# ***Lucy***

# **SOFTWARE INTERFACE SPECIFICATION**

# ***Thermal Emission Spectrometer (LTES) Data Products***

June, 2021

SwRI® Project 22668

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Rev 1 Chg 0

Contract NNM16AA08C

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**TABLE OF CONTENTS**

Page

[1. INTRODUCTION 1](#_Toc75509893)

[1.1 Purpose and Scope 1](#_Toc75509894)

[1.1 Contents 1](#_Toc75509895)

[1.2 Applicable Documents 1](#_Toc75509896)

[1.3 Relationship with Other Interfaces 2](#_Toc75509897)

[2. Data Product Characteristics and Environment 3](#_Toc75509898)

[2.1 Instrument Overview 3](#_Toc75509899)

[2.1.1 Observation Profile and Data Acquisition 5](#_Toc75509900)

[2.2 Data Product Overview 6](#_Toc75509901)

[2.3 Data Processing 6](#_Toc75509902)

[2.3.1 Data Processing Level 7](#_Toc75509903)

[2.3.2 Data Product Generation 8](#_Toc75509904)

[2.3.3 Data Flow 9](#_Toc75509905)

[2.3.4 Labeling and Identification 11](#_Toc75509906)

[2.4 Standards Used in Generating Data Products 12](#_Toc75509907)

[2.4.1 PDS Standards 12](#_Toc75509908)

[2.4.2 Time Standards 12](#_Toc75509909)

[2.4.3 Coordinate Systems 13](#_Toc75509910)

[2.4.4 Data Storage Conventions 13](#_Toc75509911)

[2.5 Data Validation 13](#_Toc75509912)

[3. Detailed Data Product Specifications 14](#_Toc75509913)

[3.1 Data Products Structure and Organization 14](#_Toc75509914)

[3.2 Data Format Descriptions 15](#_Toc75509915)

[3.2.1 Uncalibrated Data Product Format 15](#_Toc75509916)

[3.2.2 Calibrated Data Product Format 19](#_Toc75509917)

[3.3 Label and Header Descriptions 20](#_Toc75509918)

[4. Applicable Software 20](#_Toc75509919)

[4.1 Utility Programs 20](#_Toc75509920)

[4.2 Applicable PDS Software Tools 20](#_Toc75509921)

[4.3 Software Distribution and Update Procedures 20](#_Toc75509922)

[5. Appendices 20](#_Toc75509923)

[5.1 ACRONYM LIST 21](#_Toc75509924)

**REVISION NOTICE**

|  |  |  |  |  |
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| 0 | 0 | All | (DRAFT, R0) | 01/25/2021 |
| 0 | 0 | All |  |  |

**TBD/TBS RESOLUTION SCHEDULE**

|  |  |  |
| --- | --- | --- |
| **Location** | **Description** | **Planned Resolution Date** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

# INTRODUCTION

## Purpose and Scope

The purpose of this Software Interface Specification (SIS) is to provide the consumers of the *Lucy* Thermal Emission Spectrometer (LTES) raw and calibrated data products with a detailed description of the data products, and how they were generated, including data sources and destinations. The document is intended to provide enough information to enable users to read and understand the data product. The users for whom this document is intended are the scientists who will analyze the data, including those associated with the project and those in the general planetary science community.

Raw data products described in this SIS are uncalibrated, uncorrected data products reassembled from spacecraft telemetry as acquired by the instrument. Calibrated data products described in this 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 LTES 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.

## Contents

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

## Applicable Documents

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

This Data Product SIS is responsive to the following documents:

Table ‑. List of Applicable Documents

| **Document ID** | **Title** | **Release Date** | **Revision** |
| --- | --- | --- | --- |
| JPL D-7669, Part 2 | Planetary Data System Standards Reference | June 2021 | 1.16 |
| n/a | Data Provider’s Handbook, Archiving Guide to the PDS4 Data Standards | June 2021 | 1.16\* |
| n/a | Planetary Data System Common Dictionary Document | June 2021 | 1.16 |
| 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 | *Lucy* – PDS SBN Configuration Control Plan |  | current revision unless revision is specified |
| unassigned | *Published Instrument Paper* | TBD | Publication Date and DOI |

## 

## 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 ‑. List of Interface Relationships

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

# Data Product Characteristics and Environment

## Instrument Overview

The LTES instrument measures the thermal infrared emission from each Trojan asteroid to obtain the temperature of the asteroid's surface. These observations address one of the Level 1 science requirements: determining the thermal inertia of the surface. The LTES is a near-copy of the OTES instrument on OSIRIS-REx (Christensen et al. 2018), where OTES is used to derive the surface composition and thermal inertia of the asteroid Bennu. However, because the Trojan asteroids at 5 AU are much colder than Bennu, the Lucy mission does not plan to use LTES to derive surface composition. Instead, LTES will be used primarily to infer regolith properties.

LTES is a Fourier transform infrared point spectrometer built at Arizona State University and Dr. Phil Christensen is the Instrument Principal Investigator. LTES has the same optical-mechanical design as OTES, including a 15.2 cm diameter Cassegrain telescope, a Michelson interferometer with chemical vapor deposited diamond beamsplitter, and an uncooled, deuterated L-alanine doped triglycine sulfate (DLATGS) pyroelectric detector. LTES has only small differences from the heritage instrument including removing a potential stray light path by modifying the telescope baffle and primary mirror inner diameter and improvements to the metrology laser system. An internal calibration cone blackbody target provides radiometric calibration. The LTES instrument collects data from 6-75 mm and has a noise equivalent spectral radiance (NESR) of 2.310-8 W cm-2 sr-1/cm-1 between 300 cm-1 (33 mm) and 1350 cm-1 (7.4 mm). For surfaces with temperatures greater than 75 K, LTES will determine the temperature with an accuracy of 2 K. The 50% encircled energy of the instrument subtends 6.5 mrad.

LTES has one mode of taking data. It continuously collects interferograms (every 0.5, 1.0, or 2.0 sec) and transfers them to the spacecraft for storage before downlink. The instrument will start collecting data one day before closest approach, which is before the target fills the instrument's field of view. The data collection will continue until one day after closest approach. The instrument regularly interleaves observations of an internal calibration mirror while taking science data.

The LTES instrument will measure the radiance of each Trojan asteroid at four locations at different local times of day with the additional requirement that one observation measures a location within 30° of the sub-solar point and another measures the un-illuminated surface (Figure 2-1). This observation is conducted by scanning the LTES FOV across the asteroid. The measurements are converted into temperatures by fitting one or more blackbody curves (for known temperatures) to the measured calibrated radiance. These temperatures are inputs to models of thermal inertia, which are used to infer regolith properties.

**Figure 2‑1** LTES scan of a Trojan asteroid. To observe different local times of day, Lucy will use the IPP to scan the LTES instrument across the Trojan asteroid. The scan will start on the dark limb of the Trojan asteroid and progress across the lit hemisphere. For each of the Lucy Trojan targets, there is a time when the LTES field of view is smaller than the unilluminated region allowing a measure of the night side of the Trojan asteroid. There is a pointing uncertainty of 1/8 of the Trojan's diameter and that is accounted for when planning the timing of the scan.

Diagram, venn diagram

Description automatically generated

Table ‑. List of Instrument Properties

| **Attribute** | **Value [TBR]** |
| --- | --- |
| Nominal Spectral Sampling | < 10 cm-1 (in 2-sec mode) |
| Spectral Range | 6 – 75 µm (1667-133 cm-1) |
| Telescope Aperture | 15.2 cm |
| Detectors | Single, uncooled DLATGS detector |
| Michelson Mirror Travel | ±0.3 mm |
| Mirror Velocity (physical travel) | 0.33 mm/sec |
| Laser Fringe Reference Wavelength | 850 nm |
| Interferometer Sample Rate | 770 Hz |
| Field of View (FOV) | 8 mrad (6.5 mrad FWHM; roughly circular) |
| Number of Samples per Interferogram (2 sec mode) | ~1440 |
| Number of Bits per Sample of Interferogram | 16 |
| Cycle Time per Measurement (or ICK Duration) | 2 sec, 1 sec, 0.5 sec |
| Dimensions (width x depth x height) | 38 x 29 x 30 cm |
| Mass | 7.7 kg (NTE) |
| Average Power | 17.6 watts (NTE) |
| Operating Temperature Range (AFT) | -10 to +40 °C |
| Non-Operating Temperature Range (AFT) | -20 to +50 °C |

### Observation Profile and Data Acquisition

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

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

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 in the Terminal Tracking Cameras, the on-board terminal-tracking state estimation begins to provide an estimate of the Trojan's location relative to the spacecraft. This terminal tracking allows the Lucy spacecraft to have updated knowledge of the target which allows for a more efficient observing strategy. The large uncertainty in the target location (relative to its size) is collapsed by the on-board terminal tracking system.

## Data Product Overview

The basic unit of data from the LTES instrument is a record consisting of either engineering words only (***idle*** data), or engineering plus interferograms (***look*** data). On the ground, records from an ***LTES Observation Sequence*** are collected into a sequence of raw files made up of *idle* and/or *look* data. The *engineering-only* data are reformatted into PDS standard format files and are processed to convert Digital Numbers (DN) to physical units (e.g. temperature, voltages and currents). The *engineering+interferogram* (***look***) data are reformatted into PDS standard files. The ***look*** data files for the entire ***LTES Observation Sequence*** are processed together and converted to physical units and then calibrated into radiance spectra. The calibrated spectra are stored in calibrated spectra files following the PDS standards.

Within each file, data are organized as fixed length records in a time sequential (or chronological) order. A complete description of the various files is given in Detailed Data Product Specifications.

## Data Processing

The Lucy Science Operations Center (SOC) is responsible for all Lucy science data processing. LTES science and engineering telemetry are received by the SOC via the Mission Operations Center (MOC). LTES raw telemetry data are reconstructed, sorted, and stored in the SOC data repository. LTES science data (along with its associated engineering) are retrieved from the data repository and fed into the LTES-specific data processing software. The pipeline produces the LTES uncalibrated and calibrated science and engineering data products. The data are stored in HDF5 file format.

Production rates of calibrated spectra vary over the course of the mission and are dependent on observing campaigns during specific mission phases. Specific file sizes will vary dependent on the number of records in each sequence, and how long the instrument idles, which is driven by the mission operations plan. The contents (and thus size) of a LTES product are tied to the ObsID (i.e., all packets tagged with a given ObsID belong to the same observation) and so are determined on the uplink side by how LTES is commanded. The longer the overall observation duration and the shorter the individual collection interval (ICK) period, the more packets are generated for that ObsID. For example, the ground testing sequence for the Polymele encounter SVT contained 15 science observations: 8 of commanded length (typically around 30 minutes, but a couple about half that size), and 7 “indefinite” length observations, terminated by explicit abort commands. Also, 10 calibrations were commanded (30 seconds in length each). Each of those 25 total observations used a 2-second scan period. This resulted in typical data product sizes of about 5MB for the science files and 150K for the cal files.

### Data Processing Level

The LTES data products comply with NASA processing level standards as shown in Table 2‑3. Data Processing Levels. LTES data products are derived from the previous level product. Calibration file data processing levels are not discussed, as calibration files require special production techniques.

Table ‑. Data Processing Levels

| Lucy Archive Data Product | PDS4 Processing Level | Description |
| --- | --- | --- |
| N/A | Telemetry | An encoded byte stream used to transfer data from one or more instruments to temporary storage where the raw instrument data will be extracted. PDS does not archive telemetry data. |
| Uncalibrated Data Product | Raw | Original data from an instrument. If compression, reformatting, packetization, or other translation has been applied to facilitate data transmission or storage, those processes will be reversed so that the archived data are in a PDS approved archive format.  Lucy LTES uncalibrated engineering and science interferogram data in units of DN are examples of raw data products. |
|  | Partially Processed | Data that have been processed beyond the raw stage, but which have not yet reached calibrated status.  Lucy LTES voltage spectra data in physical units are partially processed data products. |
| Calibrated Data Product | Calibrated | Data converted to physical units, which makes values independent of the instrument.  Lucy LTES engineering and spectra data in physical or radiance units are calibrated data 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. |

### Data Product Generation

The LTES Uncalibrated files will be generated by the SOC from the downlinked LTES telemetry. The Uncalibrated products 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, as indicated in Section 2.3.4.1 and by the Version\_Id field in the PDS label. On successful completion through the LTES 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 LTES engineers.

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

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

#### Uncalibrated Data Product Generation

LTES science, engineering, and ancillary packet telemetry are received from the Mission Operations Center (MOC) via a dedicated connection. The packet data are ingested into the SOC data repository using the Database Downlink Ingestion Tool (DDIT) which is responsible for decompression, database communication, parsing, data insertion, and querying. Once LTES 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 Unprocessed Data Processing (UDP) module that manages the setup and execution of the individual instrument pipeline functions. The LTES UDP module builds uncalibrated data products, in HDF5 format, containing housekeeping datasets in all cases, and also voltage interferograms when those data are present.  The data packets included within a given HDF5 product file are determined by the Acquisition ID (aka Observation ID = ObsID) defined within the packets. The LTES UDP module returns both UDP products and logfile information.

#### Calibrated Data Product Generation

The observations acquired during a single LTES observation sequence (interferograms) are converted into voltage spectra by performing a Discrete Fourier Transform (DFT) in the ground processing pipeline. These spectra are then converted into calibrated radiance spectra using the LTES calibration software, which uses the space and calibration observations taken just before and just after the science observations, as available. The LTES data calibration flow and algorithms are documented in the LTES Instrument Paper (TBD) with a general overview also provided by Christensen et al. [2018].

The LTES CDP (Calibrated Data Processing) software queries the SOC database for products ready to be processed. The LTES *looks* are separated by their Acquisition ID and only include records with science data. The CDP process retrieves the uncalibrated science files and their associated observation spatial and geometric information for a single ***LTES Observation Sequence*** as inputs from the SOC database. Spatial and geometric information were calculated after insertion of the uncalibrated products into the database. The geometry contains the geometry information for each OTES individual collection interval in the *look* needed for optimal calibration of LTES data. The LTES CDP module transforms the interferogram into a voltage spectrum. The transformation is done by performing Discrete Fourier Transform (DFT) on the raw interferogram. Note that a raw interferogram will have 1414 points, which is the buffer size of the LTES instrument. The buffer is large compared to the actual number of points collected in the interferogram (~1350 ±5). To compensate for this variation the raw interferogram is padded with zeros to a value of 1360. The data are then saved to the data repository. Voltage interferogram conversion coefficients can be found at the end of LTES Engineering Dictionary (otes\_eng\_dic.pdf) located in the documents collection of this archive.

The voltage interferogram is calibrated using the following equation (Christensen et al., 2018, equation 18):



Terms in this equation are listed below:

Table ‑. LTES Calibration Coefficient Terms

|  |  |
| --- | --- |
| Equation Term | Value, Data Source or Definition |
| *εsceneBscene* | Radiance of the scene |
| *Vscene* | Voltage value of the scene, which is the Fourier transform value of the interferogram. |
| *Vspace* | Voltage value of space, which is the Fourier transform value of the interferogram. |
| *Vcal* | Voltage value of the cal, which is the Fourier transform value of the interferogram. |
| εcal | Emissivity of the calibration target vs. wavenumber (currently all 1.0, not delivered to PDS. If a change is made, it will be noted in delivery release notes.) |
| Bcal | The black body radiation of the calibration target from the associated engineering data |
| flag | 0.998 |
| Bflag | The black body radiation of the calibration target flag from associated engineering data |
| flag | 0.002 |
| primary | 0.002 |
| Bprimary | The black body radiation of the primary mirror from associated engineering data |
| secondary | 0.998 |
| secondary | 0.002 |
| Bsecondary | The black body radiation of the secondary mirror from associated engineering data |
| fore | 0.996004  (= 0.998^2) |
| space | 1.00000 |
| Bspace | Black body spectrum at T=3 K |

The resulting data and associated telemetry are stored in an LTES Calibrated HDF5 file, which is stored in the SOC repository.

Processing log messages (including error messages) generated during data processing are captured by the SOC Pipeline Executive into log files. The log files will be used by the LTES engineers for diagnosis in case of a processing failure but will not be archived.

### Data Flow

LTES 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 LTES calibration pipeline queries the SOC data repository for the raw telemetry, science and ancillary data. Figure 2‑2 illustrates the SOC LTES data processing pipeline data flow. The Lucy Instrument and Science Teams access data products in the data repository through local rsync processes.

Figure ‑. SOC Data Processing Diagram

![Diagram

Description automatically generated]()

The table below shows the expected LTES data collection by encounter/mission phase. The number of expected individual collection intervals (ICKs) is specified as well as the expected data volume of the processed data products. Level-0 science data product volume is based on the per ICK data volume of TBR-bytes, Uncalibrated engineering data product volume is based on the per collection data volume of TBR-bytes, assuming an equivalent number of engineering only collections as science collections. Calibrated engineering data product volume is based on the per collection data volume of TBR-bytes and science is based on per ICK data volume of TBR-bytes. Calibrated science data product volume is based on the per ICK data volume of TBR-bytes. This table will be updated at the conclusion of mission data collection to reflect actual data collections and data volumes.

Table ‑. Data Volume by Mission Phase

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Mission Phase | Donaldjohanson | Eurybates | Polymele | Leucus | Orus | PMB |
| #ICKs |  |  |  |  |  |  |
| Uncalibrated Engineering |  |  |  |  |  |  |
| Uncalibrated Science |  |  |  |  |  |  |
| Calibrated Engineering |  |  |  |  |  |  |
| Calibrated Spectra |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

### Labeling and Identification

All LTES products consist of a data file and a PDS4-compliant detached XML label that describes the content and format of the associated data file. These labels describe the content and format of the associated data product. Labels and products are associated by file name with the label having the same name as the data product except that the label file has an .xml extension. Labels are constructed with the PDS4 Product Class, Product\_Observational sub-class. The Product\_Observational sub-class describes a set of information objects produced by an observing system. A hierarchical description of the contents of Product\_Observational is presented below.

Product\_Observational

Identification\_Area - 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)

Modification\_History - attributes describing changes in data product

Observation\_Area - attributes that provide information about the circumstances under which the data were collected.

Time\_Coordinates - time attributes of data product

Primary\_Results\_Summary - high-level description of the types of products included in the collection or bundle

Investigation\_Area - mission, observing campaign or other coordinated, large-scale data collection attributes

Observing\_System - observing system (instrument) attributes

Target\_Identification - observation target attributes

Discipline \_Dictionaries – discipline specific attributes collected by specific discipline areas.

Mission\_Area - mission specific attributes needed to describe 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.

Table\_Binary/Character/Delimited – contains classes that define binary or text type tables.

Array\_\* - contains classes that describe a number or 2D or 3D arrays, typically images or spectra.

File\_Area\_Supplemental - describes a supplemental 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.

Table\_Binary/Character/Delimited – contains classes that define binary or text type tables.

Array\_\* - contains classes that describe a number or 2D or 3D arrays, typically images or spectra.

Parseable\_Byte\_Stream – contains classes used to describe parseable data objects.

Encoded\_\*- contains classes used to describe encoded objects.

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>.

#### Product Naming

All LTES data products are named using the following naming conventions:

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

**inst** = lor (LORRI), lei (LEISA), mvi (MVIC), ltes (LTE), and ttc (TTCam)  
**acqtime** = data acquisition time (details TBD: exact format, and which time reference to use for flight vs. test data, actual acq time or ground received time)  
**obsid** = 16-bit integer observation ID  
**level** = data processing level (NH uses "eng" vs "sci", OTES uses "l0" vs "l1" and "l2", so details to be worked)  
**version** = product version number  
**ext** = file type (e.g., "fit", "hdf", "jpg", etc.)

LTES data products are HDF5 file type so therefore have suffixes of “.hdf”. All LTES files are created with detached PDS labels, indicated by the “.xml” file extension. The labels are PDS4 compliant XML format.

## Standards Used in Generating Data Products

### 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.

### Time Standards

Time Standards used by the Lucy mission conform to PDS time standards. Discussion of the types of times used on the mission, i.e. SCLK, MET, ET and UTC conversions.

### Coordinate Systems

All coordinate systems used by the *Lucy* mission conform to IAU standards. A

complete discussion of the coordinate systems and how they are deployed in the mission can

be found in the document “***Lucy* Mission Coordinate System Plan”** found in the archive documents directory.

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.

### Data Storage Conventions

LTES data products will be stored as HDF5 files and conform to the standard: http://docs.opengeospatial.org/is/18-043r3/18-043r3.html.

## 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 review and 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 LTES 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 LTES data products will, however, occur as a manual inspection by the LTES team and the *Lucy* science team.

# Detailed Data Product Specifications

General statement of what the data products to be described are.

## 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 data processing level of each data type. Collections will be sub-divided by time interval (mission phase). Each PDS bundle also contains a document collection, to provide the appropriate ancillary information to properly interpret and use the data. LTES data products are structured as Binary Table files. LTES data products are organized by type and data processing level and then by target.

The LTES bundle structure is as follows:

Bundle: urn:nasa:pds:lucy:ltes

Collection: urn:nasa:pds:lucy:ltes:data\_uncalibrated

Eurybates

Polymele

Leucus

Orus

PMB

Collection: urn:nasa:pds:lucy:ltes:data\_calibrated\_eng

Eurybates

Polymele

Leucus

Orus

PMB

Collection: urn:nasa:pds:lucy:ltes:data\_calibrated\_sci

Eurybates

Polymele

Leucus

Orus

PMB

Collection: urn:nasa:pds:lucy:ltes:document\_ltes

Collection: urn:nasa:pds:lucy:ltes:calibration\_ltes

Collection: urn:nasa:pds:lucy:ltes:geometry\_ltes

## Data Format Descriptions

The following sections describe in detail the formats of LTES uncalibrated through calibrated data products.

### Uncalibrated Data Product Format

#### Uncalibrated Engineering Format

The uncalibrated engineering data will be stored in an HDF5 file. The file will have an associated PDS4 label describing the table structure and various ancillary fields. The LTES L0 uncalibrated engineering record structure are given below:

Table ‑. Uncalibrated Engineering Format

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Array Num** | | **Array Name** | **Array Loc (Bytes)** | | | **Data Type** | | **Units** | | **Description** |
| 1 | | sclk | 6144 | | | UnsignedMSB4 | | Sec | | OTES time in seconds |
| 2 | | sclk\_sub | 6416 | | | UnsignedMSB2 | |  | | OTES time in sub-seconds. Each count represents 1/(2^16) seconds |
| 3 | | seq\_count | 6688 | | | UnsignedMSB2 | |  | | Number of telemetry (housekeeping / science) packets sent (resets on power up). |
| 4 | | acq\_id | 6960 | | | UnsignedByte | |  | | This ID helps correlate the science data frames with the command. |
| 5 | | cmd\_fc\_echo | 7232 | | | UnsignedByte | |  | | Echo of last valid instrument command received. |
| 6 | | cmd\_seq\_echo | 7300 | | | UnsignedByte | |  | | Echo of the sequence ID of the last valid instrument command received. |
| 7 | | instr\_cmd\_acc\_count | 7368 | | | UnsignedByte | |  | | Number of accepted instrument commands. |
| 8 | | time\_upd\_acc\_count | 7436 | | | UnsignedByte | |  | | Number of accepted time update commands |
| 9 | | cmd\_rej\_count | 7504 | | | UnsignedByte | |  | | Number of rejected commands. |
| 10 | | watchdog\_status | 7572 | | | UnsignedByte | |  | | Watchdog status, 0=Disabled, 1=Enabled |
| 11 | | flash\_pwr\_status | 7640 | | | UnsignedByte | |  | | Flash power status, 0=Off, 1=On |
| 12 | | led1\_pwr\_status | 7708 | | | UnsignedByte | |  | | Linear motor LED 1 power status, 0=Off, 1=On |
| 13 | | led2\_pwr\_status | 7776 | | | UnsignedByte | |  | | Linear motor LED 2 power status, 0=Off, 1=On |
| 14 | | missing\_time\_tic\_ctr | 7844 | | | UnsignedByte | |  | | Missing time tic counter |
| 15 | | pps\_timer\_mode | 7912 | | | UnsignedByte | |  | | PPS timer mode. 1=Oscillator, 2=Nominal, 4=PPS, 8=Command mode |
| 16 | | tic\_ctr | 7980 | | | UnsignedByte | |  | | Number of tic (PPS) pulses received. |
| 17 | | cal\_flag\_prot | 8048 | | | UnsignedByte | |  | | Cal flag protection, 0=Disabled, 1=Enabled |
| 18 | | cal\_flag\_status | 8116 | | | UnsignedByte | |  | | Commanded cal flag status, 0=Open, 1=Closed. |
| 19 | | cal\_flag\_prot\_timeout | 14272 | | | UnsignedByte | |  | | Cal flag protection timeout |
| 20 | | gravity\_comp\_status | 14340 | | | UnsignedByte | |  | | Gravity compensation status, 0=Off, 1=On |
| 21 | | sample\_dir | 14408 | | | UnsignedByte | |  | | Sample direction status, 0=Forward, 1=Backward direction |
| 22 | | servo\_ctl\_tim\_status | 14476 | | | UnsignedByte | |  | | Servo controller / sample timing status, 0=Closed loop/fringe based, 1=Closed loop/timer based, 2=Open loop/fringe based, 3=Open loop/timer based samples |
| 23 | | linear\_mtr\_pwr\_status | 14544 | | | UnsignedByte | |  | | Linear motor power status, 0=Off, 1=On |
| 24 | | image\_boot\_select | 14612 | | | UnsignedByte | |  | | Identifies which boot image is running. Reflects the lower 3 bits of the image select register at 0xA1000018 |
| 25 | | image\_check\_checksum | 14680 | | | UnsignedMSB4 | |  | | Indicates checksum of the image data (written to SRAM), in response to the image check command. |
| 26 | | image\_store\_checksum | 15224 | | | UnsignedMSB4 | |  | | Indicates checksum calculated by FSW of image data written to SRAM which is to be copied with the image store command. A value of 0xFAFAFA indicates byte-by-byte comparison by FSW of flash written and the SRAM source has failed. |
| 27 | | image\_exp\_checksum | 15768 | | | UnsignedMSB4 | |  | | Indicates the expected checksum from the image store command. |
| 28 | | acq\_scan\_count | 19856 | | | UnsignedMSB2 | |  | | Counts the number of acquisitions taken during the current acquisition sequence |
| 29 | | subcom\_param\_subaddr | 20128 | | | UnsignedByte | |  | | Sub-commutated parameter sub-address. Identifies the subcommutated parameter block. |
| 30 | | subcom\_param1 | 20196 | | | SignedMSB4 | |  | | Sub-commutated parameter 1 |
| 31 | | subcom\_param2 | 20468 | | | SignedMSB4 | |  | | Sub-commutated parameter 2 |
| 32 | | subcom\_param3 | 20740 | | | SignedMSB4 | |  | | Sub-commutated parameter 3 |
| 33 | | subcom\_param4 | 21012 | | | SignedMSB4 | |  | | Sub-commutated parameter 4 |
| 34 | | subcom\_param5 | 21284 | | | SignedMSB4 | |  | | Sub-commutated parameter 5 |
| 35 | | subcom\_param6 | 21556 | | | SignedMSB4 | |  | | Sub-commutated parameter 6 |
| 36 | | edac\_single\_bit\_errs | 21828 | | | UnsignedByte | |  | | Single bit error detected in SRAM. Single bit errors are corrected. |
| 37 | | subcom\_param7 | 24408 | | | SignedMSB4 | |  | | Sub-commutated parameter 7 |
| 38 | | subcom\_param8 | 24680 | | | SignedMSB4 | |  | | Sub-commutated parameter 8 |
| 39 | | os\_pos | 24952 | | | UnsignedMSB2 | |  | | Linear motor optical switch position |
| 40 | | fringe\_count | 25224 | | | UnsignedMSB2 | |  | | Fringe count |
| 41 | | peak\_fringe | 25496 | | | UnsignedMSB2 | |  | | Peak to peak fringe amplitude |
| 42 | | fringe\_offset | 25768 | | | UnsignedMSB2 | |  | | Fringe reading |
| 43 | | sw\_cmd\_acc\_cnt | 26040 | | | UnsignedByte | |  | | Number of commands software has accepted |
| 44 | | sw\_cmd\_rej\_cnt | 26108 | | | UnsignedByte | |  | | Number of commands software has rejected |
| 45 | | scan\_period | 26176 | | | UnsignedByte | |  | | Scan period, 0=2 second, 1=1second, 2=0.5 second scan |
| 46 | | ir\_gain | 26244 | | | UnsignedByte | |  | | IR gain, 0=1x, 1=2x gain |
| 47 | | acq\_cmd\_executing | 26312 | | | UnsignedByte | |  | | Acquisition command executing, 0=Not executing, 1=Executing |
| 48 | | nsamples | 31184 | | | UnsignedMSB2 | |  | | Number of valid entries in the science data section |
| 49 | | ick\_counter | 31456 | | | UnsignedMSB2 | |  | | Resettable scan counter |
| 50 | | sci\_data\_size | 31728 | | | UnsignedMSB4 | |  | | Size of science data IDP size in bytes. 0x0 for engineering data packets, variable (max 3312 bytes) for science data packets |
| 51 | | laser\_temp | 32000 | | | UnsignedMSB2 | |  | | Laser temperature |
| 52 | | motor\_temp | 32272 | | | UnsignedMSB2 | |  | | Motor temperature |
| 53 | | sec\_mirror\_temp1 | 32544 | | | UnsignedMSB2 | |  | | Secondary mirror temperature 1 |
| 54 | | sec\_mirror\_temp2 | 32816 | | | UnsignedMSB2 | |  | | Secondary mirror temperature 2 |
| 55 | | bb\_temp1 | 35464 | | | UnsignedMSB2 | |  | | Blackbody temperature 1 |
| 56 | | bb\_temp2 | 35736 | | | UnsignedMSB2 | |  | | Blackbody temperature 12 |
| 57 | | cal\_act\_temp | 36008 | | | UnsignedMSB2 | |  | | Calibration flag actuator temperature |
| 58 | | cal\_ref\_temp | 36280 | | | UnsignedMSB2 | |  | | Calibration flag doghouse (reference) temperature |
| 59 | | pri\_mirror\_temp | 36552 | | | UnsignedMSB2 | |  | | Primary mirror temperature 1 |
| 60 | | bsplit\_temp | 36824 | | | UnsignedMSB2 | |  | | Beam Splitter temperature |
| 61 | | det\_temp1 | 37096 | | | UnsignedMSB2 | |  | | Detector temperature 1 |
| 62 | | det\_temp2 | 39744 | | | UnsignedMSB2 | |  | | Detector temperature 2 |
| 63 | | board\_temp1 | 40016 | | | UnsignedMSB2 | |  | | FPGA temperature on the control board |
| 64 | | board\_temp2 | 40288 | | | UnsignedMSB2 | |  | | DC/DC converter temperature on control board |
| 65 | | cal\_res1 | 40560 | | | UnsignedMSB2 | |  | | Calibration resistance 1 |
| 66 | | cal\_res2 | 40832 | | | UnsignedMSB2 | |  | | Calibration resistance 2 |
| 67 | | p12v\_status | 41104 | | | UnsignedMSB2 | |  | | +12V Status |
| 68 | | m12v\_status | 41376 | | | UnsignedMSB2 | |  | | -12V Status |
| 69 | | p5v\_status | 44352 | | | UnsignedMSB2 | |  | | +5V Status |
| 70 | | m5v\_status | 44624 | | | UnsignedMSB2 | |  | | -5V Status |
| 71 | | p5vd\_status | 44896 | | | UnsignedMSB2 | |  | | +5V digital Status |
| 72 | | p3\_3v\_status | 45168 | | | UnsignedMSB2 | |  | | +3.3V Status |
| 73 | | p2\_5v\_status | 45440 | | | UnsignedMSB2 | |  | | +2.5V Status |
| 74 | | p1v\_status | 45712 | | | UnsignedMSB2 | |  | | +1V Status |
| **Array Num** | **Array Name** | | | **Array Loc (Bytes)** | **Data Type** | | **Units** | | **Description** | | |
| 1 | sclk | | | 6144 | UnsignedMSB4 | | Sec | | OTES time in seconds | | |
| 2 | sclk\_sub | | | 6416 | UnsignedMSB2 | |  | | OTES time in sub-seconds. Each count represents 1/(2^16) seconds | | |
| 3 | seq\_count | | | 6688 | UnsignedMSB2 | |  | | Number of telemetry (housekeeping / science) packets sent (resets on power up). | | |
| 4 | acq\_id | | | 6960 | UnsignedByte | |  | | This ID helps correlate the science data frames with the command. | | |
| 5 | cmd\_fc\_echo | | | 7232 | UnsignedByte | |  | | Echo of last valid instrument command received. | | |
| 6 | cmd\_seq\_echo | | | 7300 | UnsignedByte | |  | | Echo of the sequence ID of the last valid instrument command received. | | |
| 7 | instr\_cmd\_acc\_count | | | 7368 | UnsignedByte | |  | | Number of accepted instrument commands. | | |
| 8 | time\_upd\_acc\_count | | | 7436 | UnsignedByte | |  | | Number of accepted time update commands | | |
| 9 | cmd\_rej\_count | | | 7504 | UnsignedByte | |  | | Number of rejected commands. | | |
| 10 | watchdog\_status | | | 7572 | UnsignedByte | |  | | Watchdog status, 0=Disabled, 1=Enabled | | |
| 11 | flash\_pwr\_status | | | 7640 | UnsignedByte | |  | | Flash power status, 0=Off, 1=On | | |
| 12 | led1\_pwr\_status | | | 7708 | UnsignedByte | |  | | Linear motor LED 1 power status, 0=Off, 1=On | | |
| 13 | led2\_pwr\_status | | | 7776 | UnsignedByte | |  | | Linear motor LED 2 power status, 0=Off, 1=On | | |
| 14 | missing\_time\_tic\_ctr | | | 7844 | UnsignedByte | |  | | Missing time tic counter | | |
| 15 | pps\_timer\_mode | | | 7912 | UnsignedByte | |  | | PPS timer mode. 1=Oscillator, 2=Nominal, 4=PPS, 8=Command mode | | |
| 16 | tic\_ctr | | | 7980 | UnsignedByte | |  | | Number of tic (PPS) pulses received. | | |
| 17 | cal\_flag\_prot | | | 8048 | UnsignedByte | |  | | Cal flag protection, 0=Disabled, 1=Enabled | | |
| 18 | cal\_flag\_status | | | 8116 | UnsignedByte | |  | | Commanded cal flag status, 0=Open, 1=Closed. | | |
| 19 | cal\_flag\_prot\_timeout | | | 14272 | UnsignedByte | |  | | Cal flag protection timeout | | |
| 20 | gravity\_comp\_status | | | 14340 | UnsignedByte | |  | | Gravity compensation status, 0=Off, 1=On | | |
| 21 | sample\_dir | | | 14408 | UnsignedByte | |  | | Sample direction status, 0=Forward, 1=Backward direction | | |
| 22 | servo\_ctl\_tim\_status | | | 14476 | UnsignedByte | |  | | Servo controller / sample timing status, 0=Closed loop/fringe based, 1=Closed loop/timer based, 2=Open loop/fringe based, 3=Open loop/timer based samples | | |
| 23 | linear\_mtr\_pwr\_status | | | 14544 | UnsignedByte | |  | | Linear motor power status, 0=Off, 1=On | | |
| 24 | image\_boot\_select | | | 14612 | UnsignedByte | |  | | Identifies which boot image is running. Reflects the lower 3 bits of the image select register at 0xA1000018 | | |
| 25 | image\_check\_checksum | | | 14680 | UnsignedMSB4 | |  | | Indicates checksum of the image data (written to SRAM), in response to the image check command. | | |
| 26 | image\_store\_checksum | | | 15224 | UnsignedMSB4 | |  | | Indicates checksum calculated by FSW of image data written to SRAM which is to be copied with the image store command. A value of 0xFAFAFA indicates byte-by-byte comparison by FSW of flash written and the SRAM source has failed. | | |
| 27 | image\_exp\_checksum | | | 15768 | UnsignedMSB4 | |  | | Indicates the expected checksum from the image store command. | | |
| 28 | acq\_scan\_count | | | 19856 | UnsignedMSB2 | |  | | Counts the number of acquisitions taken during the current acquisition sequence | | |
| 29 | subcom\_param\_subaddr | | | 20128 | UnsignedByte | |  | | Sub-commutated parameter sub-address. Identifies the subcommutated parameter block. | | |
| 30 | subcom\_param1 | | | 20196 | SignedMSB4 | |  | | Sub-commutated parameter 1 | | |
| 31 | subcom\_param2 | | | 20468 | SignedMSB4 | |  | | Sub-commutated parameter 2 | | |
| 32 | subcom\_param3 | | | 20740 | SignedMSB4 | |  | | Sub-commutated parameter 3 | | |
| 33 | subcom\_param4 | | | 21012 | SignedMSB4 | |  | | Sub-commutated parameter 4 | | |
| 34 | subcom\_param5 | | | 21284 | SignedMSB4 | |  | | Sub-commutated parameter 5 | | |
| 35 | subcom\_param6 | | | 21556 | SignedMSB4 | |  | | Sub-commutated parameter 6 | | |
| 36 | edac\_single\_bit\_errs | | | 21828 | UnsignedByte | |  | | Single bit error detected in SRAM. Single bit errors are corrected. | | |
| 37 | subcom\_param7 | | | 24408 | SignedMSB4 | |  | | Sub-commutated parameter 7 | | |
| 38 | subcom\_param8 | | | 24680 | SignedMSB4 | |  | | Sub-commutated parameter 8 | | |
| 39 | os\_pos | | | 24952 | UnsignedMSB2 | |  | | Linear motor optical switch position | | |
| 40 | fringe\_count | | | 25224 | UnsignedMSB2 | |  | | Fringe count | | |
| 41 | peak\_fringe | | | 25496 | UnsignedMSB2 | |  | | Peak to peak fringe amplitude | | |
| 42 | fringe\_offset | | | 25768 | UnsignedMSB2 | |  | | Fringe reading | | |
| 43 | sw\_cmd\_acc\_cnt | | | 26040 | UnsignedByte | |  | | Number of commands software has accepted | | |
| 44 | sw\_cmd\_rej\_cnt | | | 26108 | UnsignedByte | |  | | Number of commands software has rejected | | |
| 45 | scan\_period | | | 26176 | UnsignedByte | |  | | Scan period, 0=2 second, 1=1second, 2=0.5 second scan | | |
| 46 | ir\_gain | | | 26244 | UnsignedByte | |  | | IR gain, 0=1x, 1=2x gain | | |
| 47 | acq\_cmd\_executing | | | 26312 | UnsignedByte | |  | | Acquisition command executing, 0=Not executing, 1=Executing | | |
| 48 | nsamples | | | 31184 | UnsignedMSB2 | |  | | Number of valid entries in the science data section | | |
| 49 | ick\_counter | | | 31456 | UnsignedMSB2 | |  | | Resettable scan counter | | |
| 50 | sci\_data\_size | | | 31728 | UnsignedMSB4 | |  | | Size of science data IDP size in bytes. 0x0 for engineering data packets, variable (max 3312 bytes) for science data packets | | |
| 51 | laser\_temp | | | 32000 | UnsignedMSB2 | |  | | Laser temperature | | |
| 52 | motor\_temp | | | 32272 | UnsignedMSB2 | |  | | Motor temperature | | |
| 53 | sec\_mirror\_temp1 | | | 32544 | UnsignedMSB2 | |  | | Secondary mirror temperature 1 | | |
| 54 | sec\_mirror\_temp2 | | | 32816 | UnsignedMSB2 | |  | | Secondary mirror temperature 2 | | |
| 55 | bb\_temp1 | | | 35464 | UnsignedMSB2 | |  | | Blackbody temperature 1 | | |
| 56 | bb\_temp2 | | | 35736 | UnsignedMSB2 | |  | | Blackbody temperature 12 | | |
| 57 | cal\_act\_temp | | | 36008 | UnsignedMSB2 | |  | | Calibration flag actuator temperature | | |
| 58 | cal\_ref\_temp | | | 36280 | UnsignedMSB2 | |  | | Calibration flag doghouse (reference) temperature | | |
| 59 | pri\_mirror\_temp | | | 36552 | UnsignedMSB2 | |  | | Primary mirror temperature 1 | | |
| 60 | bsplit\_temp | | | 36824 | UnsignedMSB2 | |  | | Beam Splitter temperature | | |
| 61 | det\_temp1 | | | 37096 | UnsignedMSB2 | |  | | Detector temperature 1 | | |
| 62 | det\_temp2 | | | 39744 | UnsignedMSB2 | |  | | Detector temperature 2 | | |
| 63 | board\_temp1 | | | 40016 | UnsignedMSB2 | |  | | FPGA temperature on the control board | | |
| 64 | board\_temp2 | | | 40288 | UnsignedMSB2 | |  | | DC/DC converter temperature on control board | | |
| 65 | cal\_res1 | | | 40560 | UnsignedMSB2 | |  | | Calibration resistance 1 | | |
| 66 | cal\_res2 | | | 40832 | UnsignedMSB2 | |  | | Calibration resistance 2 | | |
| 67 | p12v\_status | | | 41104 | UnsignedMSB2 | |  | | +12V Status | | |
| 68 | m12v\_status | | | 41376 | UnsignedMSB2 | |  | | -12V Status | | |
| 69 | p5v\_status | | | 44352 | UnsignedMSB2 | |  | | +5V Status | | |
| 70 | m5v\_status | | | 44624 | UnsignedMSB2 | |  | | -5V Status | | |
| 71 | p5vd\_status | | | 44896 | UnsignedMSB2 | |  | | +5V digital Status | | |
| 72 | p3\_3v\_status | | | 45168 | UnsignedMSB2 | |  | | +3.3V Status | | |
| 73 | p2\_5v\_status | | | 45440 | UnsignedMSB2 | |  | | +2.5V Status | | |
| 74 | p1v\_status | | | 45712 | UnsignedMSB2 | |  | | +1V Status | | |

#### Uncalibrated Science Data Format

The raw science data will be stored in an HDF5 file. The file will have an associated PDS4 label describing the table structure and various ancillary fields in addition to what the raw engineering file format has.

Science record structure is the same as the engineering record structure with the following additional fields added to the end of the engineering record:

Table ‑. Uncalibrated Science Format

| Array Num | Array Name | Array Loc  (Byte Offset) | Data Type | Units | Description |
| --- | --- | --- | --- | --- | --- |
| 75 | ifgm | 48448 | UnsignedMSB2 |  | Interferogram data. |
| 76 | Ifgm\_chksum | 435104 | UnsignedMSB4 |  | Interferogram checksum (last 4 bytes of ifgm) |

### Calibrated Data Product Format

Short description of product

Table with metadata description of products

Table ‑. Calibrated Science Format

| Array Num | Array Name | Array Loc  (Byte Offset) | Data Type | Units | Description |
| --- | --- | --- | --- | --- | --- |
| 77 | Voltage\_spectrum | TBD | UnsignedMSB2 | V | Voltage spectrum |
| 78 | Calibrated\_spectrum | TBD | UnsignedMSB4 |  | Calibrated\_spectrum |
| 79 | Brightness\_temperature | TBD |  |  | Calculated brightness temperature |
| 80 | (anything else) | TBD |  |  |  |

## Label and Header Descriptions

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

# Applicable Software

The LTES team will use “Davinci” (http://davinci.mars.asu.edu) to examine, display and analyze the data products. Davinci is a hyperspectral image processing software produced by the Mars Space Flight Facility at Arizona State University, Tempe, AZ 85287. It has been used as the calibration and analysis software for multiple missions, including MGS/TES, Odyssey/THEMIS, OSIRIS-Rex/OTES, and MER/Mini-TES. The minimum release number for Davinci to access and open PDS4, HDF5 and FITS Files is 2.17.

Davinci will be maintained by the Davinci development team at ASU. Feature requests and bugs may be submitted via email to the Davinci development team.

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/)

## Utility Programs

Davinci depends upon “gnuplot” for its plotting needs and an external image viewer to display images. Location of both is controlled via environment variables as described on the Davinci web-site. Standard complement of Linux/Unix tools and scripting languages will be used in conjunction as needed. Examples of such utilities include “od”, “dd”, “awk”, “perl” (<http://www.perl.org>), “xmlstarlet” (<http://xmlstar.sourceforge.net>) for data dump, selection, formatting and xml query etc.

## Applicable PDS Software Tools

The PDS supplies a number of software tools that can be used in conjunction with PDS data

products. Please refer to the PDS4 software website

(https://pds.nasa.gov/tools/about/) for additional information on these tools.

## Software Distribution and Update Procedures

Current and future releases of Davinci will be available from its web-site (<http://davinci.mars.asu.edu>) in both source and binary forms. Its documentation is hosted on the same site.

# Appendices

## ACRONYM LIST

Table ‑**: **Acronym List****

|  |  |
| --- | --- |
| **Acronym** | **Definition** |
| DMAP | Data Management and Archive Plan |
| DPI | Deputy Principal Investigator |
| ICD | Interface Control Document |
| ICK | *Individual collection Interval* |
| 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 |
| LTES | *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 |
| TTCAM | Terminal Tracking Camera |
| TBD | To Be Determined |