them; the value currently being used for this purpose in the filename is a 16-bit concatenation of the 8-bit sequence number + 8-bit sequence offset associated with the image. These numbers are not necessarily unique over the course of the mission, since sequence ID/offset combos can be reused from encounter to encounter.)

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

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

FITS data products are stored according to the FITS 4.0 Standard.

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 Management 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 TTCam 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 TTCam data products will, however, occur as a manual inspection by the TTCam team and the *Lucy* science team.

3. DETAILED DATA PRODUCT SPECIFICATIONS

The paragraphs below describe the TTCams raw and calibrated data products.

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. TTCam data products are structured as Flexible Image Transport System (FITS) files. TTCam data products are organized by mission phase and data processing level.

The TTCam bundle structure is as follows:

Table 3-1. TTCam bundle/collection structure.

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

Bundle	*Collection*	*LID*
	data_leucus_calibrated	urn:nasa:pds:lucy.ttcam:data_leucus_calibrated
	data_cruise6_raw	urn:nasa:pds:lucy.ttcam:data_cruise6_raw
	data_cruise6_calibrated	urn:nasa:pds:lucy.ttcam:data_cruise6_calibrated
	data_orus_raw	urn:nasa:pds:lucy.ttcam:data_orus_raw
	data_orus_calibrated	urn:nasa:pds:lucy.ttcam:data_orus_calibrated
	data_cruise7_raw	urn:nasa:pds:lucy.ttcam:data_cruise7_raw
	data_cruise7_calibrated	urn:nasa:pds:lucy.ttcam:data_cruise7_calibrated
	data_patroclus-menoetius_raw	urn:nasa:pds:lucy.ttcam:data_patroclus-menoetius_raw
	data_patroclus-menoetius_calibrated	urn:nasa:pds:lucy.ttcam:data_patroclus-menoetius_calibrated
	calibration	urn:nasa:pds:lucy.ttcam:calibration
	document	urn:nasa:pds:lucy.ttcam:document

Note that Table 3-1 lists all collections that will eventually comprise the TTCam archive. Collections will be added as data are collected for each encounter.

Context, schema, and mission documentation are located in the Lucy Mission Bundle.

3.2 Data Format Descriptions

The following sections describe in detail the formats of TTCam raw through calibrated data products.

3.2.1 Uncalibrated Image Data Product Format

The TTCam raw image data product is generated by the Lucy SOC processing pipeline that transforms the downlinked observation into the FITS formatted product with the keywords and other header information as shown in Table 3-2. The only processing performed is to strip the SP header, CRC (and pad bytes) if present, and Fletcher-32 checksum, leaving the mini-header and image stream (in the acquired and transmitted format). Image data is then decompressed and decompanded (as needed) to generate the 12-bit image (stored as 16-bit data).

When storing unsigned 16-bit (which the FITS standard doesn't allow), values are transformed via the equation: *physical value = BSCALE * stored_value + BZERO*. For TTCam, these values are expected to typically be BSCALE = 1 and BZERO = 32768.

Table 3-2 TTCam Raw Image FITS Header Keywords

FITS Keyword	PDS XML Label Class/Attribute	Definition
SIMPLE	n/a	File conforms to FITS standard
BITPIX	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/Element_Array[1]/data_type[1]	Pixel bit depth
NAXIS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/axes[1]	Number of axes in the data array (2)
NAXIS1	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/axes[1]	Number of rows (lines)
NAXIS2	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/axes[1]	Number of columns (samples)
EXTEND	n/a	FITS dataset may contain extensions
BSCALE	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/Element_Array[1]/scaling_factor[1]	Multiplicative factor for scaled data
BZERO	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/Element_Array[1]/value_offset[1]	Additive factor for scale data
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 (Terminal Tracking Camera)
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) for the first line of the detector read out (line 1, row 1)
MIDSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_sclk[1]	observation midpoint (SCLK seconds) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)

FITS Keyword	PDS XML Label Class/Attribute	Definition
STARTUTC	/Product_Observational[1]/Observation_Area[1]/Time_Coordinates[1]/start_date_time[1]	observation start time (UTC, ISOT format) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
STOPUTC	/Product_Observational[1]/Observation_Area[1]/Time_Coordinates[1]/stop_date_time[1]	observation stop time (UTC, ISOT format) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
EXPTIME	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Exposure[1]/img:exposure_duration[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	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]	product processing level

FITS Keyword	PDS XML Label Class/Attribute	Definition
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]	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?
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	input UDP filename
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	n/a	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

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)
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]	Target 1 in Field of View
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
SOL_ELON	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:Geometry_Orbiter[1]/geom:Illumination_Geometry[1]/geom:Illumination_Specific[1]/geom:solar_elongation[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	n/a	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_Position_Spacecraft_To_Target[1]/geom:z_position[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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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:spice_kernel_file_name[1]	SPICE metakernel filename
SPCKNUM	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[2]	count of loaded SPICE kernels
SPCK[n]	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[number]	SPICE kernel number
CRPIX1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:horizontal_coordinate_pixel[1]	WCS x-coordinate of reference pixel
CRPIX2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:vertical_coordinate_pixel[1]	WCS y-coordinate of reference pixel

FITS Keyword	PDS XML Label Class/Attribute	Definition
CD1_1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Coordinate_Frame_Transformation_Matrix[1]/ebt:Transformation_Element[1]	WCS dRA/dNAXIS1 lin xform param value
CD1_2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Coordinate_Frame_Transformation_Matrix[1]/ebt:Transformation_Element[2]	WCS dRA/dNAXIS2 lin xform param value
CD2_1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Coordinate_Frame_Transformation_Matrix[1]/ebt:Transformation_Element[3]	WCS dDEC/dNAXIS1 lin xform param value
CD2_2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Coordinate_Frame_Transformation_Matrix[1]/ebt:Transformation_Element[4]	WCS dDEC/dNAXIS2 lin xform param value
CTYPE1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:coordinate_name[1]	WCS coordinate type for the first axis (sample)
CTYPE2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[2]/ebt:coordinate_name[1]	WCS coordinate type for the second axis (line)
RADESYS	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:Reference_Frame_Identification[1]/ebt:name[1]	WCS inertial reference frame

FITS Keyword	PDS XML Label Class/Attribute	Definition
EQUINOX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:Reference_Frame_Identification[1]/ebt:frame_spice_name[1]	WCS reference epoch
CUNIT1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:world_coordinate_reference_point[1]/@unit	WCS units for the first axis (sample)
CUNIT2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[2]/ebt:world_coordinate_reference_point[1]/@unit	WCS units for the second axis (line)
CRVAL1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:world_coordinate_reference_point[1]	WCS RA of ref pix (deg); this is the boresight
CRVAL2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[2]/ebt:world_coordinate_reference_point[1]	WCS Dec of ref pix (deg); this is the boresight
T2CMH001	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:camera_product_id[1]	Sequence ID
T2CMH002	n/a	Image ID
T2CMH003	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:spacecraft_clock_start[1]	SCLK seconds
T2CMH004	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:spacecraft_clock_start[1]	SCLK subseconds

FITS Keyword	PDS XML Label Class/Attribute	Definition
T2CMH005	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Instrument_State[1]/img:Device_Temperatures[1]/img:Device_Temperature[1]/img:raw_count[1]	[deg C] Camera head temperature
T2CMH006	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:initial_size[1]/node()[1]	Initial size estimate for image in flash
T2CAI001	n/a	Camera
T2CAI002	n/a	Sequence
T2CAI003	n/a	N_Images
T2CAI004	n/a	Exp1
T2CAI005	n/a	Exp0
T2CAI006	n/a	Int1
T2CAI007	n/a	Int0
T2CAI008	n/a	SX
T2CAI009	n/a	SY
T2CAI010	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Detector[1]/img:samples[1]	Width
T2CAI011	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Detector[1]/img:lines[1]	Height
T2CAI012	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:instrument_mode_id[1]	Mode
T2CAI013	n/a	Gain
T2CAI014	n/a	Subsample
T2CAI015	n/a	Compression
DVRON	n/a	DVR ID (0 = S/N 194503, 1 = S/N 194504)
T2CTI001	n/a	Sequence
T2CTI002	n/a	Offset
T2CTI003	n/a	Whence
T2CTI004	n/a	Bits per Pixel
T2CTI005	n/a	Compression
T2CTI006	n/a	Summing

FITS Keyword	PDS XML Label Class/Attribute	Definition
T2CCHTMP	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Instrument_State[1]/img:Device_Temperatures[1]/img:Device_Temperature[1]/img:temperature_value[1]	[deg C] camera head temperature
END	n/a	FITS header end
HDU{0}	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]	First FITS Data Unit (2d_Array_Image) - TTCam 2592 x2000 raw image

3.2.2 Calibrated Data Product Format

The TTCam calibrated image data product is a FITS-formatted file similar to that of the uncalibrated data product with the exceptions that all metadata keywords are in physical units, the main image array is in radiance units, and four additional FITS "extension" images are provided in the FITS file to represent the Bad Pixel Map, an estimate of the radiance error, derived radiance factor, and an estimate of the radiance factor error. See Tables 3-2 through 3-6 for a full description of the product metadata.

Table 3-3 TTCam Calibrated Image FITS Main Header (Radiance Image) Keywords

FITS Keyword	PDS XML Label Class/Attribute	Definition
SIMPLE	n/a	File conforms to FITS standard
BITPIX	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/Element_Array[1]/data_type[1]	Pixel bit depth
NAXIS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/axes[1]	Number of axes in the data array (2)
NAXIS1	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/axes[1]	Number of rows (lines)
NAXIS2	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/axes[1]	Number of columns (samples)
EXTEND	n/a	FITS dataset may contain extensions
BSCALE	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/Element_Array[1]/scaling_factor[1]	Multiplicative factor for scaled data
BZERO	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/Element_Array[1]/value_offset[1]	Additive factor for scale data
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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 (Terminal Tracking Camera)
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) for the first line of the detector read out (line 1, row 1)
MIDSCLK	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Time_Information[1]/lucy:mid_sclk[1]	observation midpoint (SCLK seconds) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
STARTUTC	/Product_Observational[1]/Observation_Area[1]/Time_Coordinates[1]/start_date_time[1]	observation start time (UTC, ISOT format) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
STOPUTC	/Product_Observational[1]/Observation_Area[1]/Time_Coordinates[1]/stop_date_time[1]	observation stop time (UTC, ISOT format) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
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) for the first line of the detector read out (line 1, row 1)
EXPTIME	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Exposure[1]/img:exposure_duration[1]	[s] Exposure time (sec)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]	product 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]	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?
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[4]/lid_reference[1]/node()[1]	input UDP filename
LOADID	/Product_Observational[1]/Observation_Area[1]/Mission_Area[1]/lucy:Lucy_Observation_Planning[1]/lucy:load_identifier[1]	command sequence load ID

FITS Keyword	PDS XML Label Class/Attribute	Definition
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	n/a	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.

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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]	Target 1 in Field of View
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:Illumination_Geometry[1]/geom:Illumination_Specific[1]/geom:solar_elongation[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	n/a	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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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_Position_Spacecraft_To_Target[1]/geom:z_position[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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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)

FITS Keyword	PDS XML Label Class/Attribute	Definition
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:spice_kernel_file_name[1]	SPICE metakernel filename
SPCKNUM	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[2]	count of loaded SPICE kernels

FITS Keyword	PDS XML Label Class/Attribute	Definition
SPCK[n]	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/geom:Geometry[1]/geom:SPICE_Kernel_Files[1]/geom:SPICE_Kernel_Identification[number]	SPICE kernel number
CRPIX1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:horizontal_coordinate_pixel[1]	WCS x-coordinate of reference pixel
CRPIX2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:vertical_coordinate_pixel[1]	WCS y-coordinate of reference pixel
CD1_1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Coordinate_Frame_Transformation_Matrix[1]/ebt:Transformation_Element[1]	WCS dRA/dNAXIS1 lin xform param value
CD1_2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Coordinate_Frame_Transformation_Matrix[1]/ebt:Transformation_Element[2]	WCS dRA/dNAXIS2 lin xform param value
CD2_1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Coordinate_Frame_Transformation_Matrix[1]/ebt:Transformation_Element[3]	WCS dDEC/dNAXIS1 lin xform param value
CD2_2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Coordinate_Frame_Transformation_Matrix[1]/ebt:Transformation_Element[4]	WCS dDEC/dNAXIS2 lin xform param value

FITS Keyword	PDS XML Label Class/Attribute	Definition
CTYPE1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:coordinate_name[1]	WCS coordinate type for the first axis (sample)
CTYPE2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[2]/ebt:coordinate_name[1]	WCS coordinate type for the second axis (line)
RADESYS	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:Reference_Frame_Identification[1]/ebt:name[1]	WCS inertial reference frame
EQUINOX	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:Reference_Frame_Identification[1]/ebt:frame_spice_name[1]	WCS reference epoch
CUNIT1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:world_coordinate_reference_point[1]/@unit	WCS units for the first axis (sample)
CUNIT2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[2]/ebt:world_coordinate_reference_point[1]/@unit	WCS units for the second axis (line)
CRVAL1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[1]/ebt:world_coordinate_reference_point[1]	WCS RA of ref pix (deg); this is the boresight

FITS Keyword	PDS XML Label Class/Attribute	Definition
CRVAL2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/ebt:Earth_Based_Telescope_Parameters[1]/ebt:Telescope_Geometry[1]/ebt:World_Coordinate_System[1]/ebt:Reference_Frame_Parameters[1]/ebt:World_Axis[2]/ebt:world_coordinate_reference_point[1]	WCS Dec of ref pix (deg); this is the boresight
T2CMH001	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:camera_product_id[1]	Sequence ID
T2CMH002	n/a	Image ID
T2CMH003	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:spacecraft_clock_start[1]	SCLK seconds
T2CMH004	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:spacecraft_clock_start[1]	SCLK subseconds
T2CMH005	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Instrument_State[1]/img:Device_Temperatures[1]/img:Device_Temperature[1]/img:raw_count[1]	[deg C] Camera head temperature
T2CMH006	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:initial_size[1]/node()[1]	Initial size estimate for image in flash
T2CAI001	n/a	Camera
T2CAI002	n/a	Sequence
T2CAI003	n/a	N_Images
T2CAI004	n/a	Exp1
T2CAI005	n/a	Exp0
T2CAI006	n/a	Int1
T2CAI007	n/a	Int0
T2CAI008	n/a	SX
T2CAI009	n/a	SY
T2CAI010	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Detector[1]/img:samples[1]	Width

FITS Keyword	PDS XML Label Class/Attribute	Definition
T2CAI011	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Detector[1]/img:lines[1]	Height
T2CAI012	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/msss_cam_mh:instrument_mode_id[1]	Mode
T2CAI013	n/a	Gain
T2CAI014	n/a	Subsample
T2CAI015	n/a	Compression
DVRON	n/a	DVR ID (0 = S/N 194503, 1 = S/N 194504)
T2CTI001	n/a	Sequence
T2CTI002	n/a	Offset
T2CTI003	n/a	Whence
T2CTI004	n/a	Bits per Pixel
T2CTI005	n/a	Compression
T2CTI006	n/a	Summing
T2CCHTMP	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/msss_cam_mh:MSSS_Camera_Mini_Header[1]/img:Instrument_State[1]/img:Device_Temperatures[1]/img:Device_Temperature[1]/img:temperature_value[1]	[deg C] camera head temperature
HISTORY	n/a - data is provided in array descriptions	History of calibration processing
UNITS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]/Element_Array[1]/unit[1]	Unit of the radiometrically corrected image
PARAFILE	/Product_Observational[1]/Reference_List[1]/Internal_Reference[1]/lid_reference[1]	Parameter file used in the calibration
BPMFILE	/Product_Observational[1]/Reference_List[1]/Internal_Reference[2]/lid_reference[1]	Bad Pixel Map file used in the calibration
FLATFILE	/Product_Observational[1]/Reference_List[1]/Internal_Reference[3]/lid_reference[1]	Flat file used in the calibration
C1	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[1]/proc:value[1]	Dark model parameter C1
C1_ERR	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[2]/proc:value[1]	Error on dark model parameter C1

FITS Keyword	PDS XML Label Class/Attribute	Definition
C2	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[3]/proc:value[1]	Dark model parameter C2
C2_ERR	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[4]/proc:value[1]	Error on dark model parameter C2
C3	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[5]/proc:value[1]/node()[1]	Dark model parameter C3
C3_ERR	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[6]/proc:value[1]/node()[1]	Error on dark model parameter C3
RADCOEF	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[7]/proc:value[1]	Coefficient of conversion to radiance
RC_ERR	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[8]/proc:value[1]/node()[1]	Error on radiance conversion coefficient
NONLIN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[9]/proc:value[1]	DN value above which pixels become nonlinear
SCALEF	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[10]/proc:value[1]	scale factor (e-/DN)
END	n/a	FITS header end
HDU[0]	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[1]	First FITS Data Unit (2d_Array_Image) - TTCam radiometrically calibrated image.

Table 3-3 TTCam Calibrated Image FITS Extension 1 Header (Bad Pixel Map Image) Keywords

FITS Keyword	PDS XML Label Class/Attribute	Definition
XTENSION	n/a	IMAGE extension

FITS Keyword	PDS XML Label Class/Attribute	Definition
BITPIX	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[2]	Pixel bit depth
NAXIS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[2]/axes[1]	Number of axes in the data array (2)
NAXIS1	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[2]/Axis_Array[1]/elements[1]/node()[1]	Number of rows (lines)
NAXIS2	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[2]/Axis_Array[2]/elements[1]/node()[1]	Number of columns (samples)
PCOUNT	n/a	No Group Parameters
GCOUNT	n/a	One Data Group
HISTORY	n/a	
NBAD_1	n/a	No. of bad pixels flagged before launch
NBAD_2	n/a	No. saturated pixels
NBAD_3	n/a	No. nonlinear pixels (incl. sat pix)
NONLIN	/Product_Observational[1]/Observation_Area[1]/Discipline_Area[1]/proc:Processing_Information[1]/proc:Process[2]/proc:Software[1]/proc:Software_Program[1]/proc:Software_Program_Parameters[1]/proc:Parameter[9]/proc:value[1]	DN value above which pixels become nonlinear.
DATASUM	n/a	data unit checksum
CHECKSUM	n/a	HDU checksum
END		FITS End keyword
HDU[1}	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[2]	Second FITS data unit - Updated bad pixel map where 0 is a good pixel; 1 is a pre-flight determined bad pixel; 2 is a saturated pixel; 3 is a nonlinear pixel; and 4 is an under bias pixel.

Table 3-4 TTCam Calibrated Image FITS Extension 2 Header (Radiance Error Image) Keywords

FITS Keyword	PDS XML Label Class/Attribute	Definition
XTENSION	n/a	IMAGE extension
BITPIX	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[2]	Pixel bit depth

FITS Keyword	PDS XML Label Class/Attribute	Definition
NAXIS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[2]/axes[1]	Number of axes in the data array (2)
NAXIS1	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[2]/Axis_Array[1]/elements[1]/node()[1]	Number of rows (lines)
NAXIS2	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[2]/Axis_Array[2]/elements[1]/node()[1]	Number of columns (samples)
PCOUNT	n/a	No Group Parameters
GCOUNT	n/a	One Data Group
BSCALE	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[3]/Element_Array[1]/scaling_factor[1]	Multiplicative factor for scaled data
BZERO	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[3]/Element_Array[1]/value_offset[1]	Additive factor for scale data
HISTORY	n/a	
UNITS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[3]/Element_Array[1]/unit[1]	Radiance error units.
DATASUM	n/a	data unit checksum
CHECKSUM	n/a	HDU checksum
END		FITS end keywords
HDU[2]	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[3]	Third FITS Data Unit (2d_Array_Image) - TTCam radiometric error image in unit of (uW/cm^2/sr)

Table 3-5 TTCam Calibrated Image FITS Extension 3 Header (Radiance Factor Image) Keywords

FITS Keyword	PDS XML Label Class/Attribute	Definition
XTENSION		IMAGE extension

FITS Keyword	PDS XML Label Class/Attribute	Definition
BITPIX	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[4]/Element_Array[1]/data_type[1]	Pixel bit depth
NAXIS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[4]/axes[1]	Number of axes in the data array (2)
NAXIS1	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[4]/Axis_Array[1]/elements[1]	Number of rows (lines)
NAXIS2	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[4]/Axis_Array[2]/elements[1]	Number of columns (samples)
PCOUNT	n/a	No Group Parameters
GCOUNT	n/a	One Data Group
BSCALE	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[4]	Multiplicative factor for scaled data
BZERO	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[4]/Element_Array[1]/value_offset[1]	Additive factor for scale data
HISTORY		
UNITS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[4]/Element_Array[1]/unit[1]	I/F or radiance factor is unitless
FSUN	n/a	TTCam solar radiance (uW/cm^2/sr/nm) at 1 AU
TARG_AU	n/a	target heliocentric distance, in AU
DATASUM	n/a	data unit checksum
CHECKSUM	n/a	HDU checksum
END		FITS End keyword
HDU[3]	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[4]	Fourth FITS Data Unit (2d_Array_Image) - TTCam radiance factor image (unitless).

Table 3-6 TTCam Calibrated Image FITS Extension 4 Header (Radiance Factor Error Image) Keywords

FITS Keyword	PDS XML Label Class/Attribute	Definition
XTENSION	n/a	IMAGE extension
BITPIX	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[5]/Element_Array[1]/data_type[1]	Pixel bit depth
NAXIS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[5]/axes[1]	Number of axes in the data array (2)
NAXIS1	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[5]/Axis_Array[1]/elements[1]	Number of rows (lines)
NAXIS2	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[5]/Axis_Array[2]/elements[1]	Number of columns (samples)
PCOUNT	n/a	No Group Parameters
GCOUNT	n/a	One Data Group
BSCALE	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[5]/Element_Array[1]/scaling_factor[1]	Multiplicative factor for scaled data
BZERO	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[5]/Element_Array[1]/value_offset[1]/node()[1]	Additive factor for scale data
HISTORY		
UNITS	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[5]/Element_Array[1]/unit[1]/node()[1]	I/F or radiance factor is unitless
DATASUM	n/a	data unit checksum
CHECKSUM	n/a	HDU checksum
END		FITS end keyword
HDU[4]	/Product_Observational[1]/File_Area_Observational[1]/Array_2D_Image[5]	Fifth FITS Data Unit (2d_Array_Image) - TTCam radiance factor error image (unitless).

3.3 Label and Header Descriptions

All TTCam 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.nasa.gov/tools/tool-registry/)

4.1 Utility Programs

As the TTCam images are formatted as FITS files, any FITS library can be used to manipulate the images. A good list of these libraries and software programs can be found at the FITS Support Office at the 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/tool-registry/) for additional information on these tools.

4.3 Software Distribution and Update Procedures

There are no plans to distribute software specific to TTCam to the PDS. If these plans change, they will be noted here.

5. APPENDICES

5.1 ACRONYM LIST

Table 5-1: **Acronym List**

Acronym	Definition
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
SOC	Science Operations Center

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
T2Cam	Alternate acronym also used on the Lucy Project for Terminal Tracking Camera
TTCam	Terminal Tracking Camera
TBD	To Be Determined

5.2 References

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