Radio Science Data Data Product Software Interface Specification

LICIACube

Technical Content Approval

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CONTENTS

1. Purpose and Scope

This Software Interface Specification (SIS) describes the Radio Science (RS) and Maneuver Vector Files (also known as Small Forces, Historical, or SFH) data collected by the LICIAcube mission. The LICIACube Science Operations Center (SOC) hosted at the ASI premise produces these products and distributes them to the LICIAcube and DART Investigation Team (IT) and the Planetary Data System (PDS).

This document provides users with a description of the data products, how they were generated, and how they are organized in the archive. The document is intended to provide sufficient information with suitable references, to enable users to read and understand the radio science data products. The intended audience is the scientists who will analyze the data, including those associated with the DART mission and those in the general planetary science community.

2. Applicable Documents and Constraints

This DRACO data product SIS is consistent with the following NASA Planetary Data System documents:

1. Planetary Data System Standards Reference, Version 1.14.0, May 22, 2020
2. PDS4 Data Dictionary, Abridged, Version 1.14.0.0, March 23, 2020
3. PDS4 Information Model Specification, Version 1.14.0.0, March 23, 2020

This RS data product SIS is responsive to the following DART documents:

1. DART Data Management and Archive Plan (DMAP), Rev C, 24 May 2021
2. TRK-2-34 DSN Tracking System Data Archival format, Rev. R, 03 June 2021
3. TRK-2-23 DSN Media Calibration Interface Rev. C, 05 March 2008
4. DART Coordinate System for Didymos and Dimorphos, March 2021
5. Radio Science Uncalibrated/Calibrated Data Product SIS, July 2023

3. Relationships with Other Interfaces

Changes to the data products described in this SIS may affect the documents listed in Table 1. In the event of a conflict between the RS SIS and the DART mission DMAP, the DMAP takes precedence.

Table 1. Interface Relationships

Name	Type	Owner
DART Data Management and Archive Plan	Document	DART SOC

4. Data Product Characteristics and Environment

4.1. Radio Science Overview

The LICIAcube mission receives spacecraft tracking data from the Deep Space Network (DSN). These data are collected primarily from signals emitted by the high gain antenna (HGA) onboard the LICIACube spacecraft. The scientifically useful RS data were collected once LICIAcube was deployed by the DART spacecraft, ~10 days before DART's impact with the moon of Didymos, and Dimorphos. These data continue to be available until a few hours after DART's impact. Both mission navigators and investigation team members working on radio science investigations use these data. The LICIACube navigation and radio science teams receive DSN Tracking and Navigation File (trk-2-34) data, and Ionosphere Calibration Files via secure FTP. The files are all formatted in standard ways and documented in a series of Software Interface Specifications (SIS) noted in Table 1. Troposphere Calibration files and Weather Files that pertain to when LICIAcube collected data can be found at radio science multi-mission archive maintained by the Radio Science Sub-Node and hosted by PDS Geosciences Node (urn:nasa:pds:jpl.dsn.mmm). The DSN SIS documents are not mission specific, they are applicable to all DSN produced data products. The DSN files are transferred to a secure area within the LICIACube Mission Operations Center (MOC) data repository, and then made available to the LICIACube SOC. For the final PDS archive, DSN data files are retrieved from the SOC data repository and prepared for delivery using software provided by the Planetary Data System specifically for the purpose of convert the DART and LICIACube trk 2-34 into PDS 4 format.

Along with the DSN provided RS data, the LICIACube mission also provides a small forces file, or Maneuver Vector File (SFH) that describe the thrusting undertaken by LICIACube and aids in undertaking science associated with the RS data. These files record the delta-v effect of attitude thruster firings at a given time period. The location of the LICIACube thrusters are defined in the LICIACube frame kernel. The LICIAcube maneuvers are impulsive, and are given in the EMO2000 inertial frame. An estimate of mass loss due to usage is included in these SFH. These files were produced at the LICIACube Argotec Mission Control Center from onboard telemetry and were then pulled to the DART SOC before delivery to the PDS. The original vml files were converted into text files (by replacing *.vml with *.txt), to be consistent with PDS4 standard, and not to confuse them with PDS xml labels.

The LICIACube TX HGA is a 4x8 patch array with a low profile (Figure 1). Its compact design allows the antenna to be placed on the cubesat structure providing high directivity and high gain (21.7 dBi). It is the primary LICIACube antenna for downlink transmission, operating in the deep space frequency band allocation (8437 MHz). The LICIACube NAIF Ck kernel provide the attitude of the antenna; a NAIF structure kernel was deemed unnecessary for modeling the RS data from LICIACube because the HGA is pasted directly onto the structure of the very small 10x20x30cm cube satellite.

Table 2. NAIF Data Products Relevant for Radio Science

Data Product	Reference	Availability
NAIF Ck-kernels	Include antenna attitude	urn:nasa:pds:dart.spice:spice_kernels
NAIF Fk-kernels	Includes solar array panels, antennas, and thrusters reference frames (coordinate systems)	urn:nasa:pds:dart.spice:spice_kernels

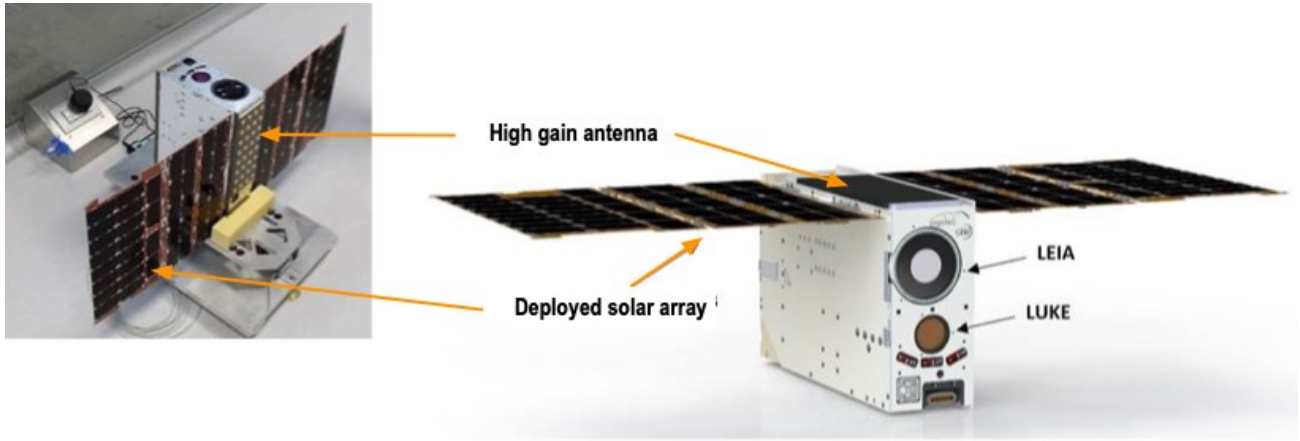

Figure 1. LICIAcube spacecraft showing location of the HGA.

4.2. Data Processing

All LICIAcube RS and SFH data are either generated by the DSN or by the LICIACube Argotec Mission Control Center. The DART SOC collects these data from the LICIACube SOC and delivers these data to the PDS in the PDS format.

4.2.1. Labeling and identification

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

Additional information regarding the XML labels and PDS4 data product specification can be found in the PDS documents referenced in Section 2.

RS 2-34 tracking files are identified with file names in the format of:

lcc_hga_tnf_yyyymmddthhmnss_v##.<extension>

The file name sections are described in Table .

Table 3. Definition of RS filename

File name section	Description
yyyy	Calendar year (e.g., 2021)
mm	Month of year (e.g., 08 is August)
dd	Day of month
hh	Hour of day
mn	Minute of hour
ss	Second of hour
tnf	defines product track 2-34 file when extention equals .dat

The SFH files have the following naming convention, with the definitions given in Table 4:

lccyymmdd-sfh-des#-v#.txt

Table 4. Definition of maneuver acceleration files filename

File name section	Description
yy	Calendar year (e.g., 21)
mm	Month of year (e.g., 07 for July)

dd	Day of month
sfh	Maneuver Vector File
des#	Where # defines the number of desaturation maneuvers after deployment
v#	one digit version number, e.g., “1”
.txt	defines product as a text file

4.3. Standards used in Generating Data Products

4.3.1. PDS Standards

All data products described in this SIS conform with PDS4 standards as described in the PDS Standards document noted in the Applicable Documents section of this SIS. The PDS took the DSN files provided by the DART mission and generated the appropriate PDS4 compliant files. Prior to public release, all data products will have passed both a data product format PDS peer review and a data product production pipeline PDS peer review to ensure compliance with applicable standards.

4.3.2. Time Standards

Time standards used by the DART mission conform to PDS time standards.

4.4. Data Validation

Data validation falls into two types, validation of the science data and validation of the compliance of the archive with PDS archiving and distribution requirements. The first type of validation will be carried out by the SOC and the Investigation Team, and the second will be overseen by the PDS, in coordination with the SOC.

The formal validation of data content, adequacy of documentation, and adherence to PDS archiving and distribution standards is subject to an external peer review. The peer review will be scheduled and coordinated by the PDS. The peer review process may result in "liens," actions recommended by the reviewers or by PDS personnel to correct the archive. All liens must be resolved by the SOC. Once the liens are cleared, PDS will do a final validation prior to packaging and delivery. When data are prepared for submission to PDS, the SOC will use PDS-provided validation tools to ensure conformance to PDS standards.

Continuous validation of the data products will be performed throughout the mission.

5. Detailed Data Product Specifications

The following sections provide detailed data product specifications for the RS and SFH data products.

5.1. Data Product Structure and Organization

All the RS data collected by LICIACube are provided, from before deployment to end of mission several hours after the DART impact. The LICIACube Radio Science directory structure within the LICIACube Spacecraft Bundle is as follows:

The data_tnf collection folder contains the TRK-2-34 data. The data files are contained within this single directory and organized by date and time.

The document_rs collection folder contains the SFH files as well as other supporting documentation such as the SIS. The content of the SFH files is in XML format, hence they are designated as documents that accompany the data and located in the document_rs collection.

5.2. Data Format Descriptions

The LICIACube RS tracking data from the DSN were stored in the appropriate TRK files, and then updated by the PDS into PDS4 format. The SFH files, which were originally vml files, are ASCII text files, stored with PDS4 compliant labels.

5.2.1. Radio Science Tracking Data

The DSN Tracking and Navigation Files (trk-2-34) are natively formatted as a binary collection of approximately 18 different data record types. Not all data record types are present in each file. Each of the data record types can be described in a PDS4 XML label as a PDS4 Table_Binary object. The difficulty in labeling the natively formatted trk-2-34 files is that data records are not sorted by type, meaning that in a worst-case scenario, the PDS XML label would be required to have a binary specification for each data record in the trk-2-34 file, resulting in an XML label file that is hundreds of times larger in size than the data file. To remedy this unwieldy labeling result, the original trk-2-34 files (formatted according to the SIS referenced in Table 7), have been sorted by data record type.

Table 7. DSN Data Product SIS References

Data Product	SIS Reference	Availability
Tracking and Navigation Files	TRK 2-34 DSN Tracking System Data Archival Format, DSN No. 820-013, TRK-2-34, Rev N. JPL D-76488. November 7, 2013.	**urn:nasa:pds:radiosci.documentation:dsn.trk-2-34:2021-06-03**
Ionosphere and Troposphere Calibration Files	TRK 2-23 Media Calibration Interface, DSN No. 820-013, TRK-2-23, Rev C. JPL D-16765. March 5, 2008.	**urn:nasa:pds:radiosci.documentation:dsn.trk-2-23:2008-03-05**

The DART trk-2-34 tracking data product were converted from their original format to the PDS4 standard using software provided by the Planetary Data System specifically for the purpose of convert the DART trk 2-34 into PDS 4 format. The TRK 2-23 files are unchanged from their original format as they are ASCII, and accepted by PDS4 as is.

5.2.1. Maneuver Vector File (SFH)

The LICIACube SFH files describe the desaturation thrusts undertaken by LICIACube after its deployment from the DART spacecraft. The files include vml text describing the content of the SFH file (Table 8), and values (Table 9). The following describe what is captured in the files. The coordinates of the thursters are indicated in NAIF frame FK file for the LICIACube spacecraft.

Table 8. SFH Header data

Keyword	Example	Definition
projectName	LICIACube	Name of mission.
version	1	Version of SFH file
spacecraftNumber	-210	NAIF ID of the LICIACube spacecraft
preparer	argotec	Preparer of the SFH file
creationDate	2022-10-03T08:12:38.413431	Creation date of SFH file. UTC

comment	Impulsive maneuver reconstructed from telemetry	Comment describing the SFH file
maneuverName	DES3	Name of maneuver. This is the 3rd maneuver after LICIACube's deployment from DART
spkFileName	ubo/LCC220927-NOB-UBO003-DEN181-220911-230401-220923-V1.bsp	Relevant NAIF SPICE ephemeris (SPK) file for LICIACube

Table 9. SFH Table data

Keyword	Example	Definition
frame	EME2000	Describes frame in which the impulsive thrust is provided.
ra units	3.485634739508648E+02	Direction of thrust in RA direction in degrees.
dec units	4.596166056701566E+01	Direction of thrust in DEC direction in degrees.
magnitude units	1.179028361733385E-02	Magnitude of impulsive thrust in m/s
startTime sys	2022-10-03T02:09:11.176845	Start time of impulsive maneuver in Ephmeris time (ET)
deltaMass	-7.258676750421245E-04	Estimate mass of fuel spent as a result of maneuver in kg.

6. Applicable Software

6.1. Utility Programs

At the current time the DART project has no plans to release any mission specific utility programs.

6.2. Applicable PDS Software Tools

Data products found in the DART archive can be viewed with any PDS4 compatible software utility.

6.3. Software Distribution and Update Procedures

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

7. Appendices

7.1. List of Acronyms and Abbreviations

Acronym or Abbreviation	Definition
ASCII	American Standard Code for Information Interchange
ASI	Italian Space Agency
CODMAC	Committee on Data Management and Computation
DART	Double Asteroid Redirection Test
DMAP	Data Management and Archive Plan
DSN	Deep Space Network
ET	Ephemeris Time
LICIA	Light Italian CubeSat for Imaging of Asteroids
MCC	Argotec Mission Control Center
MOC	Mission Operations Center
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
PDS	Planetary Data System
SBN	Small Bodies Node
SFH	Maneuver Vector File. Acronym is from LICIACube: Small Forces History
SIS	Software Interface Specification
TXT	ASCII text file
UBO	University of Bologna
UTC	Coordinated Universal Time
XML	Extensible Markup Language

7.2. Definitions of Data Processing Levels

Table 4 shows the comparison of DART, NASA and CODMAC data processing levels.

Table 4. Definition of data processing levels for science data (RS, PDS4, NASA & CODMAC)

RS	PDS4	NASA	CODMAC	Description
	Packet Data	Packet Data	Raw Level 1	Telemetry data stream as received at the ground station, with science and engineering data embedded.
TRK 2-34	Raw Data	Level 0	Edited Level 2	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed. Prior to PDS4, referred to as Experiment Data Records (EDRs).
	Partially Processed Data	Level 1A	Calibrated Level 3	NASA Level 0 data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied). Prior to PDS4, referred to as Calibrated Data Records (CDRs) and in some cases Derived Data Products (DDPs).
	Calibrated Data	Level 1B	Resampled Level 4	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength). Prior to PDS4, referred to as either Derived Data Products (DDPs) or Derived Analysis Products (DAPs).
	Derived Data	Level 2	Derived Level 5	Geophysical parameters, generally derived from NASA Level 1 (CODMAC level 3 and 4) data, and located in space and time commensurate with instrument location, pointing, and sampling. Prior to PDS4, referred to as Derived Analysis Products (DAPs).
		Level 3	Derived Level 5	Geophysical parameters mapped onto uniform space-time grids. Prior to PDS4, referred as derived analysis products (DAPs).

TRK 2-23 and TRK 2-24 Calibration Files		Level 4	Ancillary Data Level 6	Non-science data needed to generate calibrated or resampled data sets and consisting of instrument gains, and offsets, spacecraft positions, target information, pointing information for scan platforms, etc.