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Department of the Interior
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LANDSAT DATA CONTINUITY MISSION (LDCM) LEVEL 0 REFORMATTED (L0R) DATA FORMAT CONTROL BOOK (DFCB)

Version 9.0

October 2012

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October 2012

EROS
Sioux Falls, South Dakota

Executive Summary

This Data Format Control Book (DFCB) provides a detailed description of the Data Processing and Archive System (DPAS) generated Landsat Data Continuity Mission (LDCM) Level 0 Reformatted archive (L0Ra) files.

This document is under U.S. Geological Survey (USGS) Development Configuration Control Board (DCCB) control. Please submit changes to this document, as well as supportive materials justifying the proposed changes, via Configuration Change Request (CCR) to the DCCB.

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Section 1 Introduction

1.1 Purpose and Scope

This Data Format Control Book (DFCB) provides a detailed description of the Data Processing and Archive System (DPAS) generated Landsat Data Continuity Mission (LDCM) Level 0 Reformatted Product (L0Rp) files.

This DFCB describes the format and data content of the Level 0 Reformatted Archive (L0Ra) and L0Rp files for all LDCM collection types. Other data products with similar formats include the Level 1 Radiometric (Corrected) (L1R) format. These three formats do not have Sensor Chip Assembly (SCA) or band alignment performed. The Level 1 Systematic (Corrected) (L1G) and Level 1 Terrain (Corrected) (L1T) products, which include alignments, are quite different and are described in a separate document.

1.2 Document Organization

This document contains the following sections:

- Section 1 contains an introduction to this document.
- Section 2 describes L0Ra data and provides information in the following subsections:
    - Data Format Overview – describes the general contents of the files and how the data are logically arranged.
    - L0Ra File Naming Convention – defines the naming convention of the L0Ra files.
    - L0Ra Data Format Definition – describes each file in detail.
    - Example Files – supplied for reference purposes.
- Section 3 describes mission data and provides L0Ra data notes.
- Section 4 describes L0Rp processing and the L0Rp product.
- Appendix A contains the glossary, which defines technical terms and algorithms used in this document.
- The References section provides a list of reference documents.

1.3 Assumptions

- Data received from the Ground Network Element (GNE) contain only complete intervals.
- Data received from GNE contain only one collection type per interval.
- It is possible to receive intervals that contain only ancillary data, but it is not an intentional acquisition (e.g., there is no 'Ancillary only' COLLECTION_TYPE).

1.4 Caveats

- Ancillary data definition and content is in-work. Changes occur as these definitions are finalized.
- The SCAs for OLI are referenced as 1–14, and for TIRS as A, B, C. It is desired to reference them in the same context (e.g., numerically and by position, where

TIRS SCA A, B, and C map to 1, 3, and 2). TIRS Header Read-Out Integrated Circuit (ROIC) and Telemetry parameters (sca_) referring to TIRS SCAs should be renamed. However, because the final ancillary data formats are not currently defined, the parameters retain the mission format conventions for now.

- Subsection 2.1 contains overview information about the relationship between the detectors on the spacecraft sensors and the corresponding L0Ra pixel locations. While this information is not typically included in a DFCB, it is provided as introductory information at least until all of the spacecraft data formats are finalized. At that time, this section may be moved to Section 3 or removed.
- The l0r_time_seconds_of_day parameter (added by DPAS) is defined as "Seconds of the current day with a microsecond resolution". Some values received in the ancillary data are of a higher resolution that may not be able to be stored accurately. The original time value is preserved if the possible loss of precision is an issue.

Section 2 L0Ra Data

The L0Ra data are Operational Land Imager (OLI), Thermal Infrared Scanner (TIRS) sensor data, and spacecraft ancillary data that are reformatted for easier processing. Minor corrections to the ancillary data are performed (such as frame number and time code corrections), and ancillary raw data units are converted to engineering units. Image data are left in counts or Digital Numbers (DN). Image data are stored in separate band files for file manageability. Ancillary data are stored in a separate file to avoid repeating the information in each of the band files. Metadata are stored in a separate file.

Twenty-one files constitute the nominal L0Ra data. Eighteen band files, an ancillary data file, and a metadata file are stored in the Hierarchical Data Format, v5 (HDF5) format. In addition to the 20 HDF5 files, each L0Ra dataset contains a checksum file in text format. Table 2-1 summarizes the L0Ra files. The band numbers for each band are presented along with a color chart to identify the band within several figures in this document. Additionally, the format definition and the band type are given for each file. The band formats include Multispectral (MS), Panchromatic (PAN), and Blind. Bands 1, 2, 3, 4, 5, and 8 are referred to as the Visible and Near Infrared (VNIR) bands, and bands 6, 7, and 9 are referred to as the Short Wavelength Infrared (SWIR) bands. Bands 10, 11, 16, and 17 are referred to as the Thermal Infrared (TIR) bands.

L0Ra File	Band	Color	Format	Type
OLI Coastal/Aerosol	1	(cyan)	MS	VNIR
OLI Blue	2	(blue)	MS	VNIR
OLI Green	3	(green)	MS	VNIR
OLI Red	4	(red)	MS	VNIR
OLI NIR (Near Infrared)	5	(dark red)	MS	VNIR
OLI SWIR1 (Short Wavelength Infrared)	6	(light orange)	MS	SWIR
OLI SWIR2 (Short Wavelength Infrared)	7	(orange)	MS	SWIR
OLI Panchromatic	8	(gray)	PAN	VNIR
OLI Cirrus	9	(purple)	MS	SWIR
TIRS 10.8 µm	10	(light green)	MS	TIR
TIRS 12.0 µm	11	(dark red)	MS	TIR
OLI Blind SWIR1	12	(black)	Blind	OLI
OLI Blind SWIR2	13	(black)	Blind	OLI
OLI Blind Cirrus	14	(black)	Blind	OLI
TIRS Blind	15	(black)	Blind	TIR
TIRS 10.8 µm Secondary	16	(light green)	MS	TIR
TIRS 12.0 µm Secondary	17	(dark red)	MS	TIR
TIRS Blind Secondary	18	(black)	Blind	TIR
Ancillary Data File (OLI, TIRS, and spacecraft)	n/a	n/a	Ancillary	n/a
Metadata File	n/a	n/a	Metadata	n/a
Checksum File	n/a	n/a	n/a	n/a

Table 2-1. L0Ra File Types

The OLI blind bands are composed of masked detectors in the three SWIR bands (Cirrus, SWIR1, and SWIR2). The OLI blind data are downlinked in a single band from the instrument and separated into three band files (by detector type) in the L0Ra data. The OLI instrument has a redundant pixel capability in that the instrument focal plane contains multiple rows of detectors per band line. The detectors used in operation are defined by a selection table, which is referenced in the Image Header.

TIRS data has a redundant pixel capability in that there are two separate rows of detectors on the instrument (primary and secondary), per detector type (10.8 µm, 12 µm, and blind). The secondary bands are saved in separate band files and give TIRS a full redundant pixel capability. If redundant pixel replacement is performed the frame CRC values cannot be recalculated without first reversing the operation.

LDCM data intervals are received in their entirety (e.g., it is not possible to receive only specific data bands from either instrument). However, it is possible to receive intervals that contain only OLI data (bands 1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, and 14) or only TIRS data (bands 10, 11, 15, 16, 17, and 18). The nominal LDCM Level 1 product contains the primary OLI and TIRS bands (1–11).

2.1 Data Format Overview

2.1.1 Image Files (From Instrument Detectors to Image Pixels)

Throughout this document, the term detector refers to a single physical sensing element that produces an electrical output in response to incident electromagnetic radiation, whereas pixel, short for "picture element," refers to the smallest discrete piece of image data in an image and corresponds to a single spatial sample. Both the OLI and the TIRS are push-broom instruments, which means that the spectral response from each unique detector corresponds to an individual column of pixels within the Level 0 dataset.

The OLI has fourteen SCAs with nine rows of active detectors and one row of masked detectors (referred to as blind detectors). The TIRS has three SCAs with four rows of active detectors and two rows of blind detectors. Figure 2-1 and Figure 2-2 depict the arrangement of SCAs on the instrument focal planes.

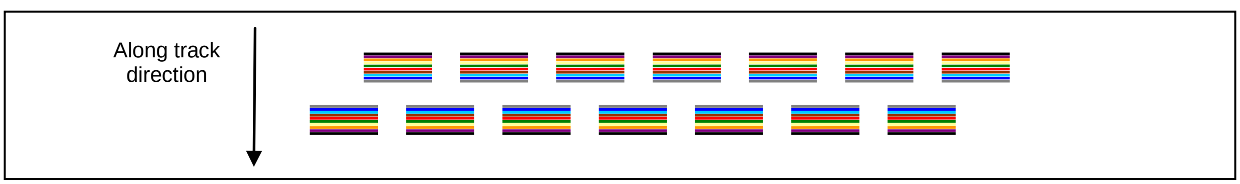

Figure 2-1. OLI Arrangement of SCAs

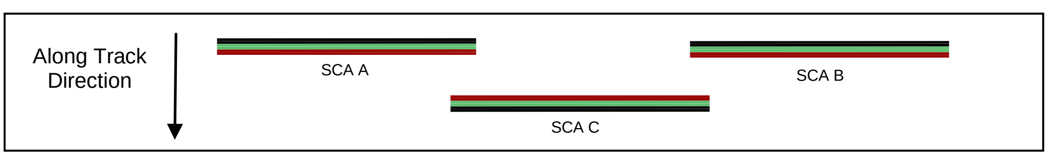

Figure 2-2. TIRS Arrangement of SCAs

The band designators and arrangement for even-numbered and odd-numbered SCAs are shown in Figure 2-3 for the OLI and in Figure 2-4 for the TIRS. Even-numbered SCAs are the same as the odd-numbered SCAs, only rotated 180 degrees with respect to the even-numbered detectors. The band order is consistent as the SCAs are read, but the detector readout order for even-numbered SCAs is reversed in the L0Ra image output to account for their 'flipped' orientation on the focal plane. The image data are written to 18 separate files, 1 band per file. Each file contains the imagery collected by all SCAs on the instrument that generates the band.

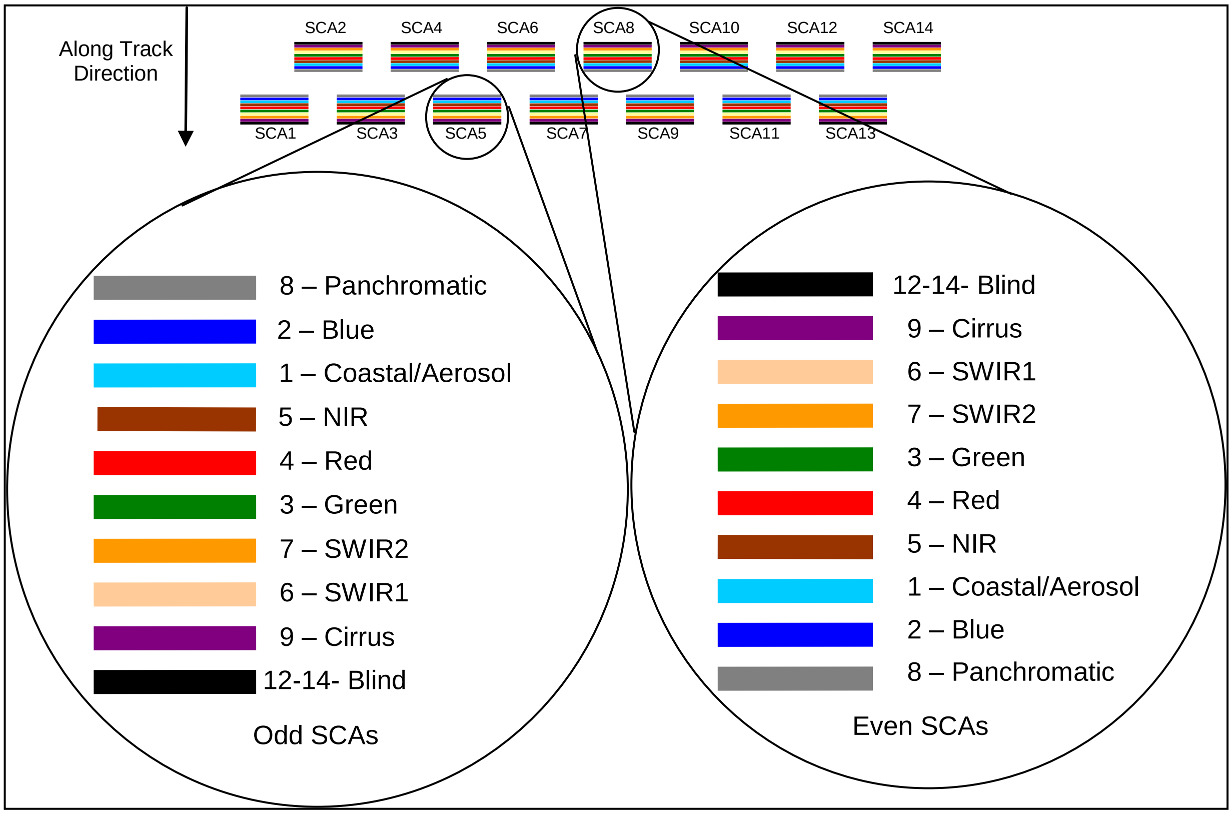

Figure 2-3. OLI Band Arrangement (Odd SCAs, Even SCAs)

For every OLI multispectral band, each of the 14 SCAs contains 494 detectors in the cross-track direction, which produces an image with a width of 494 pixels for each SCA. For the OLI Panchromatic band (band 8), each SCA contains 988 detectors which produces an image with a width of 988 pixels for each SCA. Also collected and saved with the imagery are 12 Video Reference Pixels (VRPs) in each multispectral band (6 on either side of the imaging detectors), 24 VRPs for the Panchromatic band (12 on either side), and 195 VRPs for the blind band (intermixed as shown in Figure 2-13). VRPs are created from detector locations where a capacitor exists instead of a detector. These VRPs are stored in the corresponding band files, but separately from the imaging pixels for easier L1R processing.

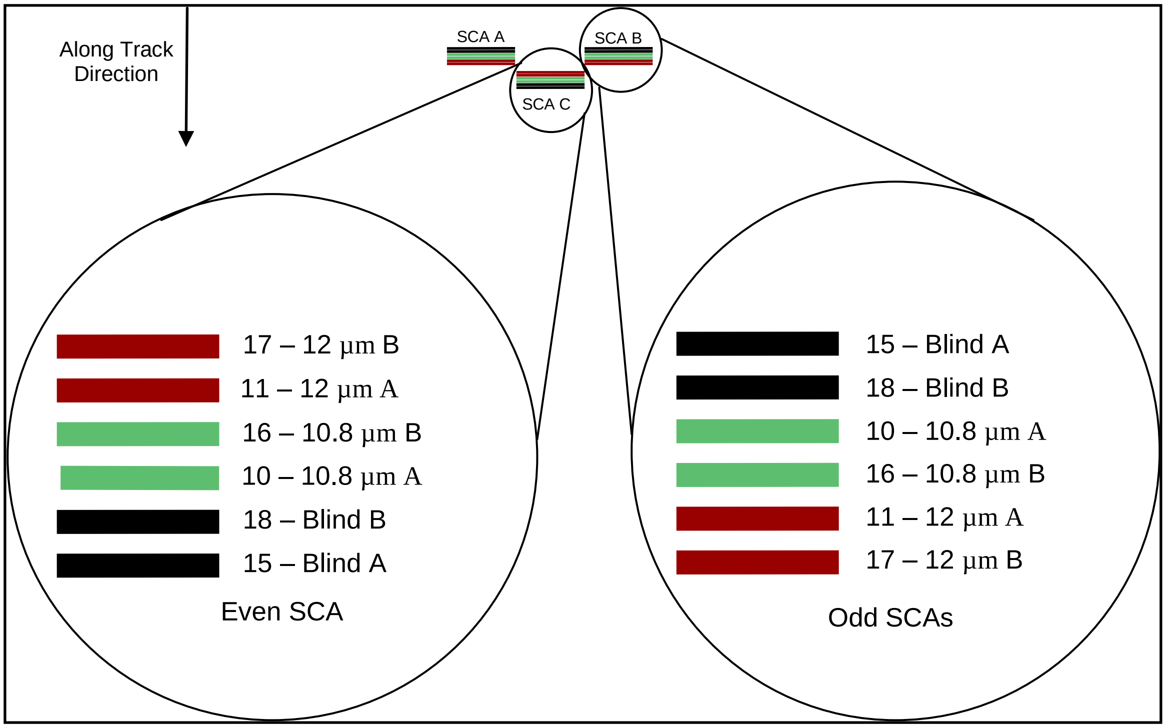

Figure 2-4. TIRS Band Arrangement

For every band TIRS generated, each of the 3 SCAs contains 640 detectors. The TIRS SCAs do not have any VRPs or size difference between the multispectral and blind bands.

Parameter	OLI-PAN	OLI-MS	OLI-Blind	TIRS
Number of SCAs	14	14	14	3
Number of Detectors across the SCA	1012	506	506	640
Imaging Detectors	988	494	311	640
VRPs	24	12	195	0
Detectors per Frame per Band	14168	7084	7084	1920

Table 2-2. SCA Characteristics

The SCA detector to L0Ra pixel relationship is described in the following subsections. The format of the stored L0Ra image files is described in subsection 2.3.

2.1.1.1 SCA Overlap

The SCA arrangement on the OLI focal plane creates an overlapping coverage of approximately 20 detectors (i.e., pixels) between each adjacent odd-even pair of SCAs for the multispectral bands and approximately 50 detectors for the Panchromatic band. The SCA arrangement on the TIRS focal plane creates an overlapping coverage of 35 detectors between adjacent SCAs. This overlap is not removed from the L0Ra images. See Figure 2-5 for the SCA alignment arrangement.

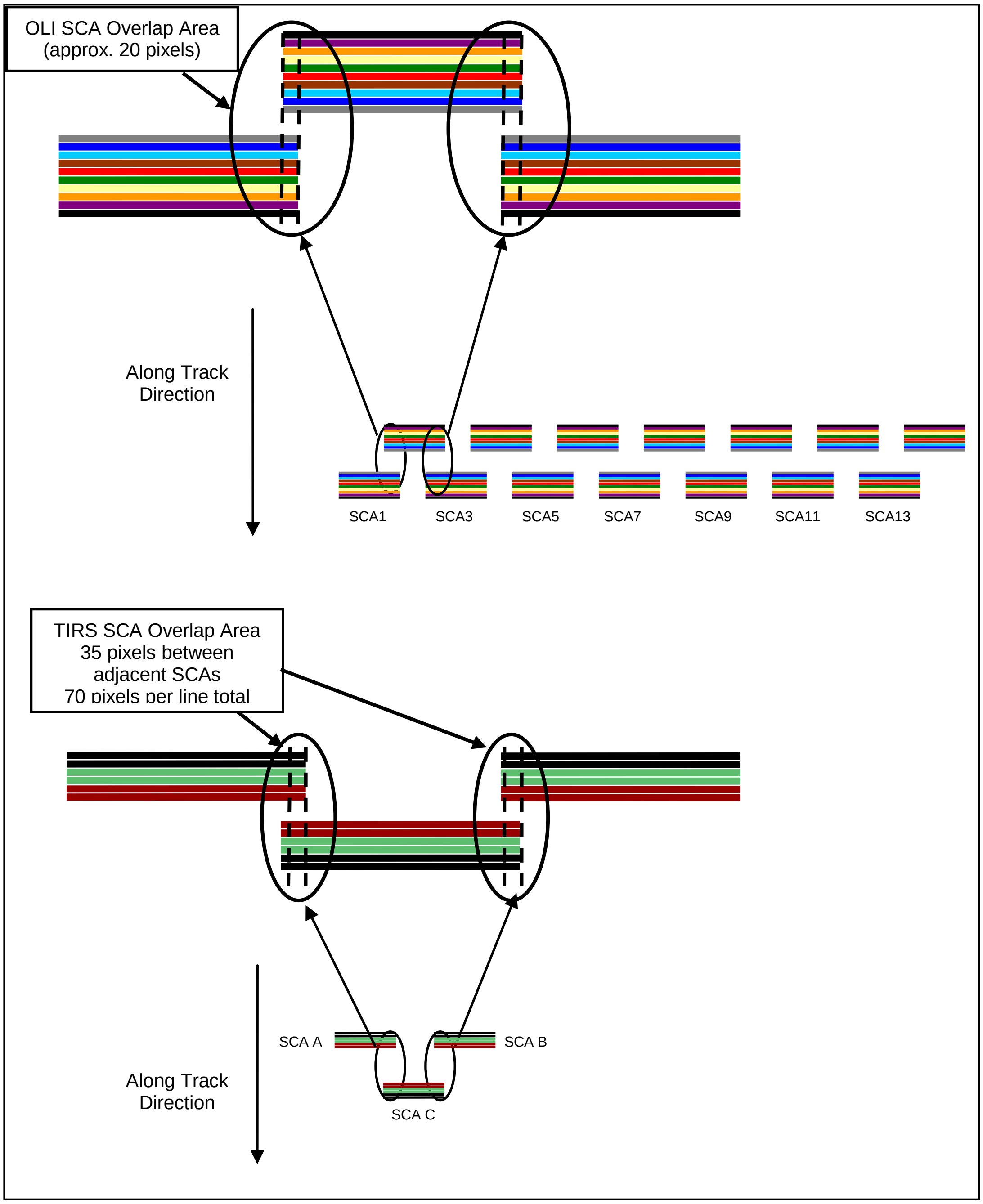

Figure 2-5. SCA Detector Overlap

2.1.1.2 Detector to L0Ra Pixel (ground) Overview

Refer to Figure 2-6 for an OLI example detector to pixel mapping. The detector readout order for the even-numbered SCAs is reversed in the L0Ra image output to account for their 'flipped' orientation on the focal plane, and that the VRP pixels are stripped from the image bands.

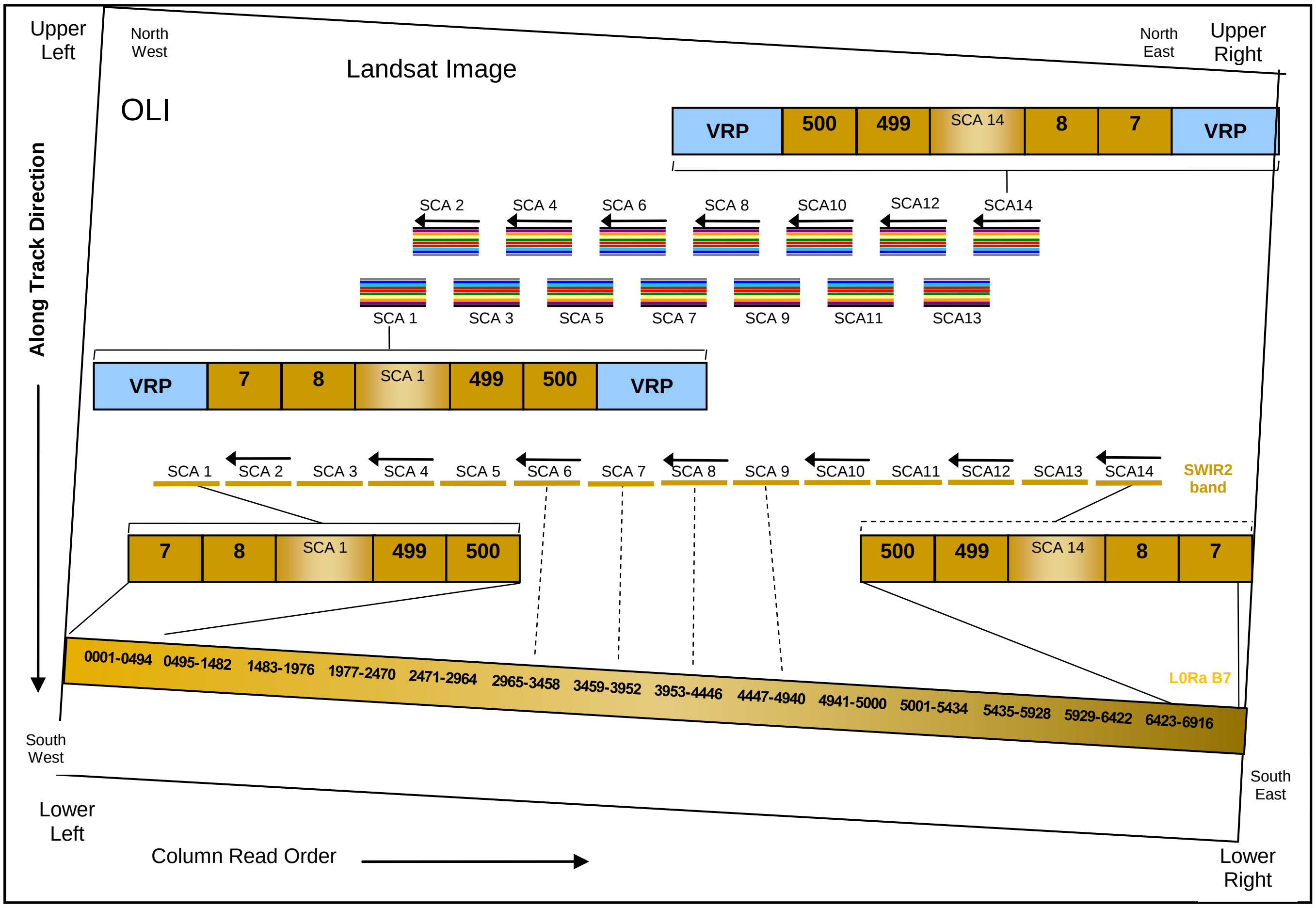

Figure 2-6. OLI Detector to L0Ra Pixel Ordering

Figure 2-6 also illustrates the L0Ra image boundaries. For the OLI, each multispectral band contains 6916 pixels per line and each Panchromatic band contains 13832 pixels.

In the TIRS mission data, the SCAs are read out in "letter" order, i.e., SCA-A, then SCA-B, then SCA-C. In Level 0 processing, the SCAs are reordered into numerical order SCA-A(1), SCA-C(2), SCA-B(3). Furthermore, the Level 0 detector orders for the individual SCAs are SCA01/B forward (1 to 640), SCA02/C reverse (640 to 1) and SCA03/A forward (1 to 640). Level 0 processing flips SCA-C (2) detector order in order to make the image data contiguous across-track. However, the TIRS telescope causes a mirror effect on the imagery and the data is "reversed" east-to-west (descending) rather than west-to-east. Thus, the TIRS detector mapping is a mirror of the OLI detector mapping as shown in Figure 2-7Figure 2-7. SCA-A(1) is on the east and SCA-B(3) is on the west. Note: This reversal is corrected during Level 1 processing, where all pixels will be placed at the correct locations in the output image.

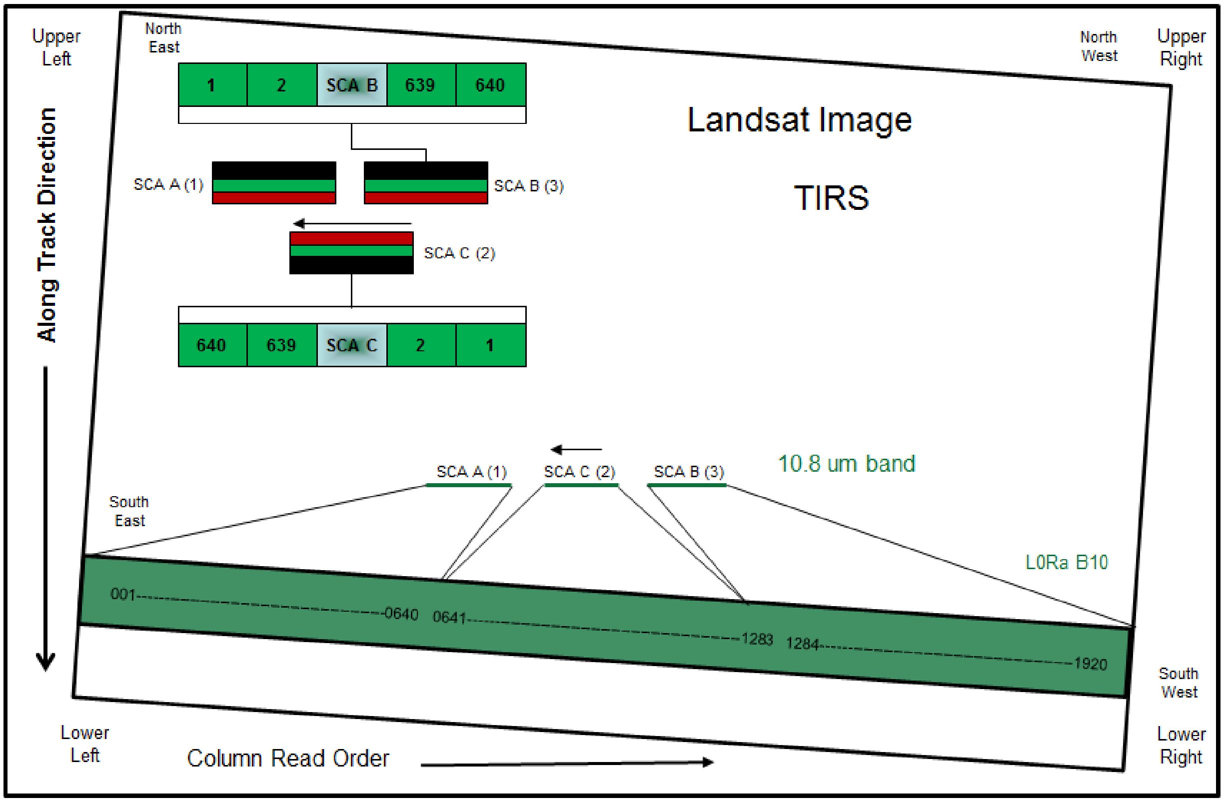

Figure 2-7. TIRS Detector to L0Ra Pixel Ordering

The following subsections (2.1.1.3 through 2.1.1.7) show the detector to pixel mappings for the OLI and TIRS multispectral bands and OLI VRPs, the OLI PAN band and OLI VRPs, and the OLI blind bands.

2.1.1.3 MS Band Detector Mapping

Figure 2-8 depicts the OLI detector numbering to L0Ra pixel mapping for one MS band on one odd and one even SCA. Figure 2-9 depicts the TIRS detector numbering to L0Ra pixel mapping for one odd SCA and the even SCA. The numbering of pixels and detectors is per SCA.

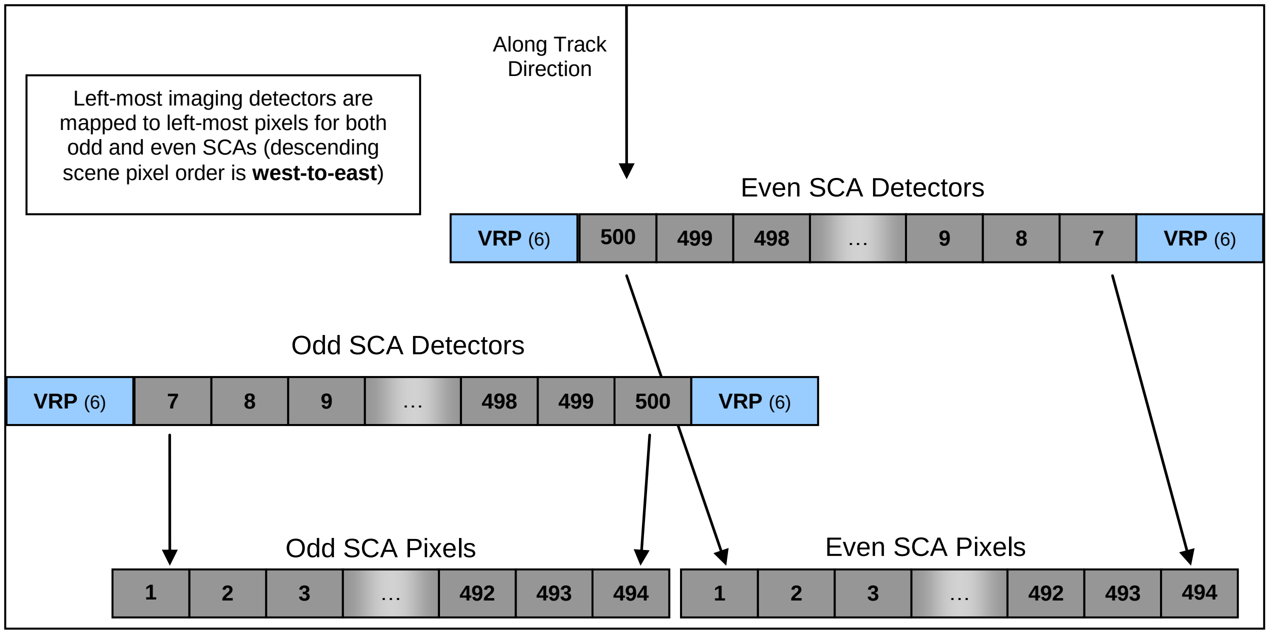

Figure 2-8. OLI Detector to L0Ra Pixel Mapping (MS Bands)

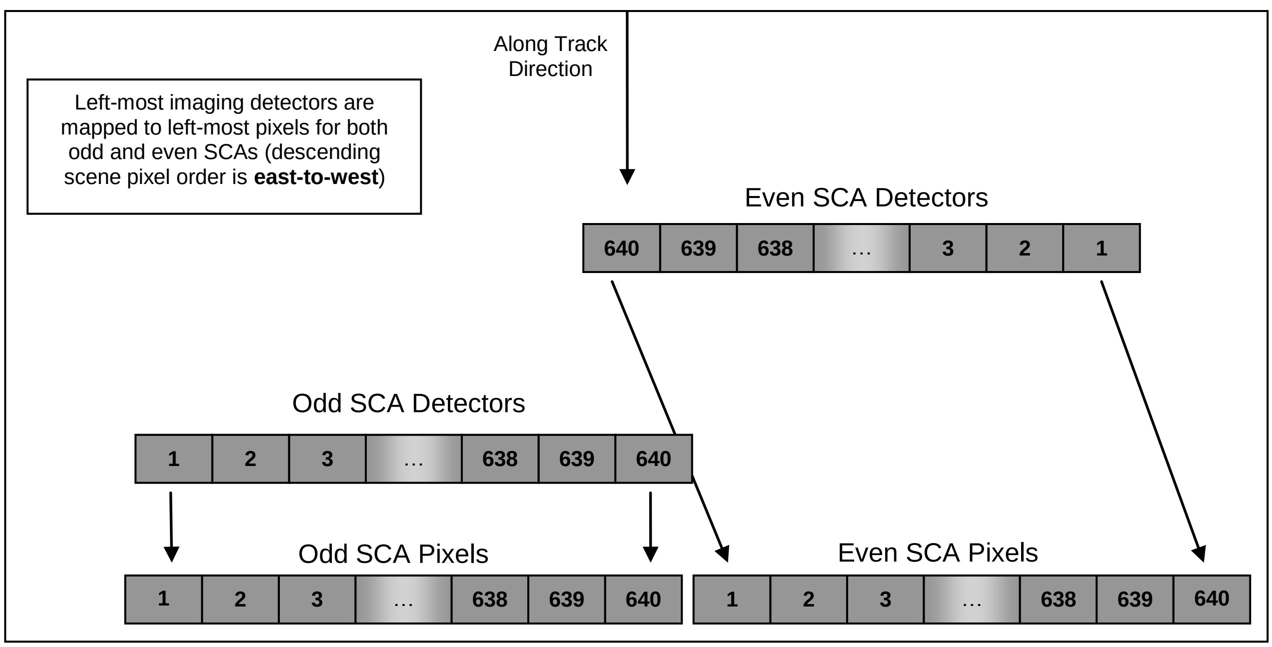

Figure 2-9. TIRS Detector to L0Ra Pixel Mapping

2.1.1.4 MS Bands VRP Mapping

Figure 2-10 depicts the OLI detector numbering to L0Ra pixel mapping for the VRP for one MS band on one odd and one even SCA.

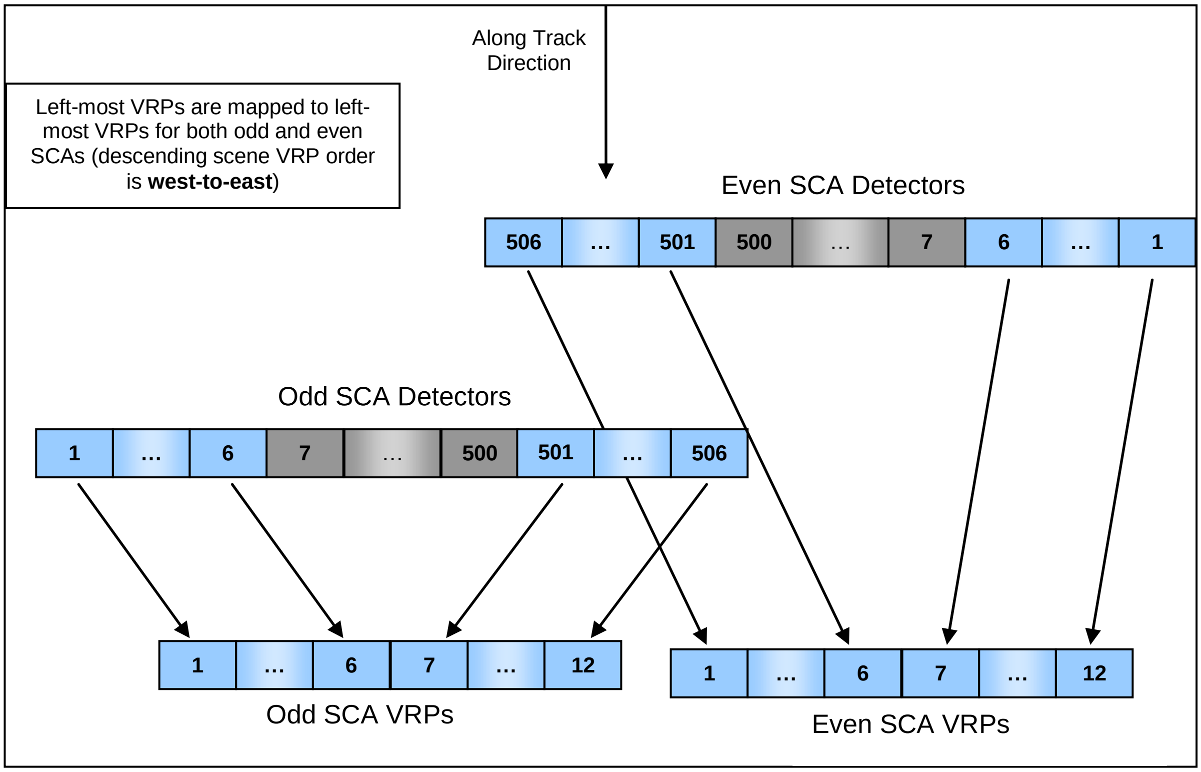

Figure 2-10. OLI VRPs to L0Ra VRPs Mapping (MS Bands)

2.1.1.5 Panchromatic Band Detector Mapping

Figure 2-11 depicts the OLI detector numbering to L0Ra pixel mapping for the Panchromatic band detectors for one odd and one even SCA.

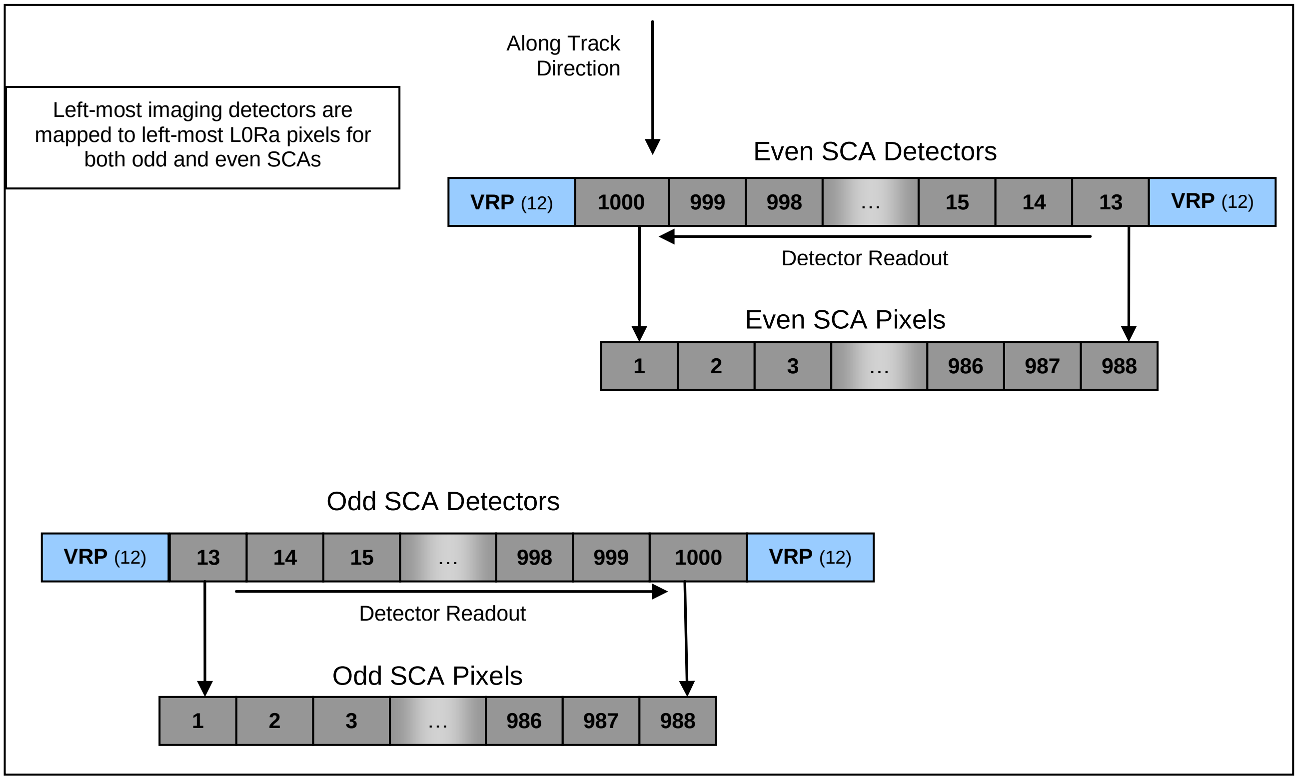

Figure 2-11. OLI Detector to L0Ra Pixel Mapping (PAN Band)

2.1.1.6 Panchromatic Band VRP Mapping

The Panchromatic band has a similar mapping for its detectors with twice as many detectors and twice as many VRPs. See Figure 2-12 for the mapping of Panchromatic VRPs to L0Ra pixels.

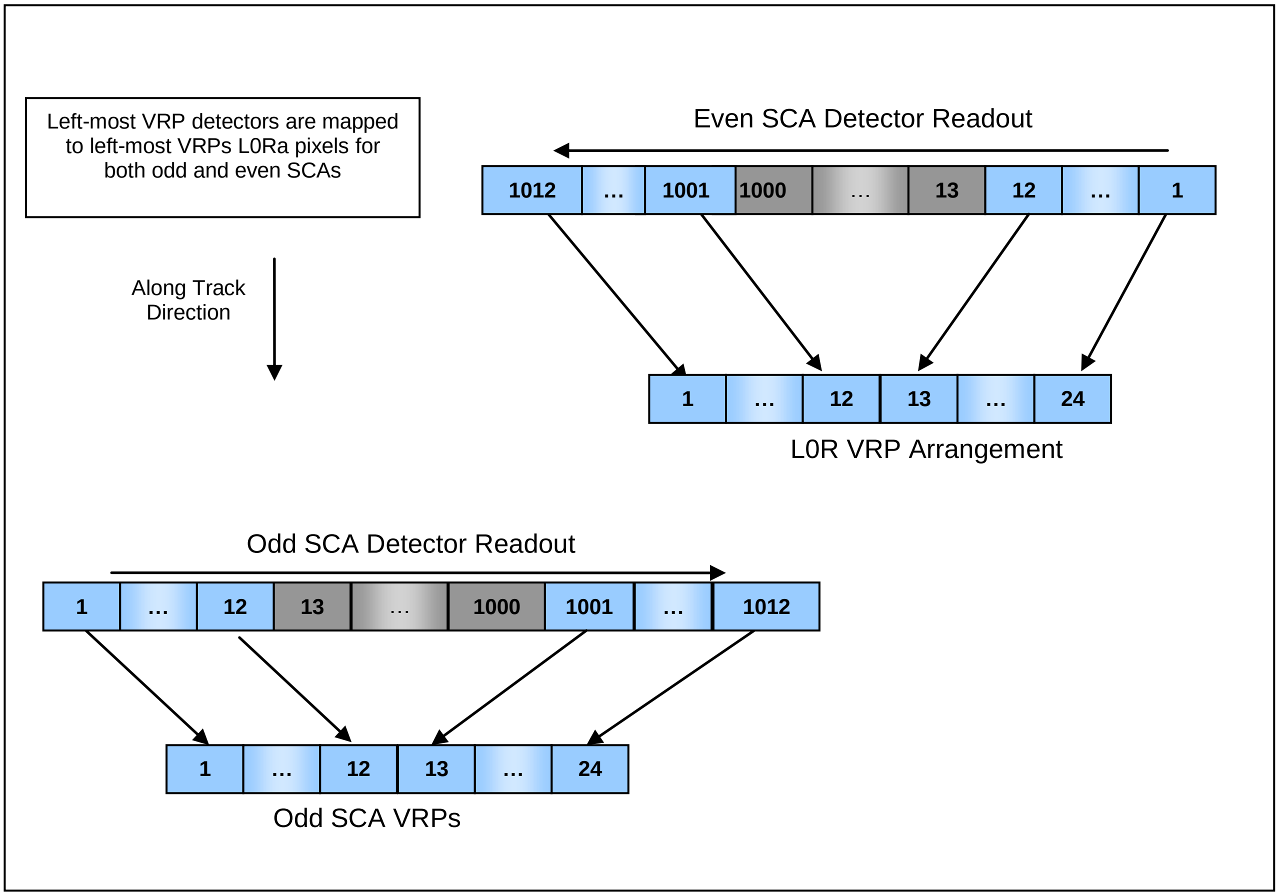

Figure 2-12. VRPs to L0Ra VRPs Mapping (PAN Band)

2.1.1.7 Blind Bands

The OLI and TIRS blind bands consist of pixels created from masked detectors.

The OLI blind band is the same width (506 detectors) as the MS bands on each SCA, but consists of 13 sets of SWIR2 / SWIR1 / Cirrus detector groups containing 5 VRPs and 8 detectors in each band per group. With a total of 39 detectors per group (15 VRPs and 24 image), the total number of detectors is 507; however, the last Cirrus set has only 7 detectors instead of 8, which makes the total detector count match the 506 width of the other bands. DPAS processing separates the OLI blind band into three L0Ra bands (SWIR2, SWIR1, and Cirrus), each with its associated VRPs.

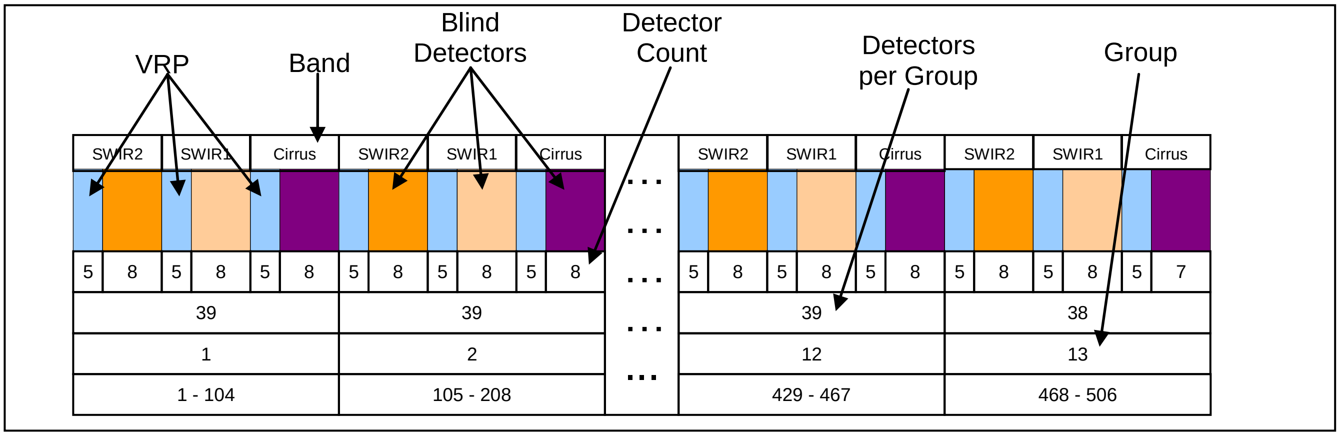

Figure 2-13. Blind Band Detector Arrangement

Figure 2-14 depicts the mapping of the OLI blind band detectors to the L0Ra pixels. Like the other bands, the pixel order is reversed for the even SCAs in the blind bands.

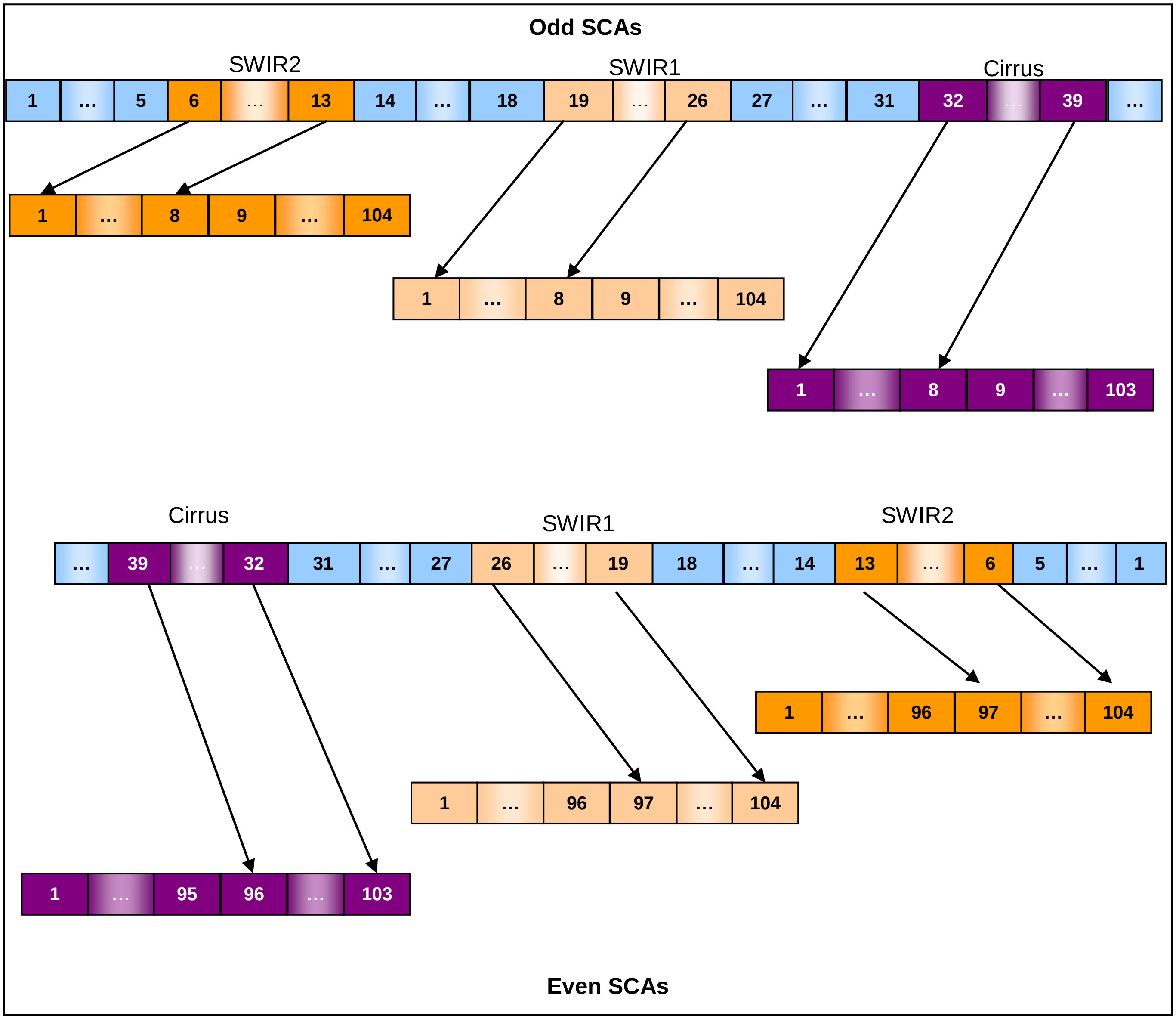

Figure 2-14. OLI Blind Band Detector to L0Ra Pixel Mapping

The VRPs are stored in the associated blind band L0Ra file along with the blind detector data. Figure 2-15 shows the mapping of the VRPs to the L0Ra data.

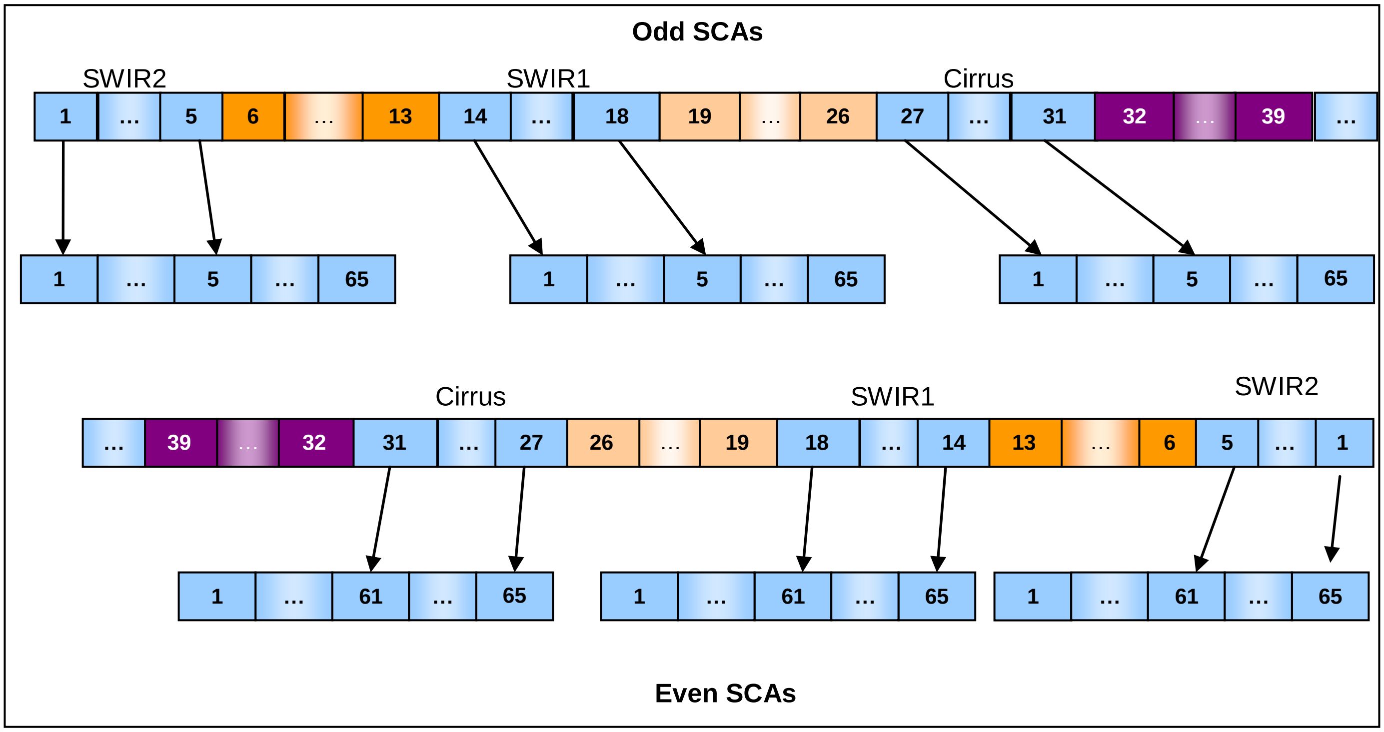

Figure 2-15. OLI Blind Band OLI VRP to L0Ra Mapping

The TIRS blind bands are identical in size and format to other TIRS bands. Table 2-3 shows the L0Ra image band names, numbers, and widths in pixels.

L0Ra File	Band	Color	Pixels	VRPs	Total
OLI Coastal/Aerosol	1		6916	168	7084
OLI Blue	2		6916	168	7084
OLI Green	3		6916	168	7084
OLI Red	4		6916	168	7084
OLI NIR (Near Infrared)	5		6916	168	7084
OLI SWIR1 (Short Wavelength Infrared)	6		6916	168	7084
OLI SWIR2 (Short Wavelength Infrared)	7		6916	168	7084
OLI Panchromatic	8		13832	336	14168
OLI Cirrus	9		6916	168	7084
TIRS 10.8 µm	10		1920	0	1920
TIRS 12.0 µm	11		1920	0	1920
OLI Blind SWIR1	12		1456	910	2366
OLI Blind SWIR2	13		1456	910	2366
OLI Blind Cirrus	14		1442	910	2352
TIRS Blind	15		1920	0	1920
TIRS 10.8 µm Secondary	16		1920	0	1920
TIRS 12.0 µm Secondary	17		1920	0	1920
TIRS Blind Secondary	18		1920	0	1920

Table 2-3. L0Ra Earth Imaging Collection – Band Widths

2.1.1.8 Missing Frame Fill

For OLI and TIRS, missing frames of mission data are detected using the time stamp information in the Frame Headers and filled. Missing image frames are zero-filled to uniquely identify the fill data in the L0Ra image. For the Panchromatic band, two consecutive lines are filled to complete the frame. This is completed because PAN frames contain two lines, due to twice the resolution.

The selected OLI detectors are sampled simultaneously and the pixels are read out from the OLI as depicted in Figure 2-16. In this example, a dropped frame exists at sample time t8.

1	2	3	4	5	6	…	…	…	…	489	490	491	492	493	494
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
t0	t0	t0	t0	t0	t0	t0	t0	t0	t0	t0	t0	t0	t0	t0	t0
t1	t1	t1	t1	t1	t1	t1	t1	t1	t1	t1	t1	t1	t1	t1	t1
t2	t2	t2	t2	t2	t2	t2	t2	t2	t2	t2	t2	t2	t2	t2	t2
t3	t3	t3	t3	t3	t3	t3	t3	t3	t3	t3	t3	t3	t3	t3	t3
t4	t4	t4	t4	t4	t4	t4	t4	t4	t4	t4	t4	t4	t4	t4	t4
t5	t5	t5	t5	t5	t5	t5	t5	t5	t5	t5	t5	t5	t5	t5	t5
t6	t6	t6	t6	t6	t6	t6	t6	t6	t6	t6	t6	t6	t6	t6	t6
t7	t7	t7	t7	t7	t7	t7	t7	t7	t7	t7	t7	t7	t7	t7	t7
t9	t9	t9	t9	t9	t9	t9	t9	t9	t9	t9	t9	t9	t9	t9	t9
t10	t10	t10	t10	t10	t10	t10	t10	t10	t10	t10	t10	t10	t10	t10	t10
tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3	tN-3
tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2	tN-2
tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1	tN-1
tN	tN	tN	tN	tN	tN	tN	tN	tN	tN	tN	tN	tN	tN	tN	tN

Figure 2-16. OLI L0Ra Pixel Readout

2.1.2 Ancillary Data File

An ancillary data file is created for every interval collection. It contains OLI, TIRS, and spacecraft data needed to identify and process the band data. Subsection 2.3.2 describes the content in more detail.

2.1.3 Checksum File

A checksum file is created for every collection. It contains a Message-Digital Algorithm 5 (MD5) checksum for each file in the L0Ra output, excluding the checksum file itself. Subsection 2.3.3 describes the checksum file in more detail.

2.1.4 Metadata File

A metadata file is created for every interval collection. It contains information about the L0Ra files, the interval, and the scenes contained within the interval. Scene metadata are only provided for Earth Imaging intervals. Subsection 2.3.4 describes the metadata file content in more detail.

2.2 L0Ra File Naming Convention

Like previous Landsat missions, LDCM uses Landsat-unique interval and scene file naming conventions. Unlike previous Landsat missions, LDCM collects many calibration datasets; therefore, a new Landsat convention was created. All collections are named using one of two naming conventions, as outlined in the following subsections. Path and Row values in Landsat interval and scene file names are orbital (nadir-pointing) values.

2.2.1 Image Collections

The Landsat_Interval_ID naming convention for Earth Imaging LDCM collections is VINpppRRRrrrYYYYdddGSIvv. The names of the L0Ra files are based on that standard. Table 2-4 describes the components of the filename format. The grayed parameters highlight changes for calibration collection filenames as described in subsection 2.2.2.

Parameter Description	Filename Position	Values
<Vehicle>	V	L = Landsat
<Instrument>	I	O = OLI, T = TIRS, C = Combined instruments
<Vehicle Number>	N	8 = Landsat 8
<WRS-2 Path>	ppp	001–233 (starting path)
<WRS-2 Start Row>	RRR	001–248
<WRS-2 End Row>	rrr	001–248
<Year>	YYYY	Four digit acquisition starting year
<Day>	ddd	Three digit acquisition starting day-of-year
<Ground Station>	GSI	Three character Ground Station Identifier
<version>	vv	Version (vv = 00–99)

File content and format indicators are appended to the Landsat_Interval_ID for file names.

<File Contents>	_Bn, _ANC, _MTA, or _MD5	_Bn for Band n _ANC for ancillary _MD5 for checksum _MTA for metadata
<File Extension>	.h5 or .txt	h5 suffix depicts the HDF5 format txt suffix depicts text format (checksum file)

*The file naming convention applicable to a band file for Earth Imaging collections is VINpppRRRrrrYYYYdddGSIvv_Bn.h5.

Table 2-4. L0Ra Earth Imaging Collection – File Naming Convention

2.2.1.1 Example L0Ra Image File Name(s)

The L0Ra files created for an LDCM Earth Imaging collection over path 222, rows 001–004 on day 265 of 2014 and received by the Landsat Ground Network (LGN) Ground Station are named as follows:

```
LC82220010042014265LGN00_B1.h5
LC82220010042014265LGN00_B2.h5
LC82220010042014265LGN00_B3.h5
LC82220010042014265LGN00_B4.h5
LC82220010042014265LGN00_B5.h5
LC82220010042014265LGN00_B6.h5
LC82220010042014265LGN00_B7.h5
LC82220010042014265LGN00_B8.h5
LC82220010042014265LGN00_B9.h5
LC82220010042014265LGN00_B10.h5
LC82220010042014265LGN00_B11.h5
LC82220010042014265LGN00_B12.h5
LC82220010042014265LGN00_B13.h5
LC82220010042014265LGN00_B14.h5
LC82220010042014265LGN00_B15.h5
LC82220010042014265LGN00_B16.h5
LC82220010042014265LGN00_B17.h5
LC82220010042014265LGN00_B18.h5
LC82220010042014265LGN00_ANC.h5
LC82220010042014265LGN00_MD5.txt
LC82220010042014265LGN00_MTA.h5
```

2.2.2 Calibration Collections

For calibration intervals, the path and row information (pppRRRrrr) is replaced with collection type and collection start time (00DHHMMSS) in Coordinated Universal Time (UTC). Table 2-5 describes these components. Side Slither collections are defined as calibration datasets, even though they contain Earth Imaging data.

Parameter Description	Filename Position	Values
<Vehicle>	V	L = Landsat
<Instrument>	I	O = OLI, T = TIRS, C = Combined instruments
<Vehicle Number>	N	8 = Landsat 8
<filler>	00	00
<Collection Type>	D	T = Stellar U = Lunar Y = Side Slither L = OLI Lamp O = OLI Solar S = OLI Shutter H = OLI Shutter Integration Time Sweep Z = OLI Solar Integration Time Sweep B = TIRS Blackbody D = TIRS Deep Space G = TIRS Integration Time Sweep E = OLI Test Patterns Q = TIRS Test Patterns

Parameter Description	Filename Position	Values
		Note: The following LDCM collection types are not processed into L0Ra: P = SSR PN Test Sequence
<Hour>	HH	00–23 (UTC)
<Minute>	MM	00–59 (UTC)
<Second>	SS	00–60 (allowing for leap second)
<Year>	YYYY	Four digit acquisition year
<Day>	ddd	Three digit acquisition day-of-year
<Ground Station>	GSI	Three character Ground Station Identifier
<version>	vv	Version (vv = 00–99)

File content and format indicators are appended to the interval ID for file names.

<File Contents>	_Bn, _ANC, _MTA, or _MD5	_Bn for Band n _ANC for ancillary _MD5 for checksum _MTA for metadata
<File Extension>	.h5 or .txt	h5 suffix depicts the HDF5 format txt suffix depicts text format (checksum file)

*The file naming convention for calibration collections is VIN00DHHMMSSYYYYdddGSIvv_Bn.h5.

Table 2-5. L0Ra Calibration Collection – File Naming Convention

2.2.2.1 Example L0Ra Calibration File Name(s)

The 21 L0Ra files created for an LDCM Lunar collection received at the LGN Ground Station on day 265 of 2014 at 12:34:56 UTC are named as follows:

```
LC800U1234562014265LGN00_B1.h5
LC800U1234562014265LGN00_B2.h5
LC800U1234562014265LGN00_B3.h5
LC800U1234562014265LGN00_B4.h5
LC800U1234562014265LGN00_B5.h5
LC800U1234562014265LGN00_B6.h5
LC800U1234562014265LGN00_B7.h5
LC800U1234562014265LGN00_B8.h5
LC800U1234562014265LGN00_B9.h5
LC800U1234562014265LGN00_B10.h5
LC800U1234562014265LGN00_B11.h5
LC800U1234562014265LGN00_B12.h5
LC800U1234562014265LGN00_B13.h5
LC800U1234562014265LGN00_B14.h5
LC800U1234562014265LGN00_B15.h5
LC800U1234562014265LGN00_B16.h5
LC800U1234562014265LGN00_B17.h5
LC800U1234562014265LGN00_B18.h5
LC800U1234562014265LGN00_ANC.h5
LC800U1234562014265LGN00_MD5.txt
LC800U1234562014265LGN00_MTA.h5
```

2.3 L0Ra Data Format Definition

2.3.1 L0Ra Band Image Files

There are 18 separate HDF5 formatted image files, one for each of the nine OLI bands, one for each of the two TIRS bands, one for each of the three bands corresponding to OLI blind detectors, one for the band corresponding to TIRS blind detectors, and three for the secondary TIRS bands (see Figure 2-3 and Figure 2-4). For OLI image bands, datasets contain image, VRP, and detector offset information. The OLI blind bands contain the image dataset and the dataset for VRPs, but there are no offsets associated with blind detectors or VRPs. The non-blind TIRS bands contain image data and detector offset information. The TIRS blind band only includes image information.

Band	**Band Format**	**L0Ra File Groups**		
1, 2, 3, 4, 5, 6, 7, 9	OLI Multispectral	Image	VRP	Detector Offsets
8	OLI Panchromatic	Image	VRP	Detector Offsets
10,11	TIRS Multispectral	Image	-----	Detector Offsets
12,13,14	OLI Blind	Image	VRP	---------------
15	TIRS Blind	Image	-----	---------------
16,17	TIRS Secondary	Image	-----	Detector Offsets
18	TIRS Blind Secondary	Image	-----	---------------

Table 2-6. L0Ra Image File Groups

The Image and VRP datasets are three-dimensional. The size of the first dimension is the number of SCAs; the size of the second dimension is the number of lines; the size of the third dimension is the number of detectors (or output pixels) per SCA. The data stored within these two three-dimensional datasets are the raw data values for each detector in the image band. The pixel values are 12-bit values and should, therefore, never exceed 4095, even though they are stored inside a 16-bit integer.

The Detector_Offsets dataset is also three-dimensional. This dataset determines the amount of alignment fill at the top and bottom of the band for each detector. Because Ingest does not perform alignment of the image data, these datasets contain all zeros. The size of the first dimension is the number of SCAs; the size of the second dimension is the top / bottom index, referring to the offset at the beginning and end of the image. The dataset contains two values for each detector in each SCA. A value of 0 in the first position indicates that the value corresponds to the offset at the beginning (top) of the interval. A value of 1 in the first position indicates that the value corresponds to the offset at the end (bottom) of the interval. The second position contains the offset. The size of the third dimension is the number of detectors (or output pixels) per SCA.

Figure 2-17 through Figure 2-20 describes the content of the HDF files. The format of the figures matches the output of the HDF utility h5dump. The output is structured into dataset blocks. The names associated with the structures are surrounded with quotation marks. The size of data content is displayed in a comma-separated list inside parentheses.

```
HDF5 "LC81012412462002324EDC00_B1.h5" {
GROUP "/" {
   ATTRIBUTE "L0R Format Version" {
      DATATYPE  H5T_STD_U32LE
      DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
   }

   DATASET "Detector_Offsets" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 2, 494 ) / ( 14, H5S_UNLIMITED, 494 ) }
   }
   DATASET "Image" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 33924, 494 ) / ( 14, H5S_UNLIMITED, 494 ) }
   }
   DATASET "VRP" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 33924, 12 ) / ( 14, H5S_UNLIMITED, 12 ) }
   }
}
}
```

Figure 2-17. MS Bands File Structure

```
HDF5 "LC81012412462002324EDC00_B11.h5" {
GROUP "/" {
   ATTRIBUTE "L0R Format Version" {
      DATATYPE  H5T_STD_U32LE
      DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
   }

   DATASET "Detector_Offsets" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 3, 2, 640 ) / ( 3, H5S_UNLIMITED, 640 ) }
   }
   DATASET "Image" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 3, 10289, 640 ) / ( 3, H5S_UNLIMITED, 640 ) }
   }
}
}
```

Figure 2-18. Thermal Bands File Structure

```
HDF5 "LC81012412462002324EDC00_B8.h5" {
GROUP "/" {
   ATTRIBUTE "L0R Format Version" {
      DATATYPE  H5T_STD_U32LE
      DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
   }
   DATASET "Detector_Offsets" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 2, 988 ) / ( 14, H5S_UNLIMITED, 988 ) }
   }
   DATASET "Image" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 67848, 988 ) / ( 14, H5S_UNLIMITED, 988 ) }
   }
   DATASET "VRP" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 67848, 24 ) / ( 14, H5S_UNLIMITED, 24 ) }
   }
}
}
```

Figure 2-19. PAN Band File Structure

```
HDF5 "LC81012412462002324EDC00_B12.h5" and
HDF5 "LC81012412462002324EDC00_B13.h5"
{
GROUP "/" {
   ATTRIBUTE "L0R Format Version" {
      DATATYPE  H5T_STD_U32LE
      DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
   }

   DATASET "Image" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 33924, 104 ) / ( 14, H5S_UNLIMITED, 104 ) }
   }
   DATASET "VRP" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 33924, 65 ) / ( 14, H5S_UNLIMITED, 65 ) }
   }
}
}
HDF5 "LC81012412462002324EDC00_B14.h5"
{
GROUP "/" {
   ATTRIBUTE "L0R Format Version" {
      DATATYPE  H5T_STD_U32LE
      DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
   }
   DATASET "Image" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 33924, 103 ) / ( 14, H5S_UNLIMITED, 103 ) }
   }
   DATASET "VRP" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 33924, 65 ) / ( 14, H5S_UNLIMITED, 65 ) }
```

```
   }
}
}
```

Figure 2-20. OLI Blind Bands File Structure

In Figure 2-20, the number of detectors is different for the Cirrus blind (B14) band for a cumulative total of 506 detectors ([104 + 65] + [104 + 65] + [103 + 65])) between the OLI blind bands. Also in Figure 2-20, the offsets do not exist, as they are not applicable to OLI blind detectors.

```
HDF5 "LC81012412462002324EDC00_B15.h5" {
GROUP "/" {
   ATTRIBUTE "L0R Format Version" {
      DATATYPE  H5T_STD_U32LE
      DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
   }
   DATASET "Image" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 3, 10289, 640 ) / ( 3, H5S_UNLIMITED, 640 ) }
   }
}
}
```

Figure 2-21. TIRS Blind Bands File Structure

2.3.1.1 Band Image / Data File Volume

The maximum expected interval for earth imagery is 77 full scenes, which equates to approximately 420,000 OLI video frames. Therefore, the maximum band data file volumes are as follows:

- MS Bands 1–7, and 9: 2 bytes/pixel * 7084 pixels/frame * 420,000 frames/file * 1/(1024*1024*1024) gigabyte/bytes = approximately 5.5 gigabytes/file
- PAN Band: 5.5 gigabytes * 4 (the PAN band is four times as large as an MS band) = approximately 22 gigabytes
- TIRS Bands 10–12, 16–18: 2 bytes/pixel * 1920 pixels/frame * 126,000 frames/file * 1/(1024*1024*1024) gigabyte/bytes = 0.45 gigabytes/file

The HDF library compresses the image files using gzip. A typical compression ratio is 1.54:1 (a 35 percent reduction in file size).

2.3.2 Ancillary Data File

An ancillary data file is created for every interval collection. It contains the OLI Image and Frame Header data, spacecraft ancillary data, OLI and TIRS TLM data, and TIRS Frame Header data. It is an HDF5 file with groups and datasets as described in the following subsections.

Group	Description
OLI	OLI Image and Frame Headers

TIRS	TIRS Frame Headers
Spacecraft	Spacecraft Ancillary Data
Telemetry	OLI and TIRS Telemetry Data

```
HDF5 "LC82220010042014265LGN00_ANC.h5"
{
      GROUP "/" {
         ATTRIBUTE "L0R Format Version" {
      DATATYPE  H5T_STD_U32LE
      DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
   }

         GROUP "OLI" {
            DATASET "Image_Header"
            DATASET "Frame_Headers"
         }
         GROUP "TIRS" {
            DATASET "Frame_Headers"
         }
         GROUP "Spacecraft" {
            GROUP "ACS" {
               DATASET "Attitude"
               DATASET "Attitude_Filter"
            }
            DATASET "Ephemeris"
            DATASET "GPS_Position"
            DATASET "GPS_Range"
            GROUP "IMU" {
               DATASET "Gyro"
               DATASET "Latency"
            }
            DATASET "Star_Tracker_Centroid"
            DATASET "Star_Tracker_Quaternion"
            GROUP "Temperatures" {
               DATASET "Gyro"
               DATASET "OLI_TIRS"
            }
         }
         GROUP "Telemetry" {
            GROUP "OLI" {
               DATASET "Telemetry_Group_3"
               DATASET "Telemetry_Group_4"
               DATASET "Telemetry_Group_5"
            }
            GROUP "TIRS" {
               DATASET "TIRS_Telemetry"
            }
         }
      }
      }
```

Figure 2-22. Ancillary Data File Structure

When using the h5dump program to view the whole ancillary file, the GROUPs are listed alphabetically. Specific groups or datasets can be viewed using h5dump options.

Also, due to varying timestamp formats in the ancillary data, the DPAS inserts fields named l0r_time_days_from_J2000 and l0r_time_seconds_of_day into each DATASET during L0Ra processing in order to standardize the time formats. The original timestamp information is also included.

2.3.2.1 OLI Group

The OLI Group is created for every interval collection containing OLI imagery. It contains OLI-produced header data, which are stored in the /OLI group of the ancillary data file and includes the following datasets:

Dataset	Description
Image_Header	Image Header extracted from frame 0 in the logical frame structure of an OLI image. This dataset also contains the Frame Header information from frame 0.
Frame_Headers	Frame Header information extracted from the OLI image frames (starting with frame 1, the first frame after the Image Header).

Table 2-7. Ancillary Data File – OLI Group

The following subsections describe the detailed structure of the OLI Group datasets.

2.3.2.1.1 OLI Image Header Dataset

Information about the OLI image is written to the /OLI/Image_Header dataset in the ancillary data file. The first part of this dataset contains the Frame Header, which is associated with the Image Header. If the Image Header is missing, this dataset still contains a record, but with the fields zero filled. Table 2-8 defines the Image Header dataset contents.

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. The number of days that passed since J2000 International Atomic Time (TAI).
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution.
days_original	H5T_STD_I16LE	The original number of days that passed since J2000 obtained from the mission data.
milliseconds_original	H5T_STD_I32LE	The original milliseconds timestamp obtained from the mission data.
microseconds_original	H5T_STD_I16LE	The original microseconds timestamp obtained from the mission data.
frame_number	H5T_STD_U32LE	Video Frame Number (always 0 for the Image Header).
blind_data_included_in_frame	H5T_STD_U8LE	Indicates if blind data are included in this frame. Because blind data are expected to be in all frames, this should always be 1.
time_error	H5T_STD_U8LE	Indicates if the time information appears to be degraded. 0 = Time data nominal; 1 = Time data may be degraded. See Ball Aerospace and Technology Corporation (BATC) Doc # 2339436 for more information.

Parameter Name	HDF5 Type	Value, Format, Range, Units
reserved	H5T_STD_U8LE (4)	Reserved
The following status field is additional information that DPAS inserted during L0Ra processing:		
frame_status	H5T_STD_U16LE	Image Header frame status: Bit — Meaning 15–7 — Reserved 6 — 1 = CRC check successful. 5 — 1 = Frame Header verified. 4 — 1 = Frame Header suspect, but uncorrected. 3 — NA for the Image Header frame. 2 — 1 = The Image Header was not received and was zero filled. 1 — 1 = Timecode has been corrected. 0 — NA for the Image Header frame.
length_of_image	H5T_STD_I32LE	Length of Image (frames) (0–1,048,575)
420,000 frames is the approximate number of frames in the maximum expected 77-scene interval. Each video frame has two Panchromatic band lines.		
image_content_definition	H5T_STD_U32LE	Default value is 0. Other values are BATC proprietary information.
ms_integration_time	H5T_STD_U16LE	Time from the start of MS programming in microseconds.
pan_integration_time	H5T_STD_U16LE	Time from the start of PAN programming in microseconds.
ms_data_word	H5T_STD_U32LE	BATC debugging only.
pan_data_word	H5T_STD_U32LE	BATC debugging only.
extended_integration_flag	H5T_STD_U8LE	Normal integration time or Extended integration time. 0=NORMAL; 1=LONG
blind_band_record_rate	H5T_STD_U8LE	A value of 1 means blind data are present in every frame.
test_pattern_setting	H5T_STD_U8LE	0 = Video data; 1 = Test pattern
current_detector_select_table	H5T_STD_U8LE	A possible five detector select tables can be loaded in the instrument. Some tables are used for imaging, and some for testing / diagnostic purposes. The normal value for imaging is 5.
reserved_1	H5T_STD_U8LE (3)	Reserved by BATC.
detector_select_table_id_number	H5T_STD_U32LE	An identifier for the information loaded into the “primary” detector select table (table 5). Changeable by uploaded the Mission Operations Center (MOC) command. This value should match the detector table ID found in the Calibration Parameter File (CPF).
image_data_truncation_setting	H5T_STD_U8LE	Upper or lower 12-bits for IMAGE pixels only. 0 indicates the upper 12-bits. 1 indicates the lower 12-bits.
reserved_2	H5T_STD_U8LE (20)	Reserved for debug purposes only.

Table 2-8. Ancillary Data File – OLI Image_Header Dataset

2.3.2.1.2 OLI Frame Headers Dataset

Every OLI frame, including the Image Header, contains Frame Header information. This information is written as an array to the /OLI/Frame_Headers dataset in the ancillary data file. Table 2-9 shows the structure of each record in this array.

In addition to the Frame Headers extracted from the OLI Frames, a fill Frame Header is inserted for any fill frames added. See subsection 2.4 for more information.

<table>
<tr><th>Parameter Name</th><th>HDF5 Type</th><th colspan="2">Value, Format, Range, Units</th></tr>
<tr><td>l0r_time_days_from_J2000</td><td>H5T_STD_I32LE</td><td colspan="2">DPAS generated standardized time format. Days counted from J2000 TAI component.</td></tr>
<tr><td>l0r_time_seconds_of_day</td><td>H5T_IEEE_F64LE</td><td colspan="2">DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.</td></tr>
<tr><td>days_original</td><td>H5T_STD_I16LE</td><td colspan="2">Original day timestamp.</td></tr>
<tr><td>milliseconds_original</td><td>H5T_STD_I32LE</td><td colspan="2">Original milliseconds timestamp.</td></tr>
<tr><td>microseconds_original</td><td>H5T_STD_I16LE</td><td colspan="2">Original microseconds timestamp.</td></tr>
<tr><td>frame_number</td><td>H5T_STD_U32LE</td><td colspan="2">Number of this frame within the interval. The first frame in an interval is number one. OLI supports numbering up to 1048575.</td></tr>
<tr><td>blind_data_included_in_frame</td><td>H5T_STD_U8LE</td><td colspan="2">Indicates if blind data are included in this frame. 0 = No Blind Data; 1 = Blind Data Included</td></tr>
<tr><td>time_error</td><td>H5T_STD_U8LE</td><td colspan="2">Indicates if the time information appears to be degraded. 0 = Time data nominal; 1 = Time data may be degraded. See BATC Doc # 2339436 for more information.</td></tr>
<tr><td>reserved</td><td>H5T_STD_U8LE (4)</td><td colspan="2">Reserved</td></tr>
<tr><td colspan="4">The following status field is additional information that DPAS inserted during L0Ra processing:</td></tr>
<tr><td>frame_status</td><td>H5T_STD_U16LE</td><td colspan="2">Video Frame status:</td></tr>
<tr><td colspan="2" rowspan="9"></td><td>Bit</td><td>Meaning</td></tr>
<tr><td>15–7</td><td>Reserved</td></tr>
<tr><td>6</td><td>1 = CRC check successful.</td></tr>
<tr><td>5</td><td>1 = Frame Header verified.</td></tr>
<tr><td>4</td><td>1 = Frame Header suspect, but uncorrected.</td></tr>
<tr><td>3</td><td>1 = Duplicate frame detected, but not removed. L0Ra processing checks for duplicates based on frame number and time code; can be configured to drop the duplicates if so desired.</td></tr>
<tr><td>2</td><td>1 = Frame is inserted fill.</td></tr>
<tr><td>1</td><td>1 = Timecode has been corrected.</td></tr>
<tr><td>0</td><td>1 = Frame number has been corrected.</td></tr>
</table>

Table 2-9. Ancillary Data File – OLI Frame_Headers Dataset

2.3.2.1.2.1 Header Fill Values

Whenever fill data are needed in the video frames, the header has frame numbers and timestamps (using l0r_time_days_from_J2000 and l0r_time_seconds_of_day) computed from the remaining non-fill headers. The reserved bytes are filled with zeroes (0x00) and the fill flag is set to 1.

2.3.2.2 TIRS Group

The TIRS Group is created for every interval collection containing TIRS imagery. It contains TIRS-produced header data, which are stored in the /TIRS group of the ancillary data file and includes the following datasets:

Dataset	Description
Frame_Header	Frame Header information extracted from the TIRS image frames

Table 2-10. Ancillary Data File – TIRS Group

2.3.2.2.1 TIRS Frame Headers Dataset

Every TIRS frame contains Frame Header information. The DPAS extracts this Frame Header information and writes it as an array to the /TIRS/Frame_Headers dataset in the ancillary data file. Table 2-11 shows the structure of each record in this array.

In addition to the Frame Headers extracted from the TIRS frames, a fill Frame Header is inserted for any fill frames added. See subsection 2.4 for more information.

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
days_original	H5T_STD_I16LE	Original day timestamp.
milliseconds_original	H5T_STD_I32LE	Original milliseconds timestamp.
microseconds_original	H5T_STD_I16LE	Original microseconds timestamp.
frame_number	H5T_STD_U32LE	Number of this frame within the interval. The first frame in an interval is number one.
sync_byte	H5T_STD_U8LE	0x54
reserved	H5T_STD_U8LE	0x00
data_set_type	H5T_STD_U8LE	0x30 = Imagery, 0x0C = Diagnostic, 0x03 = Test Pattern
integration_duration	H5T_IEEE_F64LE	Time during FSYNC low in microseconds.
total_frames_requested	H5T_STD_U32LE	Number of frames requested in the collect.
row_offsets	H5T_STD_U8LE (18)	Row offset for each row of detectors on each SCA on a per band basis. The data are organized per band, the SCA number within the band, and then row number within the SCA.
d_header	H5T_STD_U16LE (3, 3)	Data headers for the 10.8 µm, blind, and 12.0 µm bands. This includes the sync bytes and two reserved words. See BATC Doc # 70-P58205P Sec. 6.3.1.5.2.
fpe_words	H5T_STD_U16LE	Sidecar data containing information such as start

Parameter Name	HDF5 Type	Value, Format, Range, Units
	(18,7)	code, block length, ASIC ID, etc. See Science Data Description Document, Sec. 3.2 and table 3 for more information.
roic_crc_status_blind	H5T_STD_U8LE	d_header ROIC CRC status bits for the blind band.

Bit	Meaning
7	Reserved
6	Reserved
5	Band 16 SCA 3 CRC valid flag.
4	Band 10 SCA 3 CRC valid flag.
3	Band 16 SCA 2 CRC valid flag.
2	Band 10 SCA 2 CRC valid flag.
1	Band 16 SCA 1 CRC valid flag.
0	Band 10 SCA 1 CRC valid flag.

Parameter Name	HDF5 Type	Value, Format, Range, Units
roic_crc_status_10_8	H5T_STD_U8LE	d_header ROIC CRC status bits for the 10.8 µm band.

Bit	Meaning
7	Reserved
6	Reserved
5	Band 18 SCA 3 CRC valid flag.
4	Band 15 SCA 3 CRC valid flag.
3	Band 18 SCA 2 CRC valid flag.
2	Band 15 SCA 2 CRC valid flag.
1	Band 18 SCA 1 CRC valid flag.
0	Band 15 SCA 1 CRC valid flag.

Parameter Name	HDF5 Type	Value, Format, Range, Units
roic_crc_status_12	H5T_STD_U8LE	d_header ROIC CRC status bits for the 12.0 µm band.

Bit	Meaning
7	Reserved
6	Reserved
5	Band 17 SCA 3 CRC valid flag.
4	Band 11 SCA 3 CRC valid flag.
3	Band 17 SCA 2 CRC valid flag.
2	Band 11 SCA 2 CRC valid flag.
1	Band 17 SCA 1 CRC valid flag.
0	Band 11 SCA 1 CRC valid flag.

The following status field is additional information that DPAS inserted during L0Ra processing:

Parameter Name	HDF5 Type	Value, Format, Range, Units
frame_status	H5T_STD_U16LE	Video Frame status:

Bit	Meaning
15 -7	Reserved
7	1 = TIRS CRC-12 check successful.
6	1 = CRC check successful (a global status for both the ROIC CRCs checked on board and the CRC-12 checked on ground).
5	1 = Video Frame Header verified.
4	1 = Video Frame Header suspect, but uncorrected.
3	1 = Duplicate frame detected, but not removed.
2	1 = Frame is inserted fill.
1	1 = Timecode has been corrected.
0	1 = Frame number has been corrected.

Table 2-11. Ancillary Data File – TIRS Frame_Headers Dataset

2.3.2.2.1.1 Header Fill Values

Whenever fill data are needed in the video frames, the header has timestamps computed (using l0r_time_days_from_J2000 and l0r_time_seconds_of_day) from the remaining non-fill headers. The reserved bytes are filled with zeroes (0x00) and the fill flag in the frame status field is set to 1.

2.3.2.3 Spacecraft Data Group

The spacecraft data group is created for every interval collection that includes ancillary data. It contains the spacecraft data needed for subsequent data processing. These data are stored in the /Spacecraft group of the ancillary data file, containing individual subgroup datasets for the various spacecraft data.

Ancillary data are examined during L0Ra processing. If segments of ancillary data fail the inspection, the filled flag is set to 1.

The datasets and subgroups contained within the root group consist of the following:

Group	Dataset	Description
ACS	Attitude Attitude_Filter	Attitude Control System (ACS) Data (Quaternion and Attitude Filter)
-	Ephemeris	Spacecraft Ephemeris Estimate Data
-	GPS_Position	Global Positioning System (GPS) Position Data
-	GPS_Range	GPS Range Data
IMU	Gyro Latency	Inertial Measurement Unit (IMU) Data
-	Star_Tracker_Centroid	Star Tracker Centroid Data
-	Star_Tracker_Quaternion	Star Tracker Quaternion Data
Temperatures	Gyro OLI_TIRS	Temperature Measurements

Table 2-12. Ancillary Data File – Spacecraft Group

2.3.2.3.1 Attitude Control System (ACS) Group

The ACS group includes quaternion data sampled at 50 Hertz (Hz) and attitude filter data sampled at 1Hz.

The quaternion data are stored as an array of records in a dataset named /Spacecraft/ACS/Attitude with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
seconds_original	H5T_IEEE_F64LE	Original seconds timestamp.
inertial_to_body_x	H5T_IEEE_F64LE	Inertial to body quaternion, vector 1 part.
inertial_to_body_y	H5T_IEEE_F64LE	Inertial to body quaternion, vector 2 part.
inertial_to_body_z	H5T_IEEE_F64LE	Inertial to body quaternion, vector 3 part.
inertial_to_body_scalar	H5T_IEEE_F64LE	Inertial to body quaternion, scalar part.
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No and 1 = Yes

Table 2-13. Ancillary Data File – ACS Attitude Dataset

The ACS gyro data are stored as an array of records in a dataset named /Spacecraft/ACS/Attitude_Filter with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
seconds_original	H5T_STD_I32LE	Original seconds timestamp.
subseconds_original	H5T_STD_I32LE	Original timestamp with 100ns resolution.
gyro_combined_bias_rad_sec_x	H5T_IEEE_F64LE	Gyro combined X bias (AD frame) (rad/sec).
gyro_combined_bias_rad_sec _y	H5T_IEEE_F64LE	Gyro combined Y bias (AD frame) (rad/sec).
gyro_combined_bias_rad_sec _z	H5T_IEEE_F64LE	Gyro combined Z bias (AD frame) (rad/sec).
gyro_scale_factor_x	H5T_IEEE_F64LE	Gyro Scale Factor Correction.
gyro_scale_factor_y	H5T_IEEE_F64LE	Gyro Scale Factor Correction.
gyro_scale_factor_z	H5T_IEEE_F64LE	Gyro Scale Factor Correction.
gyro_x_misalignment_along_y_rad	H5T_IEEE_F32LE	Gyro X axis Misalignment Angle along Y (rad).
gyro_x_misalignment_along_z_rad	H5T_IEEE_F32LE	Gyro X axis Misalignment Angle along Z (rad).
gyro_y_misalignment_along_x_rad	H5T_IEEE_F32LE	Gyro Y axis Misalignment Angle along X (rad).
gyro_y_misalignment_along_z_rad	H5T_IEEE_F32LE	Gyro Y axis Misalignment Angle along Z (rad).
gyro_z_misalignment_along_x_rad	H5T_IEEE_F32LE	Gyro Z axis Misalignment Angle along X (rad).
gyro_z_misalignment_along_y_rad	H5T_IEEE_F32LE	Gyro Z axis Misalignment Angle along Y (rad).
kalman_filter_error_rad_x	H5T_IEEE_F64LE	Kalman Filter Attitude Error, X (rad).
kalman_filter_error_rad_y	H5T_IEEE_F64LE	Kalman Filter Attitude Error, Y (rad).
kalman_filter_error_rad_z	H5T_IEEE_F64LE	Kalman Filter Attitude Error, Z (rad).
covariance_diagonal_x	H5T_IEEE_F64LE	Covariance Diagonal, X (nd).
covariance_diagonal_y	H5T_IEEE_F64LE	Covariance Diagonal, Y (nd).
covariance_diagonal_z	H5T_IEEE_F64LE	Covariance Diagonal, Z (nd).
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-14. Ancillary Data File – ACS Attitude_Filter Dataset

2.3.2.3.2 Ephemeris Dataset

The ephemeris data are collected at 1Hz and stored as an array of records in a dataset named /Spacecraft/Ephemeris with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
seconds_original	H5T_IEEE_F64LE	Original seconds timestamp.
ecef_x_position_meters	H5T_IEEE_F64LE	Earth-Centered, Earth Fixed (ECEF) position x coordinate in meters.
ecef_y_position_meters	H5T_IEEE_F64LE	ECEF position y coordinate in meters.
ecef_z_position_meters	H5T_IEEE_F64LE	ECEF position z coordinate in meters.
ecef_x_velocity_meters_per_sec	H5T_IEEE_F64LE	ECEF x direction velocity in meters/sec.
ecef_y_velocity_meters_per_sec	H5T_IEEE_F64LE	ECEF y direction velocity in meters/sec.
ecef_z_velocity_meters_per_sec	H5T_IEEE_F64LE	ECEF z direction velocity in meters/sec.
orbit_determination_x_position_error_meters	H5T_IEEE_F64LE	ECEF position x coordinate residual error in meters.
orbit_determination_y_position_error_meters	H5T_IEEE_F64LE	ECEF position y coordinate residual error in meters.
orbit_determination_z_position_error_meters	H5T_IEEE_F64LE	ECEF position z coordinate residual error in meters.
orbit_determination_x_velocity_error_meters_per_sec	H5T_IEEE_F64LE	ECEF x coordinate velocity residual error in meters/sec.
orbit_determination_y_velocity_error_meters_per_sec	H5T_IEEE_F64LE	ECEF y coordinate velocity residual error in meters/sec.
orbit_determination_z_velocity_error_meters_per_sec	H5T_IEEE_F64LE	ECEF z coordinate velocity residual error in meters/sec.
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-15. Ancillary Data File – Ephemeris Dataset

2.3.2.3.3 Global Positioning System (GPS) Position Dataset

The raw GPS Position data are collected at 1Hz and stored as an array of records in a dataset named /Spacecraft/GPS_Position with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
month	H5T_STD_U8LE	1 to 12
day	H5T_STD_U8LE	1 to 31
year	H5T_STD_U16LE	1900 to 2999
hours	H5T_STD_U8LE	0 to 23
minutes	H5T_STD_U8LE	0 to 59

Parameter Name	HDF5 Type	Value, Format, Range, Units
seconds	H5T_STD_U8LE	0 to 59
nanoseconds	H5T_STD_U32LE	Nanoseconds
function	H5T_STD_U8LE	Unsigned and unitless.
sub_function	H5T_STD_U8LE	Unsigned and unitless.
latitude	H5T_IEEE_F64LE	Satellite position measured in arcseconds.
longitude	H5T_IEEE_F64LE	Satellite position measured in arcseconds.
height_uncorrected	H5T_IEEE_F64LE	Uncorrected height in meters.
height_corrected	H5T_IEEE_F64LE	Corrected height in meters.
velocity	H5T_IEEE_F64LE	Velocity in meters/sec.
heading	H5T_IEEE_F64LE	Heading in degrees.
current_dop	H5T_IEEE_F32LE	Current Dilution of Precision (DOP).
dop_type	H5T_STD_U8LE	0=PDOP, 1=HDOP
num_visible_satellites	H5T_STD_U8LE	0…15
num_satellites_tracked	H5T_STD_U8LE	0…12
tracked_sat_1_sat_id	H5T_STD_U8LE	0…37
tracked_sat_1_track_mode	H5T_STD_U8LE	0…8 0 – Code Search 1 – Code Acquire 2 – AGC Set 3 – Frequency Acquire 4 – Bit Sync Detect 5 – Message Sync Detect 6 – Satellite Time Available 7 – Ephemeris Acquire 8 – Available for Position (Normal state when channel is locked)
tracked_sat_1_signal_strength	H5T_STD_U8LE	0…255
tracked_sat_1_channel_status_flags	H5T_STD_U8LE	(msb) Bit 7: Using for Position Fix Bit 6: Satellite Momentum Alert Flag Set Bit 5: Satellite Anti-Spoof Flag Set Bit 4: Satellite Reported Unhealthy Bit 3: Satellite Reported Inaccurate (> 16m) Bit 2: Spare Bit 1: Spare (lsb) Bit 0: Parity Error
--- entries are repeated for satellites 2-11 ---		
tracked_sat_12_sat_id	H5T_STD_U8LE	0…37
tracked_sat_12_track_mode	H5T_STD_U8LE	0…8 0 – Code Search 1 – Code Acquire 2 – AGC Set 3 – Frequency Acquire 4 – Bit Sync Detect 5 – Message Sync Detect 6 – Satellite Time Available 7 – Ephemeris Acquire 8 – Available for Position (Normal state when channel is locked)
tracked_sat_12_signal_strength	H5T_STD_U8LE	0…255
tracked_sat_12_channel_status_flags	H5T_STD_U8LE	(msb) Bit 7: Using for Position Fix Bit 6: Satellite Momentum Alert Flag Set

Parameter Name	HDF5 Type	Value, Format, Range, Units
		Bit 5: Satellite Anti-Spoof Flag Set Bit 4: Satellite Reported Unhealthy Bit 3: Satellite Reported Inaccurate (> 16m) Bit 2: Spare Bit 1: Spare (lsb) Bit 0: Parity Error
receiver_status_flags	H5T_STD_U8LE	msb) Bit 7: Position Propagate mode Bit 6: Poor Geometry (DOP > 20) Bit 5: 3D fix Bit 4: Altitude Hold (2D fix) Bit 3: Acquiring Satellites / Position Hold Bit 2: Storing New Almanac Bit 1: Insufficient visible satellites (< 3) (lsb) Bit 0: Bad Almanac
ecef_x_pos	H5T_IEEE_F64LE	Meters
ecef_y_pos	H5T_IEEE_F64LE	Meters
ecef_z_pos	H5T_IEEE_F64LE	Meters
ecef_x_vel	H5T_IEEE_F64LE	Meters/sec
ecef_y_vel	H5T_IEEE_F64LE	Meters/sec
ecef_z_vel	H5T_IEEE_F64LE	Meters/sec
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-16. Ancillary Data File – GPS_Position Dataset

2.3.2.3.4 GPS Range Dataset

The GPS Range data are sampled at 1Hz and stored as an array of records named /Spacecraft/GPS_Range with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
seconds	H5T_STD_I32LE	GPS receiver local time 0-604799, defined as seconds of the current GPS week.
nanoseconds	H5T_STD_I32LE	Nanosecond of the GPS satellite second.
function	H5T_STD_U8LE	Unsigned and unitless
sub_function	H5T_STD_U8LE	Unsigned and unitless
id_1	H5T_STD_U8LE	Satellite ID, 0 to 32
tracking_mode_1	H5T_STD_U8LE	Channel tracking mode, 0 to 8
gps_time_seconds_1	H5T_STD_I32LE	GPS satellite time in seconds of the current GPS week.
gps_time_nanoseconds_1	H5T_STD_I32LE	Nanosecond of the GPS satellite second.
raw_code_phase_1	H5T_STD_I32LE	Carrier cycles
integrated_carrier_phase_cycles_1	H5T_STD_U32LE	Integer part of the Integrated carrier phase

Parameter Name	HDF5 Type	Value, Format, Range, Units
integrated_carrier_phase_deg_1	H5T_IEEE_F64LE	Fractional part of the Integrated carrier frequency
code_discriminator_output_1	H5T_IEEE_F64LE	Meters
--- entries are repeated for satellites 2-11 ---		
id_12	H5T_STD_U8LE	Satellite ID, 0 to 32
tracking_mode_12	H5T_STD_U8LE	Channel tracking mode, 0 to 8
gps_seconds_12	H5T_STD_U32LE	GPS satellite time in seconds.
gps_nanoseconds_12	H5T_STD_U32LE	Nanosecond of the GPS satellite second.
raw_code_phase_12	H5T_STD_I32LE	Carrier cycles.
integrated_carrier_phase_cycles_12	H5T_STD_U32LE	Integer part of the Integrated carrier phase
integrated_carrier_phase_deg_12	H5T_IEEE_F64LE	Fractional part of the Integrated carrier phase
code_discriminator_output_12	H5T_STD_U16LE	Meters
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-17. Ancillary Data File – GPS_Range Dataset

2.3.2.3.5 Inertial Measurement Unit (IMU) Group

The IMU data are sampled at 50Hz. The data are stored as an array of records, with each record containing fifty samples. A compound datatype is defined to represent each gyro sample. In Table 2-17, the “->” is used to indicate a member of the complex gyro sample datatype. The dataset is named /Spacecraft/IMU/Gyro with each record containing the following fields:

<table>
<tr><th>Parameter Name</th><th>HDF5 Type</th><th>Value, Format, Range, Units</th></tr>
<tr><td>l0r_time_days_from_J2000</td><td>H5T_STD_I32LE</td><td>DPAS generated standardized time format. Days counted from J2000 TAI component.</td></tr>
<tr><td>l0r_time_seconds_of_day</td><td>H5T_IEEE_F64LE</td><td>DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.</td></tr>
<tr><td>seconds_original</td><td>H5T_STD_I32LE</td><td>Original seconds timestamp.</td></tr>
<tr><td>subseconds_original</td><td>H5T_STD_I32LE</td><td>Original fractional second timestamp with 100ns resolution.</td></tr>
<tr><td>gyro_sample_1->
sync_event_time_tag</td><td>H5T_STD_I16LE</td><td>1/3 usec / LSB (1/3 usec is equal to 1/12 of a 4 usec SIRU clock tick).</td></tr>
<tr><td>gyro_sample_1->
time_tag</td><td>H5T_STD_U16LE</td><td>4usec / LSB</td></tr>
<tr><td>gyro_sample_1->
saturation_and_scaling</td><td>H5T_STD_U8LE</td><td>
<table>
<tr><td>Bit</td><td colspan="2">Flag</td></tr>
<tr><td>7</td><td colspan="2">Gyro A rate saturation: 0 = FTR(Force to Rebalance); 1 = WA (Whole Angle)</td></tr>
<tr><td>6</td><td colspan="2">Gyro B rate saturation: 0 = FTR; 1 = WA</td></tr>
<tr><td>5</td><td colspan="2">Gyro C rate saturation: 0 = FTR; 1 = WA</td></tr>
<tr><td>4</td><td colspan="2">Gyro D rate saturation: 0 = FTR; 1 = WA</td></tr>
<tr><td rowspan="3">3</td><td>Value</td><td>Gyro A scaling factor</td></tr>
<tr><td>0</td><td>fine, 0.05 arcsec/LSB scaling</td></tr>
<tr><td>1</td><td>coarse, 1.6 arcsec/LSB scaling</td></tr>
<tr><td rowspan="2">2</td><td></td><td>Gyro B scaling factor</td></tr>
<tr><td>0</td><td>fine, 0.05 arcsec/LSB scaling</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Parameter Name</th><th>HDF5 Type</th><th>Value, Format, Range, Units</th></tr>
<tr><td></td><td></td><td><table>
<tr><td></td><td>1</td><td>coarse, 1.6 arcsec/LSB scaling</td></tr>
<tr><td rowspan="3">1</td><td></td><td>Gyro C scaling factor</td></tr>
<tr><td>0</td><td>fine, 0.05 arcsec/LSB scaling</td></tr>
<tr><td>1</td><td>coarse, 1.6 arcsec/LSB scaling</td></tr>
<tr><td rowspan="3">0</td><td></td><td>Gyro D scaling factor</td></tr>
<tr><td>0</td><td>fine, 0.05 arcsec/LSB scaling</td></tr>
<tr><td>1</td><td>coarse, 1.6 arcsec/LSB scaling</td></tr>
</table>During nominal operations, the spacecraft should never come close to saturating even the “fine” scaling factor; therefore, all of the above bits are 0.</td></tr>
<tr><td>gyro_sample_1->
angular_rate_valid</td><td>H5T_STD_U8LE</td><td><table>
<tr><td>Bit</td><td>Flag</td></tr>
<tr><td>7</td><td>Gyro A angle valid: 0 = Invalid; 1 = Valid</td></tr>
<tr><td>6</td><td>Gyro B angle valid: 0 = Invalid; 1 = Valid</td></tr>
<tr><td>5</td><td>Gyro C angle valid: 0 = Invalid; 1 = Valid</td></tr>
<tr><td>4</td><td>Gyro D angle valid: 0 = Invalid; 1 = Valid</td></tr>
</table></td></tr>
<tr><td>gyro_sample_1->
integrated_angle_count_1</td><td>H5T_STD_U16LE</td><td>Unconverted count value of Gyro A integrated angle.</td></tr>
<tr><td>gyro_sample_1->
integrated_angle_count_2</td><td>H5T_STD_U16LE</td><td>Unconverted count value of Gyro B integrated angle.</td></tr>
<tr><td>gyro_sample_1->
integrated_angle_count_3</td><td>H5T_STD_U16LE</td><td>Unconverted count value of Gyro C integrated angle.</td></tr>
<tr><td>gyro_sample_1->
integrated_angle_count_4</td><td>H5T_STD_U16LE</td><td>Unconverted count value of Gyro D integrated angle.</td></tr>
<tr><td colspan="3">--- entries are repeated for samples 2 - 49 ---</td></tr>
<tr><td>gyro_sample_50->
sync_event_time_tag</td><td>H5T_STD_I16LE</td><td>1/3 usec / LSB (1/3 usec is equal to 1/12 of a 4 usec SIRU clock tick).</td></tr>
<tr><td>gyro_sample_50->
time_tag</td><td>H5T_STD_U16LE</td><td>4usec / LSB</td></tr>
<tr><td>gyro_sample_50->
saturation_and_scaling</td><td>H5T_STD_U8LE</td><td><table>
<tr><td>Bit</td><td colspan="2">Flag</td></tr>
<tr><td>7</td><td colspan="2">Gyro A rate saturation: 0 = FTR; 1 = WAS</td></tr>
<tr><td>6</td><td colspan="2">Gyro B rate saturation: 0 = FTR; 1 = WAS</td></tr>
<tr><td>5</td><td colspan="2">Gyro C rate saturation: 0 = FTR; 1 = WAS</td></tr>
<tr><td>4</td><td colspan="2">Gyro D rate saturation: 0 = FTR; 1 = WAS</td></tr>
<tr><td rowspan="3">3</td><td>Value</td><td>Gyro A scaling factor</td></tr>
<tr><td>0</td><td>fine, 0.05 arcsec/LSB scaling</td></tr>
<tr><td>1</td><td>coarse, 1.6 arcsec/LSB scaling</td></tr>
<tr><td rowspan="3">2</td><td></td><td>Gyro B scaling factor</td></tr>
<tr><td>0</td><td>fine, 0.05 arcsec/LSB scaling</td></tr>
<tr><td>1</td><td>coarse, 1.6 arcsec/LSB scaling</td></tr>
<tr><td rowspan="3">1</td><td></td><td>Gyro C scaling factor</td></tr>
<tr><td>0</td><td>fine, 0.05 arcsec/LSB scaling</td></tr>
<tr><td>1</td><td>coarse, 1.6 arcsec/LSB scaling</td></tr>
<tr><td rowspan="3">0</td><td></td><td>Gyro D scaling factor</td></tr>
<tr><td>0</td><td>fine, 0.05 arcsec/LSB scaling</td></tr>
<tr><td>1</td><td>coarse, 1.6 arcsec/LSB scaling</td></tr>
</table></td></tr>
<tr><td>gyro_sample_50->
angular_rate_valid</td><td>H5T_STD_U8LE</td><td><table>
<tr><td>Bit</td><td>Flag</td></tr>
<tr><td>7</td><td>Gyro A angle valid: 0 = Invalid; 1 = Valid</td></tr>
<tr><td>6</td><td>Gyro B angle valid: 0 = Invalid; 1 = Valid</td></tr>
<tr><td>5</td><td>Gyro C angle valid: 0 = Invalid; 1 = Valid</td></tr>
<tr><td>4</td><td>Gyro D angle valid: 0 = Invalid; 1 = Valid</td></tr>
</table></td></tr>
<tr><td>gyro_sample_50-></td><td>H5T_STD_U16LE</td><td>Unconverted count value of Gyro A integrated</td></tr>
</table>

Parameter Name	HDF5 Type	Value, Format, Range, Units
integrated_angle_count_1		angle.
gyro_sample_50-> integrated_angle_count_2	H5T_STD_U16LE	Unconverted count value of Gyro B integrated angle.
gyro_sample_50-> integrated_angle_count_3	H5T_STD_U16LE	Unconverted count value of Gyro C integrated angle.
gyro_sample_50-> integrated_angle_count_4	H5T_STD_U16LE	Unconverted count value of Gyro D integrated angle.
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-18. Ancillary Data File – IMU Gyro Dataset

The IMU Latency data are sampled at 10Hz. The dataset is named /Spacecraft/IMU/Latency with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
fine_ad_solution_time	H5T_IEEE_F64LE	Seconds from J2000
measured_imu_latency	H5T_IEEE_F32LE	Seconds
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-19. Ancillary Data File – IMU Latency Dataset

2.3.2.3.6 Star Tracker Datasets

The Star Tracker Centroid measurements are sampled at 5Hz. The centroid data is populated at 4Hz which results in a duplicate record being present in the data. The records are stored as an array of records in a dataset named /Spacecraft/Star_Tracker_Centroid with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
quaternion_index	H5T_STD_U16LE	DPAS generated index to corresponding quaternion record. 1-1900
star_1_valid	H5T_STD_U8LE	Flag to indicate if star 1 is valid. 0 = No and 1 = Yes
star_1_id	H5T_STD_U16LE	Unitless
star_1_position_arcsec_x	H5T_IEEE_F64LE	Horizontal boresight component +/- 4 deg nominal
star_1_position_arcsec_y	H5T_IEEE_F64LE	Horizontal boresight component +/- 4 deg nominal
star_1_background_bias	H5T_STD_U16LE	0-1023
star_1_intensity_mi	H5T_IEEE_F32LE	Star magnitude in the range of 1–7.3
--- entries are repeated for stars 2–5 ---		
star_6_valid	H5T_STD_U8LE	Flag to indicate if star 6 is valid. 0 = No and 1 = Yes
star_6_id	H5T_STD_U16LE	Unitless
star_6_position_arcsec_x	H5T_IEEE_F64LE	Horizontal boresight component +/- 4 deg nominal

Parameter Name	HDF5 Type	Value, Format, Range, Units
star_6_position_arcsec_y	H5T_IEEE_F64LE	Horizontal boresight component +/- 4 deg nominal
star_6_background_bias	H5T_STD_U16LE	0–1023
star_6_intensity_mi	H5T_IEEE_F32LE	Star magnitude in the range of 1–7.3
effective_focal_length	H5T_STD_U16LE	Effective focal length, tracker specific
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-20. Ancillary Data File – Star_Tracker_Centroid Dataset

The Star Tracker Quaternion is sampled at 1Hz measurements and is stored as an array of records in a dataset named <u>/Spacecraft/Star_Tracker_Quaternion</u> with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
quaternion_index	H5T_STD_U16LE	DPAS generated index to current quaternion record. 1-1900
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
udl_time_sec_original	H5T_STD_I32LE	Seconds since J2000
udl_time_sub_sec_original	H5T_STD_I32LE	Microseconds
sta_time_tag	H5T_STD_U32LE	Unitless
status_flags_1	H5T_STD_U8LE	Bit — Description 7 — Message incomplete flag 6–4 — Quaternion Status 3–0 — Tracker Mode Status
status_flags_2	H5T_STD_U8LE	Bit — Description 7 — ATM Mode Status 6 — ADM Mode Status 5 — Awaiting Catalog 4 — Catalog Complete 0–3 — Diagnostic Sub-Mode Status
last_processed_command	H5T_STD_U8LE	Last Processed Command ID
virtual_tracker_0_state	H5T_STD_U8LE	Virtual Tracker #0 state
virtual_tracker_1_state	H5T_STD_U8LE	Virtual Tracker #1 state
virtual_tracker_2_state	H5T_STD_U8LE	Virtual Tracker #2 state
virtual_tracker_3_state	H5T_STD_U8LE	Virtual Tracker #3 state
virtual_tracker_4_state	H5T_STD_U8LE	Virtual Tracker #4 state
virtual_tracker_5_state	H5T_STD_U8LE	Virtual Tracker #5 state
command_flags	H5T_STD_U8LE	Bit — Description 7 — Fault Detection Summary 6 — Cold Boot Indicator 5 — Time Tag Reset Received 4 — Snapshot Complete 3 — Bright Object Event 2 — Invalid Command 1 — TEC Enabled / Disabled Status 0 — Command Ignored Flag
time_message_value	H5T_STD_U8LE	Time Message Value

Parameter Name	HDF5 Type	Value, Format, Range, Units
camera_id	H5T_STD_U8LE	Camera ID
sw_version	H5T_STD_U8LE	Star Tracker Software Version
quaternion_seconds	H5T_IEEE_F64LE	Seconds
quaternion_element1	H5T_IEEE_F64LE	Increments of 1e-9 (dimensionless)
quaternion_element2	H5T_IEEE_F64LE	Increments of 1e-9 (dimensionless)
quaternion_element3	H5T_IEEE_F64LE	Increments of 1e-9 (dimensionless)
quaternion_element4	H5T_IEEE_F64LE	Increments of 1e-9 (dimensionless)
loss_function_value	H5T_IEEE_F64LE	Increments of 1e-12 (dimensionless)
atm_frame_count	H5T_STD_U16LE	4Hz ATM frame count within the 1Hz ADM cycle
total_sa_writes	H5T_STD_U8LE	Total SA Writes
total_sa_reads	H5T_STD_U8LE	Total SA Reads
sa_15_writes	H5T_STD_U8LE	SA-15 Write Counter (Standard Commands)
sa_15_reads	H5T_STD_U8LE	SA-15 Read Counter (Centroid Response)
sa_26_writes	H5T_STD_U8LE	SA-26 Write Counter (Uploads and Catalog Data)
sa_29_reads	H5T_STD_U8LE	SA-29 Read Counter (Standard Response)
status_flags_3	H5T_STD_U8LE	Bit – Description 7-3 – Reserved for future use 2 – LED Commanded State (Off/On) 1 – LED Throughput Fail (Pass/Fail) 0 – Boot ROM Checksum Fail (Pass/Fail)
adm_separation_tolerance_arc_secs	H5T_STD_U8LE	ADM Separation Tolerance
adm_position_tolerance_arc_secs	H5T_STD_U8LE	ADM Position Tolerance
adm_mag_tolerance	H5T_IEEE_F32LE	ADM Mag Tolerance
hot_pixel_count	H5T_STD_U8LE	Mapped Hot Pixel Count
hot_pixel_threshold	H5T_STD_U8LE	Hot Pixel Commanded Threshold
track_mode_pixel_threshold	H5T_STD_U8LE	Track Mode Pixel Commanded Threshold
acquisition_mode_pixel_threshold	H5T_STD_U8LE	Acquisition Mode Pixel Commanded Threshold
tec_setpoint	H5T_IEEE_F64LE	TEC Commanded Setpoint
boresight_x	H5T_IEEE_F64LE	Boresight Column
boresight_y	H5T_IEEE_F64LE	Boresight Row
ccd_temperature_celsius	H5T_IEEE_F32LE	Temp Charged Couple Device (CCD)
lens_cell_temperature_celsius	H5T_IEEE_F32LE	Temp Lens Cell
reserved	H5T_STD_U8LE (3)	Reserved bytes
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-21. Ancillary Data File – Star_Tracker_Quaternion Dataset

2.3.2.3.7 Temperatures Group

The Gyro temperature measurements are stored as an array of records in a dataset named /Spacecraft/Temperatures/Gyro with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000

Parameter Name	HDF5 Type	Value, Format, Range, Units
		TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
gyro_a_filtered_resonator	H5T_IEEE_F32LE	Gyro A resonator temperature in Celsius.
gyro_a_filtered_derivative_of_resonator	H5T_IEEE_F32LE	Filtered Gyro A resonator temperature in Celsius.
gyro_a_filtered_electronics	H5T_IEEE_F32LE	Gyro A electronics temperature in Celsius.
gyro_a_filtered_derivative_of_electronics	H5T_IEEE_F32LE	Filtered A electronics temperature in Celsius.
gyro_a_filtered_diode	H5T_IEEE_F32LE	Gyro A diode temperature in Celsius.
gyro_a_filtered_derivative_of_diode	H5T_IEEE_F32LE	Filtered Gyro A diode temperature in Celsius.
gyro_a_filtered_case	H5T_IEEE_F32LE	Gyro A case temperature in Celsius.
gyro_a_filtered_derivative_of_case	H5T_IEEE_F32LE	Filtered Gyro A case temperature in Celsius.
gyro_b_filtered_resonator	H5T_IEEE_F32LE	Gyro B resonator temperature in Celsius.
gyro_b_filtered_derivative_of_resonator	H5T_IEEE_F32LE	Filtered Gyro B resonator temperature in Celsius.
gyro_b_filtered_electronics	H5T_IEEE_F32LE	Gyro B electronics temperature in Celsius.
gyro_b_filtered_derivative_of_electronics	H5T_IEEE_F32LE	Filtered Gyro B electronics temperature in Celsius.
gyro_b_filtered_diode	H5T_IEEE_F32LE	Gyro B diode temperature in Celsius.
gyro_b_filtered_derivative_of_diode	H5T_IEEE_F32LE	Filtered Gyro B diode temperature in Celsius.
gyro_b_filtered_case	H5T_IEEE_F32LE	Gyro B case temperature in Celsius.
gyro_b_filtered_derivative_of_case	H5T_IEEE_F32LE	Filtered Gyro B case temperature in Celsius.
gyro_c_filtered_resonator	H5T_IEEE_F32LE	Gyro C resonator temperature in Celsius.
gyro_c_filtered_derivative_of_resonator	H5T_IEEE_F32LE	Filtered Gyro C resonator temperature in Celsius.
gyro_c_filtered_electronics	H5T_IEEE_F32LE	Gyro C electronics temperature in Celsius.
gyro_c_filtered_derivative_of_electronics	H5T_IEEE_F32LE	Filtered Gyro C electronics temperature in Celsius.
gyro_c_filtered_diode	H5T_IEEE_F32LE	Gyro C diode temperature in Celsius.
gyro_c_filtered_derivative_of_diode	H5T_IEEE_F32LE	Filtered Gyro C diode temperature in Celsius.
gyro_c_filtered_case	H5T_IEEE_F32LE	Gyro C case temperature in Celsius.
gyro_c_filtered_derivative_of_case	H5T_IEEE_F32LE	Filtered Gyro C case temperature in Celsius.
gyro_d_filtered_resonator	H5T_IEEE_F32LE	Gyro D resonator temperature in

Parameter Name	HDF5 Type	Value, Format, Range, Units
		Celsius.
gyro_d_filtered_derivative_of_resonator	H5T_IEEE_F32LE	Filtered Gyro D resonator temperature in Celsius.
gyro_d_filtered_electronics	H5T_IEEE_F32LE	Gyro D electronics temperature in Celsius.
gyro_d_filtered_derivative_of_electronics	H5T_IEEE_F32LE	Filtered Gyro D electronics temperature in Celsius.
gyro_d_filtered_diode	H5T_IEEE_F32LE	Gyro D diode temperature in Celsius.
gyro_d_filtered_derivative_of_diode	H5T_IEEE_F32LE	Filtered Gyro D diode temperature in Celsius.
gyro_d_filtered_case	H5T_IEEE_F32LE	Gyro D case temperature in Celsius.
gyro_d_filtered_derivative_of_case	H5T_IEEE_F32LE	Filtered Gyro C case temperature in Celsius.
reserved	H5T_STD_U8LE (188)	Reserved bytes.
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-22. Ancillary Data File – Temperatures Gyro Dataset

The OLI and TIRS temperature measurements, as sampled by the spacecraft (not the instruments), are stored as an array of records in a dataset named /Spacecraft/Temperatures/OLI_TIRS with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
oli_primary_mirror_flexure	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_telescope_positive_z_negative_y_strut_tube	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpe_heat_pipe_evaporator	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_baseplate_positive_z	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_baseplate_negative_z	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_primary_mirror_bench_at_flex	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_secondary_mirror_center	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_secondary_mirror_edge	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_secondary_mirror_flexure	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius

Parameter Name	HDF5 Type	Value, Format, Range, Units
oli_secondary_mirror_bench_at_flex	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_tertiary_mirror_center	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_tertiary_mirror_edge	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_tertiary_mirror_flexure	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_tertiary_mirror_bench_at_flex	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_quat_mirror_center	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_quat_mirror_edge	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpa_1_radiator	H5T_IEEE_F32LE	Range of -120 to 30 in degrees Celsius
oli_quat_mirror_flexure	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpa_2_heat_pipe_evaporator	H5T_IEEE_F32LE	Range of -120 to 30 in degrees Celsius
oli_fpa_3_heat_pipe_condenser	H5T_IEEE_F32LE	Range of -120 to 30 in degrees Celsius
oli_fpa_4_moly_bp_primary	H5T_IEEE_F32LE	Range of -120 to 30 in degrees Celsius
oli_fpa_5_moly_bp_redundant	H5T_IEEE_F32LE	Range of -120 to 30 in degrees Celsius
oli_fpa_6_sink	H5T_IEEE_F32LE	Range of -120 to 30 in degrees Celsius
oli_fpa_7_cold_cable_radiator	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpa_8_mli_negative_y_bench_tedlar	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpa_9_foot_at_spacecraft_interface	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpa_10_condenser	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch49_bank4_01	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch50_bank4_02	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpe_radiator	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch51_bank4_03	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpe_heat_ptpt_condenser	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch52_bank4_04	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpe_chassis_primary	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_baseplate_positive_y	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_fpe_chassis_redundant	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius

Parameter Name	HDF5 Type	Value, Format, Range, Units
oli_ise_chassis_primary	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_ise_chassis_redundant	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_ise_radiator	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_quat_mirror_bench_at_flex	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_bench_positive_y_1	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_bench_positive_y_2	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_bench_positive_y_3	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_bench_negative_y_1	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_bench_negative_y_2	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_bench_negative_x	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_bench_positive_x_1	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_bench_positive_x_2	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_cal_assembly_diffuser_cover	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_negative_x_focus_mechanism	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_stimulation_lamp_1_diode_board	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_tb1_ch72_bank5_8	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_tb1_ch73_bank5_9	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_tb1_ch74_bank5_10	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_stimulation_lamp_2_diode_board	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_bench_negative_x_panel	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_diffuser_wheel_motor	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_shutter_wheel_motor	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch87_bank6_7	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch88_bank6_8	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch89_bank6_9	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_baseplate_negative_y	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch90_bank6_10	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius

Parameter Name	HDF5 Type	Value, Format, Range, Units
oli_primary_mirror_center	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch91_bank6_11	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
oli_primary_mirror_edge	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
tirs_tb1_ch92_bank6_12	H5T_IEEE_F32LE	Range of -30 to 120 in degrees Celsius
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-23. Ancillary Data File – Temperatures OLI_TIRS Dataset

2.3.2.3.8 Telemetry Group

The OLI Group 3 Payload telemetry data are stored as an array of records in a dataset named /Telemetry/OLI/Telemetry_Group_3 with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_STD_U64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
days_original	H5T_STD_I16LE	Original day timestamp.
milliseconds_original	H5T_STD_I32LE	Original milliseconds timestamp.
microseconds_original	H5T_STD_I16LE	Original microseconds timestamp.
sync_word	H5T_STD_U16LE	Telemetry sync word.
id	H5T_STD_U16LE	Telemetry ID.
stim_lamp_output_current_amps	H5T_IEEE_F32LE	Stim Lamp Output Current in Amps.
stim_lamp_bulb_a_volts	H5T_IEEE_F32LE	Stim Lamp Bulb A Voltage.
stim_lamp_bulb_b_volts	H5T_IEEE_F32LE	Stim Lamp Bulb B Voltage.
stim_lamp_thermistor1_celsius	H5T_IEEE_F32LE	Stim Lamp Thermistor 1 in degrees Celsius.
stim_lamp_thermistor2_celsius	H5T_IEEE_F32LE	Stim Lamp Thermistor 2 in degrees Celsius.
stim_lamp_photodiode1_micro_amps	H5T_IEEE_F32LE	Stim Lamp Photodiode 1 micro amps.
stim_lamp_photodiode2_micro_amps	H5T_IEEE_F32LE	Stim Lamp Photodiode 2 micro amps.
focus_motor_lvdt_1	H5T_IEEE_F32LE	Focus Motor 1 Linear Variable Differential Transformer (LVDT).
focus_motor_lvdt_2	H5T_IEEE_F32LE	Focus Motor 2 LVDT.
focus_motor_lvdt_3	H5T_IEEE_F32LE	Focus Motor 3 LVDT.
pos_z_minus_y_temp_celsius	H5T_IEEE_F32LE	Positive Z/Minus Y Temperature (baseplate) in degrees Celsius.
bench_temp_1_celsius	H5T_IEEE_F32LE	Bench 1 Temperature in degrees Celsius.
bench_temp_2_celsius	H5T_IEEE_F32LE	Bench 2 Temperature in degrees Celsius.
bench_temp_3_celsius	H5T_IEEE_F32LE	Bench 3 Temperature in degrees Celsius.
bench_temp_4_celsius	H5T_IEEE_F32LE	Bench 4 Temperature in degrees Celsius.
bench_temp_5_celsius	H5T_IEEE_F32LE	Bench 5 Temperature in degrees Celsius.
bench_temp_7_celsius	H5T_IEEE_F32LE	Bench 7 Temperature in degrees Celsius.

Parameter Name	HDF5 Type	Value, Format, Range, Units
bench_temp_8_celsius	H5T_IEEE_F32LE	Bench 8 Temperature in degrees Celsius.
fpm_7_temp_celsius	H5T_IEEE_F32LE	Focal Plane Module 7 Interface Temperature in degrees Celsius.
calibration_assembly_a_temp_celsius	H5T_IEEE_F32LE	Calibration Assembly A Temperature in degrees Celsius.
pos_z_pos_y_temp_celsius	H5T_IEEE_F32LE	Positive Z/Positive Y Temperature (baseplate) in degrees Celsius.
tert_mirror_temp_celsius	H5T_IEEE_F32LE	Tertiary Mirror Temperature in degrees Celsius.
fp_chassis_temp_celsius	H5T_IEEE_F32LE	Focal Plane Electronics Chassis. Temperature in degrees Celsius.
pos_y_temp_celsius	H5T_IEEE_F32LE	Positive Y Fitting Temperature (baseplate) in degrees Celsius.
fp_evap_temp_celsius	H5T_IEEE_F32LE	Focal Plane Assembly HP Evap temperature in degrees Celsius.
fp_window_temp_celsius	H5T_IEEE_F32LE	Focal Plane Assembly Window temperature in degrees Celsius.
minus_z_pos_y_temp_celsius	H5T_IEEE_F32LE	Minus Z/Pos Y Fitting Temperature in degrees Celsius.
minus_z_minus_y_temp_celsius	H5T_IEEE_F32LE	Minus Z/Minus Y Fitting Temperature in degrees Celsius.
minus_y_temp_celsius	H5T_IEEE_F32LE	Minus Fitting Temperature (baseplate) in degrees Celsius.
fpm_14_temp_celsius	H5T_IEEE_F32LE	Focal Plane Module 14 Interface Temperature in degrees Celsius.
lvps_temp_celsius	H5T_IEEE_F32LE	LVPS Temperature in degrees Celsius.
reserved	H5T_STD_U8LE (16)	Reserved space in the telemetry Group 3.
spare	H5T_STD_U8LE (38)	Unused space in the telemetry Group 3.
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-24. Ancillary Data File – OLI Telemetry_Group_3 Dataset

The OLI Group 4 Payload telemetry data are stored as an array of records in a dataset named /Telemetry/OLI/Telemetry_Group_4 with each record containing the following fields:

<table>
<tr><th>Parameter Name</th><th>HDF5 Type</th><th>Value, Format, Range, Units</th></tr>
<tr><td>l0r_time_days_from_J2000</td><td>H5T_STD_I32LE</td><td>DPAS generated standardized time format. Days counted from J2000 TAI component.</td></tr>
<tr><td>l0r_time_seconds_of_day</td><td>H5T_IEEE_F64LE</td><td>DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.</td></tr>
<tr><td>days_original</td><td>H5T_STD_I16LE</td><td>Original day timestamp.</td></tr>
<tr><td>milliseconds_original</td><td>H5T_STD_I32LE</td><td>Original milliseconds timestamp.</td></tr>
<tr><td>microseconds_original</td><td>H5T_STD_I16LE</td><td>Original microseconds timestamp.</td></tr>
<tr><td>sync_word</td><td>H5T_STD_U16LE</td><td>Telemetry sync word.</td></tr>
<tr><td>id</td><td>H5T_STD_U16LE</td><td>Telemetry id.</td></tr>
<tr><td>mech_command_reject_count</td><td>H5T_STD_U8LE</td><td>Mechanism Control Command Rejected Count.</td></tr>
<tr><td>mech_command_accept_count</td><td>H5T_STD_U8LE</td><td>Mechanism Control Command Accept Counter.</td></tr>
<tr><td>shutter_active</td><td>H5T_STD_U8LE</td><td>0=not moving, 1=moving open loop
2=moving closed loop</td></tr>
<tr><td>last_command_opcode</td><td>H5T_STD_U8LE</td><td><table>
<tr><th>Opcode</th><th>Last Accepted Command</th></tr>
<tr><td>1</td><td>NOOP</td></tr>
<tr><td>2</td><td>CLEAR_SOH</td></tr>
<tr><td>3</td><td>FOCUS_SET_PULSE_WIDTH</td></tr>
<tr><td>4</td><td>FOCUS_SET_DEAD_TIME</td></tr>
<tr><td>5</td><td>FOCUS_CTRL_PWR</td></tr>
<tr><td>6</td><td>FOCUS_MTR_SELECT</td></tr>
<tr><td>7</td><td>FOCUS_MTR_DIR</td></tr>
<tr><td>8</td><td>FOCUS_MTR_STEPS</td></tr>
<tr><td>9</td><td>FOCUS_START</td></tr>
<tr><td>10</td><td>FOCUS_STOP</td></tr>
<tr><td>11</td><td>SD_SET_PULSE_WIDTH</td></tr>
<tr><td>12</td><td>SD_SET_DEAD_TIME</td></tr>
<tr><td>13</td><td>SD_CTRL_PWR</td></tr>
<tr><td>14</td><td>SD_RELAY</td></tr>
<tr><td>15</td><td>SD_MV_STEP</td></tr>
<tr><td>16</td><td>SD_MV_POS</td></tr>
<tr><td>17</td><td>SD_MV_DFLT_POS</td></tr>
<tr><td>18</td><td>SD_STOP</td></tr>
</table></td></tr>
<tr><td>diffuser_active</td><td>H5T_STD_U8LE</td><td>0 = not moving, 1 = moving open loop , 2 = moving closed loop</td></tr>
<tr><td>shutter_commanded_moves</td><td>H5T_STD_U8LE</td><td>When a shutter mechanism closed-loop move is active, this telemetry point reports how many times the shutter motor has been commanded to move. This telemetry point is reset to zero every time a new closed-loop move is started.</td></tr>
<tr><td>focus_motor_flags</td><td>H5T_STD_U8LE</td><td><table>
<tr><th>Bit</th><th>Description</th></tr>
<tr><td>7</td><td>Indicates if focus motor 1 is included in the next move.</td></tr>
<tr><td>6</td><td>Indicates if the focus motor 2 is</td></tr>
</table></td></tr>
</table>

Parameter Name	HDF5 Type	Value, Format, Range, Units
		(continued) included in the next move. 5 — Indicates if the focus motor 3 is included in the next move. 4 — Direction of focus motor move. 3 — Focus motor move status. 2 — Indicates whether or not the LVDT stays on during a move. 1 — Indicates that focus relay 2 is being pulsed to off. 0 — Indicates the focus relay 2 (Motor Drive Relay) is being pulsed to on.
diffuser_commanded_moves	H5T_STD_U8LE	When a diffuser mechanism closed-loop move is active, this telemetry point reports how many times the diffuser motor has been commanded to move. This telemetry point is reset to zero every time a new closed-loop move is started.
focus_motor_pulse_time_step_sec	H5T_IEEE_F64LE	Time between focus motor pulses.
focus_motor_pulse_length_sec	H5T_IEEE_F64LE	Length of focus motor pulses.
focus_motor_pulses	H5T_STD_U16LE	The number of steps used for a focus motor move.
focus_mechanism_lvdt_relay_status	H5T_STD_U8LE	Focus mechanism LVDT relay status 0/CLOSED 1/OPEN.
focus_mechanism_motor_relay_status	H5T_STD_U8LE	Focus mechanism motor drive relay status 0/OPEN 1/CLOSED.
shutter_motor_pulse_length_sec	H5T_IEEE_F64LE	Length of shutter motor pulses.
shutter_status_flags	H5T_STD_U8LE	**Bit** — **Shutter Status** 7-4 — Reserved for future use. 3 — Indicates the relay is to open the inactive side. 2 — Indicates the relay is to close the active side. 1 — Shutter Move Status 0 — Shutter Move Direction
diffuser_status_flags	H5T_STD_U8LE	**Bit** — **Diffuser Status** 7-2 — Reserved for future use. 1 — Diffuser motor move status. 0 — Diffuser motor direction
shutter_motor_pulse_time_sec	H5T_IEEE_F64LE	Time between shutter motor pulses.
diffuser_motor_pulse_time_sec	H5T_IEEE_F64LE	Time between diffuser motor pulses.
diffuser_motor_pulse_length_sec	H5T_IEEE_F64LE	Length of diffuser motor pulses.
shutter_move_count	H5T_STD_U16LE	The number of steps used for a shutter motor move.
shutter_resolver_position	H5T_STD_U16LE	Shutter resolver position.
diffuser_move_count	H5T_STD_U16LE	Times the diffuser motor has been moved. Reset to zero every time a new closed-loop move is started.
diffuser_resolver_position	H5T_STD_U16LE	Diffuser resolver position.

<table>
<tr><th>Parameter Name</th><th>HDF5 Type</th><th>Value, Format, Range, Units</th></tr>
<tr><td>diffuser_flags</td><td>H5T_STD_U16LE</td><td><table><tr><th>Bit</th><th></th></tr><tr><td>15</td><td>Status of the shutter/diffuser motor drive</td></tr><tr><td>14</td><td>Shutter/diffuser relay status(active side)</td></tr><tr><td>13</td><td>Shutter/diffuser relay status(inactive side)</td></tr><tr><td>12-0</td><td>Reserved for future use.</td></tr></table></td></tr>
<tr><td>stl_command_rejected_count</td><td>H5T_STD_U8LE</td><td>Stim Lamp Control CSC Command Reject Count. Range 0 - 255</td></tr>
<tr><td>stl_command_accepted_count</td><td>H5T_STD_U8LE</td><td>Stim Lamp Control CSC Command Accept Count. Range 0 - 255</td></tr>
<tr><td>stl_power_flags</td><td>H5T_STD_U8LE</td><td><table><tr><th>Bit</th><th>Diffuser Status</th></tr><tr><td>7-2</td><td>Reserved for future use.</td></tr><tr><td>1</td><td>Actual Main Power Status (0:Off, 1: On)</td></tr><tr><td>0</td><td>Actual Output Current Status (O:Off, 1:On)</td></tr></table></td></tr>
<tr><td>stl_last_accepted_command</td><td>H5T_STD_U8LE</td><td>Opcode of Last Accepted Command</td></tr>
<tr><td>stl_flags</td><td>H5T_STD_U8LE</td><td><table><tr><th>Bit</th><th></th></tr><tr><td>7-3</td><td>Reserved for future use.</td></tr><tr><td>2</td><td>Bit 2 Stim Lamp Main Power Status (0:On, 1:Off)</td></tr><tr><td>1-0</td><td>Stim Lamp Bulb Pair Selection (0:Pristine, 1:Backup, 2:Working 3:None)</td></tr></table></td></tr>
<tr><td>reserved</td><td>H5T_STD_U8LE (6)</td><td>Reserved for future use.</td></tr>
<tr><td>spare</td><td>H5T_STD_U8LE (12)</td><td>Spare bytes in the Group 4 telemetry space.</td></tr>
<tr><td>warning_flag</td><td>H5T_STD_U8LE</td><td>Flag to indicate if the time code was outside tolerance of its expected value.
0 = No, 1 = Yes</td></tr>
</table>

Table 2-25. Ancillary Data File – OLI Telemetry_Group_4 Dataset

The OLI Group 5 Payload telemetry data are stored as an array of records in a dataset named /Telemetry/OLI/Telemetry Group_5 with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
days_original	H5T_STD_I16LE	Original day timestamp.
milliseconds_original	H5T_STD_I32LE	Original milliseconds timestamp.
microseconds_original	H5T_STD_I16LE	Original microseconds timestamp.

Parameter Name	HDF5 Type	Value, Format, Range, Units
sync_word	H5T_STD_U16LE	Telemetry sync word.
id	H5T_STD_U16LE	Telemetry ID
fpe_command_reject_count	H5T_STD_U8LE	Focal Plane Control Command Reject Count.
fpe_command_accept_count	H5T_STD_U8LE	Focal Plane Control Command Accept Count.
safe_mode_consecutive_requests	H5T_STD_U8LE	Number of consecutive unacknowledged telemetry requests allowed before the Flight Software (FSW) transitions to safe mode.
last_command_opcode	H5T_STD_U8LE	**Opcode** – **Last Accepted Command** 1 – NOOP 2 – CLEAR_SOH 3 – MAIN_POWER_ON 4 – MAIN_POWER_OFF 5 – OUTPUT_CURRENT_ON 6 – OUTPUT_CURRENT_OFF 7 – BULB_PAIR_SELECT
single_bit_edac_errors_detected	H5T_STD_U8LE	Number of single-bit (corrected) EDAC errors detected during FPE message transmission.
consecutive_unacknowledged_requests	H5T_STD_U8LE	Consecutive unacknowledged telemetry request count. (0-255)
fpe_message_errors_detected	H5T_STD_U8LE	Number of errors detected in received FPE messages.
multi_bit_edac_errors_detected	H5T_STD_U8LE	Number of multiple-bit (uncorrected) EDAC errors detected during FPE message transmission.
messages_forwarded_to_fpe	H5T_STD_U16LE	Number of messages forwarded to the FPE, not including TOD messages.
command_sequence_count	H5T_STD_U8LE	Command sequence count for FPE messages. (0-255)
messages_reject_invalid_mode	H5T_STD_U8LE	Number of FPE messages rejected because of invalid mode.
fpe_telemetry_valid	H5T_STD_U8LE	Flag to indicate whether the FPE hardware telemetry is valid or not. (0: Invalid, 1: OK)
dlvps_relay_pos_28vdc_voltage	H5T_IEEE_F64LE	0–14bit (0–35vdc)
dlvps_pos_5v_voltage	H5T_IEEE_F64LE	0–6vdc
dlvps_pos_15v_voltage	H5T_IEEE_F64LE	0–15vdc
dlvps_neg_15v_voltage	H5T_IEEE_F64LE	0– -15vdc
dlvps_pos_3_3v_voltage	H5T_IEEE_F64LE	0–5vdc
alvps_hv_bias_pos_85v_voltage	H5T_IEEE_F64LE	0–75vdc
alvps_pos_12v_voltage	H5T_IEEE_F64LE	0–15vdc
alvps_pos_7_5v_voltage	H5T_IEEE_F64LE	0–10vdc
alvps_neg_2_5v_voltage	H5T_IEEE_F64LE	0– -4vdc
alvps_pos_12v_current_amps	H5T_IEEE_F64LE	0–xa
alvps_pos_7_5v_current_amps	H5T_IEEE_F64LE	0–xa
alvps_pos_2_5v_current_amps	H5T_IEEE_F64LE	0–xa
lvps_temperature_sensor_celsius	H5T_IEEE_F64LE	-20–100c
ctlr_temperature_sensor_celsius	H5T_IEEE_F64LE	-20–100c
ana_0_temperature_sensor_celsius	H5T_IEEE_F64LE	-20–100c
ana_1_temperature_sensor_celsius	H5T_IEEE_F64LE	-20–100c

Parameter Name	HDF5 Type	Value, Format, Range, Units
ana_0_ch_0_vpa_bias_voltage	H5T_IEEE_F64LE	0–6.0vdc
ana_0_ch_1_vpa_bias_voltage	H5T_IEEE_F64LE	0–6.0vdc
ana_0_ch_2_vpa_bias_voltage	H5T_IEEE_F64LE	0–6.0vdc
ana_0_ch_3_vpa_bias_voltage	H5T_IEEE_F64LE	0–6.0vdc
ana_0_ch_4_vpa_bias_voltage	H5T_IEEE_F64LE	0–6.0vdc
ana_0_ch_5_vpa_bias_voltage	H5T_IEEE_F64LE	0–6.0vdc
ana_0_ch_6_vpa_bias_voltage	H5T_IEEE_F64LE	0–6.0vdc
ana_0_ch_7_vpa_bias_voltage	H5T_IEEE_F64LE	0–6.0vdc
reserved	H5T_STD_U8LE (3)	
spare	H5T_STD_U8LE (4)	Spare bytes in the Group 4 telemetry space.
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-26. Ancillary Data File – OLI Telemetry_Group_5 Dataset

The TIRS Payload telemetry data are stored as an array of records in a dataset named /Telemetry/TIRS/TIRS_Telemetry with each record containing the following fields:

Parameter Name	HDF5 Type	Value, Format, Range, Units
l0r_time_days_from_J2000	H5T_STD_I32LE	DPAS generated standardized time format. Days counted from J2000 TAI component.
l0r_time_seconds_of_day	H5T_IEEE_F64LE	DPAS generated standardized time format. Seconds of the current day with a microsecond resolution component.
unaccepted_command_count	H5T_STD_U8LE	Maintains a count of all unaccepted (invalid CRC) commands
accepted_command_count	H5T_STD_U8LE	Maintains a count of all accepted commands
pulse_per_second_count	H5T_STD_U8LE	Pulse Per Second count is a count of how many PPSs were received since the FPGA was last reset or turned on.
tod_command_counter	H5T_STD_U8LE	Increases by one for each valid TOD command received. Nominally, this counter increases by one each second, as the CDHB receives each TOD command from the Spacecraft
day	H5T_STD_I16LE	
millisecond	H5T_STD_I32LE	
mc_encoder_flags	H5T_STD_U8LE	**Bits** **Description**

Parameter Name	HDF5 Type	Value, Format, Range, Units
		7-4 Unused 3 POWER 2 RAMP 1 IDX 0 IDX_ACQ
science_data_frame_capture_count	H5T_STD_U16LE	Total number of successful frames captured. Increments for every FSync.
science_acquisition_frame_rate	H5T_IEEE_F32LE	Frame capture time. Default value is set to 14.28ms.
active_timing_table_pattern	H5T_STD_U8LE	Defines which of the 4 possible timing table patterns is active. Only the active pattern is sent to the multiplexer. **Value** / **Description** 0 Idle 1 6-row science pattern (default) 2 Transmit all 3 Transmit all
mode_register	H5T_STD_U16LE	Indicates current state of operation
timing_table_pattern_id_1	H5T_STD_U8LE	Unique ID (1/3) associated with one of the many possible Timing Table Patterns which scientists may want loaded to TIRS
timing_table_pattern_id_2	H5T_STD_U8LE	Unique ID (2/3) associated with one of the many possible Timing Table Patterns which scientists may want loaded to TIRS
timing_table_pattern_id_3	H5T_STD_U8LE	Unique ID (3/3) associated with one of the many possible Timing Table Patterns which scientists may want loaded to TIRS
ssm_position_sel	H5T_STD_U8LE	**Value** / **Description** 1 SAFE_POSN 2 NADIR 3 SPACE 4 BLACKBODY 5 INV04 6 INV05 7 INV06 8 ARBITRARY
ssm_mech_mode	H5T_STD_U8LE	Valid values are 0 - 15
ssm_encoder_position_sample	H5T_STD_U32LE	**Bits** / **Description**

Parameter Name	HDF5 Type	Value, Format, Range, Units
	(21)	31-25: Unused (24 bit data) 24-2: Encoder data 1-0: Bits always 0
bbcal_op7_a_celsius	H5T_IEEE_F32LE	Range -27.91 to 58.13 in degrees Celsius
bbcal_op7_b_celsius	H5T_IEEE_F32LE	Range -27.48 to 58.21 in degrees Celsius
bbcal_supp_1_celsius	H5T_IEEE_F32LE	Range -16.61 to 68.67 in degrees Celsius
blackbody_calibrator_celsius	H5T_IEEE_F32LE (4)	0: Range -45.95 to 77.43 in degrees Celsius 1: Range -47.52 to 77.7 in degrees Celsius 2: Range -47.83 to 77.44 in degrees Celsius 3: Range -47.87 to 77.19 in degrees Celsius
cold_stage_heat_strap_cf_if_celsius	H5T_IEEE_F32LE	Range -249.03 to -208.53 in degrees Celsius
cryo_diode_t3_measured_celsius	H5T_IEEE_F32LE	Range -273.15 to 382.21 in degrees Celsius
cryo_diode_t4_measured_celsius	H5T_IEEE_F32LE	Range -273.15 to 382.21 in degrees Celsius
cryo_shroud_outer_at_tunnel_celsius	H5T_IEEE_F32LE	Range -155.76 to 52.21 in degrees Celsius
cryo_shroud_outer_flange_celsius	H5T_IEEE_F32LE	Range -155.72 to 52.07 in degrees Celsius
fixed_baff_nadir_aft_hot_corner_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
fixed_baff_nadir_aft_space_corner_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
fixed_baff_nadir_fwd_hot_corner_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
fixed_baff_nadir_fwd_space_corner_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
fp_a_asic_celsius	H5T_IEEE_F32LE	Range -58.62 to 058.60 in degrees Celsius
fp_b_asic_celsius	H5T_IEEE_F32LE	-62.75 in degrees Celsius
fpe1_fpe_a_asic_celsius	H5T_IEEE_F32LE	Range 204.31 to 333.88 in degrees Celsius
fpe2_fpe_b_asic_celsius	H5T_IEEE_F32LE	Range 204.84 to 334.32 in degrees Celsius
fp_f2_fine_sensor_1_celsius	H5T_IEEE_F32LE	Range 33.24 to 57.88 in degrees Celsius
fp_f4_fine_sensor_3_celsius	H5T_IEEE_F32LE	Range 36.67 to 56.72 in degrees Celsius
fp_f6_fine_sensor_1_celsius	H5T_IEEE_F32LE	Range 33.24 to 57.88 in degrees Celsius
fp_f7_fine_sensor_2_celsius	H5T_IEEE_F32LE	Range 33.24 to 57.88 in degrees Celsius
fp_op6_a_celsius	H5T_IEEE_F32LE	Range -27.61 to 58.08 in degrees Celsius

Parameter Name	HDF5 Type	Value, Format, Range, Units
fp_op6_b_celsius	H5T_IEEE_F32LE	Range -27.48 to 58.21 in degrees Celsius
optical_deck_celsius	H5T_IEEE_F32LE	Range -67.74 to 61.16 in degrees Celsius
spare_4_thermistor_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
spare_5_thermistor_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius Celsius
ssm_bearing_aft_celsius	H5T_IEEE_F32LE	Range -66.27 to 62.46 in degrees Celsius
ssm_bearing_fwd_celsius	H5T_IEEE_F32LE	Range -65.22 to 62.14 in degrees Celsius
ssm_bearing_housing_d4_aft_hot_side_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
ssm_bearing_housing_d5_fwd_hot_side_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
ssm_bearing_housing_d6_aft_space_side_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
ssm_bearing_housing_d7_fwd_space_side_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
ssm_bh_op5_a_celsius	H5T_IEEE_F32LE	Range -27.6 to 58.06 in degrees Celsius
ssm_bh_op5_b_celsius	H5T_IEEE_F32LE	Range -27.37 to 58.42 in degrees Celsius
ssm_encoder_remote_elec_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
ssm_enc_read_head_sensor_1_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
ssm_motor_housing_celsius	H5T_IEEE_F32LE	Range -200.70 to 1964.50 in degrees Celsius
structure_foot_a_neg_z_celsius	H5T_IEEE_F32LE	Range -67.54 to 61.43 in degrees Celsius
structure_foot_c_pos_z_celsius	H5T_IEEE_F32LE	Range -67.49 to 61.27 in degrees Celsius
structure_nadir_aperture_celsius	H5T_IEEE_F32LE	Range -67.74 61.10 in degrees Celsius
tcb_board_celsius	H5T_IEEE_F32LE	Range -49.31 to 119.87 in degrees Celsius
telescope_aft_barrel_neg_z_celsius	H5T_IEEE_F32LE	Range -156.28 to 51.49 in degrees Celsius
telescope_aft_barrel_pos_z_celsius	H5T_IEEE_F32LE	Range -154.03 to 54.54 in degrees Celsius
telescope_aft_op3_a_celsius	H5T_IEEE_F32LE	Range 161.26 to 200.91 in degrees Celsius
telescope_aft_op3_b_celsius	H5T_IEEE_F32LE	Range 159.97 to 199.61 in degrees Celsius
telescope_fwd_barrel_neg_z_celsius	H5T_IEEE_F32LE	Range -155.88 to 52.21 in degrees Celsius
telescope_fwd_barrel_pos_z_celsius	H5T_IEEE_F32LE	Range -155.34 to 52.95 in degrees Celsius
telescope_fwd_op4_a_celsius	H5T_IEEE_F32LE	Range 161.28 to 200.91 in degrees Celsius
telescope_fwd_op4_b_celsius	H5T_IEEE_F32LE	Range 159.99 to 199.62 in

Parameter Name	HDF5 Type	Value, Format, Range, Units
		degrees Celsius
telescope_stage_op2_a_celsius	H5T_IEEE_F32LE	Range 159.82 to 204.53 in degrees Celsius
telescope_stage_op2_b_celsius	H5T_IEEE_F32LE	Range 159.31 to 201.15 in degrees Celsius
fp_a_mon_pos_12v_volts	H5T_IEEE_F32LE	Range 0.0 to 15.06 in Volts
fp_a_a_vpd_current_1_amps_1	H5T_IEEE_F32LE	Range 0.00 to 0.04 in Amps
fp_a_a_vpd_current_1_amps_2	H5T_IEEE_F32LE	Range 0.00 to 0.04 in Amps
fp_a_a_vpd_current_1_amps_3	H5T_IEEE_F32LE	Range 0.00 to 0.04 in Amps
fp_a_detector_substrate_conn_for_sca_a_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_detector_substrate_conn_for_sca_b_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_detector_substrate_conn_for_sca_c_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_digi_supply_mon_pos_5_5_for_sca_c_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_supply_mon_pos_5_5_for_sca_a_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_supply_mon_pos_5_5_for_sca_a_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_supply_mon_pos_5_5_for_sca_b_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_supply_mon_pos_5_5_for_sca_c_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_output_ref_level_mon_5_5_for_sca_c_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_supply_10v_for_sca_a_current_mon_amps	H5T_IEEE_F32LE	Range 0.00 to 0.003 in Amps
fp_a_supply_10v_for_sca_b_current_mon_amps	H5T_IEEE_F32LE	Range 0.00 to 0.003 in Amps
fp_a_supply_10v_for_sca_c_current_mon_amps	H5T_IEEE_F32LE	Range 0.00 to 0.003 in Amps
fp_a_output_driver_pos_5_5_for_sca_c_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_output_ref_level_1_6_for_sca_c_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
fp_a_channel_ref_suppy_1_6_for_sca_c_roic_volts	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
vpe_a_sca_a_video_ref	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
vpe_a_sca_b_video_ref	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
vpe_a_sca_c_video_ref	H5T_IEEE_F32LE	Range 0.00 to 10.00 in Volts
--Entries are repeated the B side circuit board (fp_a prefix changes to fp_b and vpe_a to vpe_b) --		
cosine_motor_drive_for_mce_current_amps	H5T_IEEE_F32LE	Range -0.33 to 0.33 in Amps
sine_motor_drive_for_mce_current_amps	H5T_IEEE_F32LE	Range -0.33 to 0.33 in Amps

Parameter Name	HDF5 Type	Value, Format, Range, Units
hsib_3_3_current_mon_amps	H5T_IEEE_F32LE	Range 0.0 to 0.08 in Amps
cosine_dac_telemetry_for_mce_volts	H5T_IEEE_F32LE	Range -10.0 to 10.0 in Volts
sine_dac_telemetry_for_mce_volts	H5T_IEEE_F32LE	Range -10.0 to 10.0 in Volts
elec_enabled_flags	H5T_STD_U8LE	**Bits** – **Description** 7-4 – Unused 3 – FPE B Enable 2 – FPE A Enable 1 – MCE B Enable 0 – MCE A Enable
reserved_block_2	H5T_STD_U8LE (2)	Spare and unused bits from TIRS telemetry block 2
reserved_block_3	H5T_STD_U8LE (1)	Spare and unused bits from TIRS telemetry block 3
reserved_block_4	H5T_STD_U8LE (8)	Spare and unused bits from TIRS telemetry block 4
warning_flag	H5T_STD_U8LE	Flag to indicate if the time code was outside tolerance of its expected value. 0 = No, 1 = Yes

Table 2-27. Ancillary Data File – TIRS_Telemetry Dataset

2.3.3 Checksum File

A checksum file is created for every collection. The checksum file contains a listing of MD5 checksums for all files, except for itself, in the L0Ra data. The file is in plain text format containing the system's md5sum output.

For example, a collection with an interval ID of LC82220010052011265LGN00 would have a checksum file named LC82220010052011265LGN00_MD5.txt with contents similar to the following:

```
a5c4ef2a79f36bce369f17bc24c76f2d  LC82220010052011265LGN00_ANC.h5
97d1bbe697d75d514f1bf232270a41c4  LC82220010052011265LGN00_B1.h5
8248e8df5ce063500bf219091fdaf172  LC82220010052011265LGN00_B2.h5
d0dfd6c87353e31ff671d17f27044d04  LC82220010052011265LGN00_B3.h5
e874bf7f9dff320bb4d2d5f5473a5921  LC82220010052011265LGN00_B4.h5
926225006c17c78eb3eb62361286fd35  LC82220010052011265LGN00_B5.h5
6a5272f261280437a42c9f8873d0ac11  LC82220010052011265LGN00_B6.h5
db2e8952806ad54bff3e82bc5b491377  LC82220010052011265LGN00_B7.h5
c6908ef9a467e9020d39c99da6c71d71  LC82220010052011265LGN00_B8.h5
f4e73eec347127044a9fa232fb377e6c  LC82220010052011265LGN00_B9.h5
d20e7f27ebec3bd3023743f9b8b09063  LC82220010052011265LGN00_B10.h5
555c9a1975a987577fa0a96cdb930d41  LC82220010052011265LGN00_B11.h5
7673c9e65633f0fa8a4100991a3b2bd0  LC82220010052011265LGN00_B12.h5
dg0jd027e7563bd3023743f9b8b09063  LC82220010052011265LGN00_B13.h5
555c9a1975a987577fa0a96cdb930d41  LC82220010052011265LGN00_B14.h5
7673c92342633f0fa8a4100991a3b2bd  LC82220010052011265LGN00_B15.h5
d20e793kd90rjnsu840dm902jd0kr8fj  LC82220010052011265LGN00_B16.h5
555c9a1975a987577fa0a96cdb930d41  LC82220010052011265LGN00_B17.h5
```

```
774kf903jf0wjsfs221mdvj2fdj282u4  LC82220010052011265LGN00_B18.h5
768536f013888a4629cf6e076dccbcd4  LC82220010052011265LGN00_MTA.h5
```

2.3.4 Metadata File

A metadata file is created for every interval collection. The metadata are stored in an HDF5 file with up to three datasets. The metadata contains file and interval metadata datasets for every interval collection and a scene metadata dataset for Earth Imaging intervals. Table 2-28 provides a brief description of each dataset. The subsections that follow describe these datasets in detail.

Dataset	Description
File	Contains information about all the L0Ra files for this dataset.
Interval	Contains information about the entire interval collection.
Scene	Contains information about the Worldwide Reference System-2 (WRS-2) scenes identified in the interval (Earth Imaging data only).

Table 2-28. Metadata File Contents Description

```
HDF5 "LO82220010042014265LGN00_MTA.h5"
{
      DATASET "File"
      DATASET "Interval"
      DATASET "Scenes"
}
```

Figure 2-23. Metadata File Structure

2.3.4.1 L0Ra File Metadata

The file metadata dataset is named /File and contains information about the L0Ra files. For intervals that contain data from only one of the sensors, the band file name fields for the bands of the other sensor are empty (see Table 2-29 for detailed information).

Parameter Name	HDF5 Type	Value, Format, Range, Units
File names are based on LS-DIR-05 Landsat Metadata Description Document (LMDD) landsat_interval_id standard. See Table 2-4 and Table 2-5.		
ANCILLARY_FILE_NAME	H5T_STRING(256)	<landsat_interval_id>_ANC.h5
Name of the ancillary file.		
CHECKSUM_FILE_NAME	H5T_STRING(256)	<landsat_interval_id>_MD5.txt
The name of the file containing MD5 checksum values of L0Ra files.		
FILE_NAME_BAND_1	H5T_STRING(256)	<landsat_interval_id>_B1.h5
Name of the band 1 file. This entry is empty if a file does not exist for the band.		
--- entries are repeated for bands 2–17 ---		
FILE_NAME_BAND_18	H5T_STRING(256)	<landsat_interval_id>_B18.h5
Name of the band 18 file. This entry is empty if a file does not exist for the band.		
INTERVAL_FILES	H5T_STD_U8LE	The number of files generated for this interval.
METADATA_FILE_NAME	H5T_STRING(256)	<landsat_interval_id>_MTA.h5
Name of the metadata file.		

Table 2-29. Metadata File – File Metadata Parameters

2.3.4.2 L0Ra Interval Metadata

The interval level metadata dataset is named /Interval and contains information about the entire interval collection (see Table 2-30).

Parameter Name	HDF5 Type	Value, Format, Range, Units
ANCILLARY_START_TIME	H5T_STRING(26)	= "YYYY:DDD:HH:MI:SS.SSSSSSS" Where YYYY = four-digit year DDD = day of year (001–366) HH = hours (00–23) MI = minutes (00–59) SS = seconds (00–59) SSSSSSS = fractional seconds (0–9999999)
Spacecraft time of the first ancillary data packet associated with this interval.		
ANCILLARY_STOP_TIME	H5T_STRING(26)	= "YYYY:DDD:HH:MI:SS.SSSSSSS" (see ANCILLARY_START_TIME, above)
Spacecraft time of the last ancillary data packet associated with this interval.		
ATTITUDE_POINTS	H5T_STD_U32LE	Total number of good spacecraft attitude data points (quaternions) received and processed from the ancillary data associated with this scene.
ATTITUDE_POINTS_MISSING	H5T_STD_U32LE	Total number of spacecraft attitude data points found missing during ancillary data quality checks.
ATTITUDE_POINTS_REJECTED	H5T_STD_U32LE	Total number of spacecraft attitude data points found to fail the ancillary data quality checks.
COLLECTION_TYPE	H5T_STRING(50)	"EARTH_IMAGING" "STELLAR" "LUNAR" "SIDE_SLITHER" "OLI_LAMP" "OLI_SOLAR" "OLI_SHUTTER" "OLI_SHUTTER_INTEGRATION_TIME_SWEEP" "OLI_SOLAR_INTEGRATION_TIME_SWEEP" "TIRS_BLACKBODY" "TIRS_DEEPSPACE" "TIRS_INTEGRATION_TIME_SWEEP" "OLI_TEST_PATTERNS" "TIRS_TEST_PATTERNS" NOTE: The following LDCM collection types are not processed into L0Ra: "SSR_PN_TEST_SEQUENCE"
Type of data in this collection.		
The upper left corner (northwest corner for descending coverage / southeast corner for ascending coverage) based on the OLI Cirrus band. A positive (+) value indicates geographic North latitude. A		

Parameter Name	HDF5 Type	Value, Format, Range, Units
negative (-) value indicates geographic South latitude. Zero (0) indicates non-Earth intervals.		
CORNER_UL_LAT_OLI	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees (with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude. 0 is used as fill for calibration intervals.
Calculated latitude value (degrees) for the upper left corner. An interval starts at the first actual frame (first frame not filled).		
CORNER_UL_LON_OLI	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees (with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude. 0 is used as fill for calibration intervals.
Calculated longitude value (degrees) for the upper left corner. An interval starts at the first actual frame (not filled).		
The upper right corner (northeast corner for descending coverage / southwest corner for ascending coverage) based on the OLI Cirrus band. A positive (+) value indicates geographic North latitude. A negative (-) value indicates geographic South latitude. Zero (0) indicates non-Earth intervals.		
CORNER_UR_LAT_OLI	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude. 0 is used as fill for calibration intervals.
Calculated latitude value (degrees) for the upper right corner. An interval starts at the first actual frame (first frame not filled).		
CORNER_UR_LON_OLI	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees (with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude. 0 is used as fill for calibration intervals.
Calculated longitude value (degrees) for the upper right corner. An interval starts at the first actual frame (first frame not filled).		
The lower left corner (southwest corner for descending coverage / northeast corner for ascending coverage) based on the OLI Cirrus band. A positive (+) value indicates geographic North latitude. A negative (-) value indicates geographic South latitude. Zero (0) indicates non-Earth intervals.		
CORNER_LL_LAT_OLI	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude. 0 is used as fill for calibration intervals.
Calculated latitude value (degrees) for the lower left corner. An interval starts at the first actual frame (first frame not filled).		

Parameter Name	HDF5 Type	Value, Format, Range, Units
CORNER_LL_LON_OLI	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude. 0 is used as fill for calibration intervals.
Calculated longitude value (degrees) for the lower left corner. An interval starts at the first actual frame (first frame not filled).		
The lower right corner (southwest corner for descending coverage / northwest corner for ascending coverage) based on the OLI Cirrus band. A positive (+) value indicates geographic North latitude. A negative (-) value indicates geographic South latitude. Zero (0) indicates non-Earth intervals.		
CORNER_LR_LAT_OLI	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude. 0 is used as fill for calibration intervals.
Calculated longitude value (degrees) for the lower right corner. An interval starts at the first actual frame (first frame not filled).		
CORNER_LR_LON_OLI	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude. 0 is used as fill for calibration intervals.
Calculated longitude value (degrees) for the lower right corner. An interval starts at the first actual frame (first frame not filled).		
The upper left corner (northwest corner for descending coverage / southeast corner for ascending coverage) based on the TIRS 10.8 µm band. A positive (+) value indicates geographic North latitude. A negative (-) value indicates geographic South latitude. Zero (0) indicates non-Earth intervals.		
CORNER_UL_LAT_TIRS	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees (with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude. 0 is used as fill for calibration intervals.
Calculated latitude value (degrees) for the upper left corner. An interval starts at the first actual frame (first frame not filled).		
CORNER_UL_LON_TIRS	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees (with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude. 0 is used as fill for calibration intervals.
Calculated longitude value (degrees) for the upper left corner. An interval starts at the first actual frame (first frame not filled).		

Parameter Name	HDF5 Type	Value, Format, Range, Units
The upper right corner (northeast corner for descending coverage / southwest corner for ascending coverage) based on the TIRS 10.8 µm band. A positive (+) value indicates geographic North latitude. A negative (-) value indicates geographic South latitude. Zero (0) indicates non-Earth intervals.		
CORNER_UR_LAT_TIRS	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude. 0 is used as fill for calibration intervals.
Calculated latitude value (degrees) for the upper right corner. An interval starts at the first actual frame (first frame not filled).		
CORNER_UR_LON_TIRS	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees (with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude. 0 is used as fill for calibration intervals.
Calculated longitude value (degrees) for the upper right corner. An interval starts at the first actual frame (first frame not filled).		
The lower left corner (southwest corner for descending coverage / northeast corner for ascending coverage) based on the TIRS 10.8 µm band. A positive (+) value indicates geographic North latitude. A negative (-) value indicates geographic South latitude. Zero (0) indicates non-Earth intervals.		
CORNER_LL_LAT_TIRS	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude. 0 is used as fill for calibration intervals.
Calculated latitude value (degrees) for the lower left corner. An interval starts at the first actual frame (first frame not filled).		
CORNER_LL_LON_TIRS	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude. 0 is used as fill for calibration intervals.
Calculated longitude value (degrees) for the lower left corner. An interval starts at the first actual frame (first frame not filled).		
The upper left corner (northwest corner for descending coverage / southeast corner for ascending coverage) based on the TIRS 10.8 µm band. A positive (+) value indicates geographic North latitude. A negative (-) value indicates geographic South latitude. Zero (0) indicates non-Earth intervals.		
CORNER_LR_LAT_TIRS	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude. 0 is used as fill for calibration intervals.

Parameter Name	HDF5 Type	Value, Format, Range, Units
Calculated latitude value (degrees) for the lower right corner. An interval starts at the first actual frame (first frame not filled).		
CORNER_LR_LON_TIRS	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude. 0 is used as fill for calibration intervals.
Calculated longitude value (degrees) for the lower right corner. An interval starts at the first actual frame (first frame not filled).		
CPF_NAME	H5T_STRING(25)	="L8CPFyyyymmdd_yyyymmdd.nn" Where yyyymmdd = effective_date_begin and effective_date_end nn = increment number within a quarter (00–99)
CPF used for processing. See References for the format of the CPF.		
CRC_ERRORS_OLI	H5T_STD_U32LE	The number of CRC failures for OLI.
CRC_ERRORS_TIRS	H5T_STD_U32LE	The number of CRC failures for TIRS.
DATA_TYPE	H5T_STRING(20)	Value: OLI_L0RA, TIRS_L0RA, OLI_TIRS_L0RA. For L0Rp output, see Section 4.
Data type identifier string for the interval.		
DATE_ACQUIRED	H5T_STRING(26)	= "YYYY:DDD:HH:MI:SS.SSSSSSS" Where YYYY = 4 digit year, DDD = Day of Year, HH = Hour (00-23), MI = Minute, SS.SSSSSSS = Fractional seconds. GMT of the first line of the image.
EPHEMERIS_POINTS	H5T_STD_U32LE	Total number of good ephemeris data points received and processed from the ancillary data.
EPHEMERIS_POINTS_MISSING	H5T_STD_U32LE	Total number of spacecraft ephemeris data points found missing during ancillary data quality checks.
EPHEMERIS_POINTS_REJECTED	H5T_STD_U32LE	Total number of spacecraft ephemeris data points found to fail ancillary data quality checks.
FRAMES_FILLED_OLI	H5T_STD_U32LE	Total number of OLI frames filled using a fill data pattern. These are pre-alignment OLI frames.
FRAMES_FILLED_TIRS	H5T_STD_U32LE	Total number of TIRS frames filled using a fill data pattern. These are pre-alignment OLI frames.
HOSTNAME	H5T_STRING(20)	Hostname of the machine on which the data files for this scene were processed.
IMAGE_QUALITY_OLI	H5T_STD8LE	Values: 0–9 where 9 = Best. 0 = Worst. -1 = quality not calculated or assessed.
IMAGE_QUALITY_TIRS	H5T_STD8LE	Values: 0–9 where 9 = Best. 0 = Worst. -1 = quality not calculated or assessed.
INTERVAL_FRAMES_OLI	H5T_STD_U32LE	= 0–1048575

Parameter Name	HDF5 Type	Value, Format, Range, Units
Total number of OLI frames reported in this interval file. This value does not include frames added for alignment. This value is zero for TIRS-only intervals.		
INTERVAL_FRAMES_TIRS	H5T_STD_U32LE	= 0–16777216
Total number of TIRS frames reported in this interval file. This value does not include frames added for alignment. This value is zero for OLI-only intervals.		
INTERVAL_NUMBER	H5T_STD_U8LE	1–99
Sequence of the interval within the ingest file. For LDCM, typically only one interval exists.		
INTERVAL_VERSION	H5T_STD_U8LE	Processed version of the interval, starts at 0, and is incremented for each new version of the interval that exists. Values: 0 = Original version (first occurrence) of the file.
IS_VERSION	H5T_STRING(10)	= "X.Y.Z": X, Y, Z are all numeric values X is the major release number Y is the minor release number Z is the patch (or engineering) release number
Version number of the DPAS Ingest Subsystem software installed when L0Ra files were generated.		
LANDSAT_CAL_INTERVAL_ID	H5T_STRING(24)	Unique interval ID for calibration intervals (blank for Earth Imaging intervals) = "VIN00DHHMMSSYYYYdddGSIvv" Where V = Vehicle Series ("L" for Landsat) I = Sensor (O = OLI, T = TIRS, C = Combined) N = Satellite (8) 00 = fill D = Collection Type T = Stellar U = Lunar Y = Side Slither L = OLI Lamp O = OLI Solar S = OLI Shutter H = OLI Shutter Integration Time Sweep Z = OLI Solar Integration Time Sweep B = TIRS Blackbody D = TIRS Deep Space G = TIRS Integration Time Sweep E = OLI Test Patterns Q = TIRS Test Patterns HH = Hour (UTC) MM = Minute SS = Second YYYY = Year (2011–9999) ddd = Day of Year (001–366) GSI = Ground Station Identifier (AGS, ASN, LGN, SGS, XXX = unknown), vv = Version (00–99)

Parameter Name	HDF5 Type	Value, Format, Range, Units
		NOTE: The following LDCM collection types are not processed into L0Ra data: P = SSR PN Test Sequence
Unique Landsat Interval ID – the interval ID format for Earth Imaging data is in conformance with historical Landsat Interval ID convention. The calibration interval ID format for non-Earth Imaging intervals is used to uniquely identify calibration datasets.		
LANDSAT_INTERVAL_ID	H5T_STRING(24)	Unique Landsat interval ID for Earth Imaging intervals (blank for calibration intervals) = “VINpppRRRRRRYYYYdddGSIvv” where V = Vehicle Series (“L” for Landsat) I = Sensor (O = OLI, T = TIRS, C = Combined) N = Satellite (8) ppp = WRS-2 Start Path (001–233) RRR = Start Row (001–248) rrr = End Row (001-248) YYYY = Year (2011-9999) ddd = Day of Year (001–366) GSI = Ground Station Identifier (AGS, ASN, LGN, SGS, XXX = unknown) vv = Version (00–99)
NADIR_OFFNADIR	H5T_STRING(9)	Nadir or Off-Nadir condition of the interval.
Values: “NADIR” = The interval was captured nadir. “OFFNADIR” The interval was captured off-nadir.		
QUALITY_ALGORITHM	H5T_STRING(50)	Algorithm (date, name, and version number) used to calculate the quality for this scene or interval. See Appendix B for the algorithm description.
ROLL_ANGLE	H5T_IEEE_F32LE	The amount of spacecraft roll in degrees from nadir. The roll value is given in the Yaw Steering Frame (YSF) reference, whose x-axis is aligned with the instantaneous ground track velocity vector. Rolls about this x-axis go by the right-hand rule: a positive roll results in the instruments pointing to the left of the groundtrack, while a negative roll results in a look to the right.
SATELLITE	H5T_STD_U8LE	Value: 8 = Landsat satellite #8
Landsat vehicle number used to capture this acquisition.		
SENSOR_ID	H5T_STRING(8)	= "OLI", “TIRS”, ‘OLI_TIRS”
Sensor used to capture this interval.		
SPACECRAFT_ID	H5T_STRING(9)	= "LANDSAT_8"
Spacecraft from which the data was captured.		
START_TIME_OLI	H5T_STRING(26)	= “YYYY:DDD:HH:MI:SS.SSSSSSS” Where YYYY = 4 digit year, DDD = Day of year, HH = Hour (00–23), MI = Minute, SS.SSSSSSS = Fractional seconds.
Year, Day of year, and UTC spacecraft start time of the first OLI Video Frame timestamp in the interval.		
START_TIME_TIRS	H5T_STRING(26)	= “YYYY:DDD:HH:MI:SS.SSSSSSS”

Parameter Name	HDF5 Type	Value, Format, Range, Units
		Where YYYY = 4 digit year, DDD = Day of year, HH = Hour (00–23), MI = Minute, SS.SSSSSSS = Fractional seconds.
Year, Day of year, and UTC spacecraft start time of the first TIRS Video Frame timestamp in the interval.		
STATION_ID	H5T_STRING(3)	= SSS Where SSS indicates a three character ground station code.
Original ground receiving station to which this data was first received. The ground station codes can be found in LS-IC-04 Landsat Ground Station (GS) Identifiers. See 0.		
STOP_TIME_OLI	H5T_STRING(26)	= "YYYY:DDD:HH:MI:SS.SSSSSSS" Where YYYY = 4 digit year, DDD = Day of year, HH = Hour (00–23), MI = Minute, SS.SSSSSSS = Fractional seconds.
Year, Day of year, and UTC spacecraft stop time of the last OLI Video Frame timestamp in the interval.		
STOP_TIME_TIRS	H5T_STRING(26)	= "YYYY:DDD:HH:MI:SS.SSSSSSS" Where YYYY = 4 digit year, DDD = Day of year, HH = Hour (00–23), MI = Minute, SS.SSSSSSS = Fractional seconds.
Year, Day of year, and UTC spacecraft stop time of the last TIRS Video Frame timestamp in the interval.		
TIME_CODE_ERRORS_OLI	H5T_STD_U32LE	Number of OLI frames for which the Frame Header time code was found to be invalid and corrected. The known OLI time code error is not counted in this field. See 'OLI FPE Time Tag Error Correction Algorithm' in References for more detailed information.
TIME_CODE_ERRORS_TIRS	H5T_STD_U32LE	Number of TIRS frames for which the Frame Header time code was found to be invalid and corrected.
DETECTOR_MAP_ID_TIRS	H5T_STD_U32LE	The unique ID of the TIRS detector map table used in processing.
WRS_ENDING_ROW	H5T_STD_U8LE	= 1–248 (0 for calibration intervals)
WRS row number of the last reported scene, whether full or partial, included in this interval.		
WRS_SCENES	H5T_STD_U8LE	= 0–99 Note: DPAS produces this count from the total number of WRS scenes identified. = 0 for calibration intervals
Total number of full and partial WRS scenes in this interval.		
WRS_SCENES_FULL	H5T_STD_U8LE	= 0–99 = 0 for calibration intervals.
Total number of full scenes in an interval. See Appendix A for a description of full and partial scenes.		
WRS_SCENES_PARTIAL	H5T_STD_U8LE	= 0–99 = 0 for calibration intervals
Total number of partial scenes in an interval. See Appendix A for a description of full and partial scenes.		
WRS_STARTING_PATH	H5T_STD_U8LE	= 1–233 (0 for calibration intervals)

Parameter Name	HDF5 Type	Value, Format, Range, Units
Starting WRS path number for the scenes included in this interval.		
WRS_STARTING_ROW	H5T_STD_U8LE	= 1–248 (0 for calibration intervals)
WRS row number of the first reported scene, whether full or partial, included in this interval.		
WRS_TYPE	H5T_STD_U8LE	= 2 LDCM use the WRS-2 reference system
'WRS which applies to this acquisition (is always 2 for Landsat 8).		

Table 2-30. Metadata File – Interval Metadata Parameters

2.3.4.3 L0Ra Scene Metadata

The WRS scene level metadata records are contained in a dataset named /Scenes and contains information on each WRS scene identified within an interval during L0Ra processing. This dataset is only created for Earth Imaging data identified with WRS-2 scenes. Each scene record contains identification information on the WRS-2 scene, its geolocation references (e.g., scene center and corner information), and quality information associated with the WRS-2 scene. The WRS-2 scene level metadata (see Table 2-31) may contain records for up to 77 full WRS scenes captured during a 31-minute LDCM imaging period. For L0Rp output, see Section 4.

Parameter Name	HDF5 Type	Value, Format, Range, Units
ATTITUDE_POINTS	H5T_STD_U16LE	Total number of good spacecraft attitude data points (quaternions) received and processed from the ancillary data associated with this scene. This number is duplicated from the Interval metadata and therefore contains a count for the entire interval.
ATTITUDE_POINTS_MISSING	H5T_STD_U16LE	Total number of spacecraft attitude data points (quaternions) found missing during ancillary data quality checks. This number is duplicated from the Interval metadata and therefore contains the missing point count for the entire interval.
ATTITUDE_POINTS_REJECTED	H5T_STD_U16LE	Total number of spacecraft attitude data points (quaternions) found to fail the ancillary data quality checks. This number is duplicated from the Interval metadata and therefore contains the rejected point count for the entire interval.
CORNER_UL_LAT_OLI	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees (with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude.
CORNER_UL_LON_OLI	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees (with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude.
Scene upper left corner "actual" longitude for a full or a partial scene.		
CORNER_UR_LAT_OLI	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places)

Parameter Name	HDF5 Type	Value, Format, Range, Units
		A positive (+) value indicates North latitude. A negative (-) value indicates South latitude.
Scene upper right corner "actual" latitude for a full or a partial scene.		
CORNER_UR_LON_OLI	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude.
Scene upper right corner "actual" longitude for a full or a partial scene.		
CORNER_LL_LAT_OLI	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees (with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude.
Scene lower left corner "actual" latitude at for a full or a partial scene.		
CORNER_LL_LON_OLI	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude.
Scene lower left corner "actual" longitude for a full or a partial scene.		
CORNER_LR_LAT_OLI	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude.
Scene lower right corner "actual" latitude for a full or a partial scene.		
CORNER_LR_LON_OLI	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude.
Scene lower right corner "actual" longitude for a full or a partial scene.		
CORNER_UL_LAT_TIRS	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees (with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude.
Although the corner points are provided to five decimal points for LS-DIR-05 Landsat Metadata Definition Document (LMDD) compliance, the values are obtained without accounting for elevation and may be less accurate than the level of detail defined.		
CORNER_UL_LON_TIRS	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees (with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude.
Scene upper left corner "actual" longitude for a full or a partial scene.		
CORNER_UR_LAT_TIRS	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places)

Parameter Name	HDF5 Type	Value, Format, Range, Units
		A positive (+) value indicates North latitude. A negative (-) value indicates South latitude.
Scene upper right corner "actual" latitude for a full or a partial scene.		
CORNER_UR_LON_TIRS	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude.
Scene upper right corner "actual" longitude for a full or a partial scene.		
CORNER_LL_LAT_TIRS	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees (with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude.
Scene lower left corner "actual" latitude at for a full or a partial scene.		
CORNER_LL_LON_TIRS	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude.
Scene lower left corner "actual" longitude for a full or a partial scene.		
CORNER_LR_LAT_TIRS	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees(with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude.
Scene lower right corner "actual" latitude for a full or a partial scene.		
CORNER_LR_LON_TIRS	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude.
Scene lower right corner "actual" longitude for a full or a partial scene.		
CRC_ERRORS	H5T_STD_U32LE	Number of Video Frame Cyclic Redundancy Check failures in this scene and includes both OLI and TIRS failures.
DATE_ACQUIRED	H5T_STRING(26)	= "YYYY:DDD:HH:MI:SS.SSSSSSS" Where YYYY = 4 digit year, DDD = Day of year, HH = Hour (00-23), MI = Minute, SS.SSSSSSS = Fractional seconds
Year, Day of year, and UTC spacecraft time of the WRS scene center.		
DAY_NIGHT	H5T_STRING(5)	Day or night condition of the scene. Values: DAY = Day scene. NIGHT = Night scene.
This field indicates the day or night condition for the scene. DPAS determines the day / night condition of a scene by comparing the Sun elevation values at scene center against an angle value of 0 degrees. A scene is declared a day scene if the Sun elevation angle is greater than 0 degrees; otherwise it is declared a night scene.		
EPHEMERIS_POINTS	H5T_STD_U16LE	Total number of good ephemeris data points received and processed from the ancillary

Parameter Name	HDF5 Type	Value, Format, Range, Units
		data.
EPHEMERIS_POINTS_MISSING	H5T_STD_U16LE	Total number of spacecraft ephemeris data points found missing during ancillary data quality checks. This number is duplicated from the Interval metadata and therefore contains the missing point count for the entire interval.
EPHEMERIS_POINTS_REJECTED	H5T_STD_U16LE	Total number of spacecraft ephemeris data points found to fail ancillary data quality checks. This number is duplicated from the Interval metadata and therefore contains the rejected point count for the entire interval.
FULL_PARTIAL_SCENE	H5T_STRING(7)	= "FULL" or "PARTIAL" = "FULL" if both OLI and TIRS are full. = "PARTIAL" if either is partial. See Appendix A for a description of full and partial scenes.
HOSTNAME	H5T_STRING(20)	Hostname of the machine on which the data files for this interval were processed. For L0Rp output, see Section 4.
IMAGE_QUALITY_OLI	H5T_STD_I8LE	Composite image quality for the bands. Values: 0-9 where 9 = Best. 0 = Worst. -1 = quality not calculated or assessed.
IMAGE_QUALITY_TIRS	H5T_STD_I8LE	Composite image quality for the bands. Values: 0-9 where 9 = Best. 0 = Worst -1 = quality not calculated or assessed.
LANDSAT_SCENE_ID	H5T_STRING(21)	= "VISppprrrYYYYdddGSIvv" V = 'L' for Landsat I = 'O' for OLI, 'T' for TIRS, 'C' for both S = '8' for Landsat 8 ppp = WRS_PATH rrr = WRS_ROW YYYY = imaging year ddd = imaging day-of-year GSI = Ground Station Identifier of receiving station vv = 00-99 L0Ra version
A unique scene ID used for Landsat data consistency and tracking. This identifier matches the interval ID and the filename, except it identifies one row for the scene.		
MISSING_FRAMES	H5T_STD_U16LE	= 0–65535
Total number of frames considered zero-filled.		
NADIR_OFFNADIR	H5T_STRING (9)	Nadir or Off-Nadir condition of the interval or scene.
Values: "NADIR" = The scene was captured nadir. "OFFNADIR" The scene was captured off-nadir (absolute roll angle greater than 0.045 degrees).		
ROLL_ANGLE	H5T_IEEE_F32LE	= -15.0 to +15.0 degrees
The amount of spacecraft roll in degrees from nadir at the frame closest to the nominal WRS scene center. The roll value is given in YSF reference, whose x-axis is aligned with the instantaneous ground track velocity vector. Rolls about this x-axis go by the right-hand rule: a positive roll results in the instruments pointing to the left of the groundtrack, while a negative roll results in a look to the right.		

Parameter Name	HDF5 Type	Value, Format, Range, Units
SCENE_CENTER_LAT	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees (with a precision to five decimal places) A positive (+) value indicates North latitude. A negative (-) value indicates South latitude.
WRS scene center latitude. Calculated coordinate value. The computed "actual" scene centers are from the image frame closet to the nominal WRS scene center.		
SCENE_CENTER_LON	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees(with a precision to five decimal places) A positive value (+) indicates East longitude. A negative (-) value indicates West longitude.
WRS scene center longitude. Calculated coordinate value. The computed "actual" scene centers are from the image frame closest to the nominal WRS scene center.		
SCENE_CENTER_SHIFT	H5T_STD_I32LE	= - 999999 through + 999999 meters A negative (-) value defines a shift of the calculated "true" WRS scene center to the right side of the nominal WRS ground track. A positive (+) value defines a shift of the calculated "true" WRS scene center to the left side of the nominal WRS ground track. Any Scene Center Shift values computed from poor ephemeris values that are larger than the maximum values result in the maximum values (-999999 or +999999).
The ground distance between the DPAS-calculated actual WRS scene center and the nominal WRS scene center.		
SCENE_START_FRAME_OLI	H5T_STD_U32LE	= 1–1048575
Frame number within interval associated with the first video frame of the scene. This is the /OLI/Frame_Headers Frame Number associated with the start of a WRS-2 scene. A zero in this field indicates OLI is not present for this scene.		
SCENE_STOP_FRAME_OLI	H5T_STD_U32LE	= 1–1048575
Frame number within interval associated with the last frame of a scene. This is the /OLI/Frame_Headers Frame Number associated end of a WRS-2 scene. This is the video frame that includes the last pixels needed to complete a 180km WRS-2 scene. A zero in this field indicates OLI is not present for this scene.		
SCENE_START_FRAME_TIRS	H5T_STD_U32LE	= 1–126,000
Frame number within interval associated with the first video frame of the scene. This is the /TIRS/Frame_Headers Frame Number associated with the start of a WRS-2 scene. This field should typically not be larger than 126000, but could theoretically go up to the maximum supported by TIRS (16777216). A zero in this field indicates TIRS is not present for this scene.		
SCENE_STOP_FRAME_TIRS	H5T_STD_U32LE	= 1–126,000
Frame number within interval associated with the last frame of a scene. This is the /TIRS/Frame_Headers Frame Number associated end of a WRS-2 scene. This is the video frame that includes the last pixels needed to complete a 180km WRS-2 scene. This field should typically not be larger than 126000, but could theoretically go up to the maximum supported by TIRS (16777216). A zero in this field indicates TIRS is not present for this scene.		
PRESENT_SENSOR_OLI	H5T_STRING(1)	This field is set to Y if data for OLI is present

Parameter Name	HDF5 Type	Value, Format, Range, Units
		and N if it is not. This information is useful when reading other fields spilt by a sensor.
PRESENT_SENSOR_TIRS	H5T_STRING(1)	This field is set to N if data for TIRS is present and 0 if it is not. This information is useful when reading other fields spilt by a sensor.
START_TIME	H5T_STRING(26)	= “YYYY:DDD:HH:MI:SS.SSSSSSS” Where YYYY = 4 digit year, DDD = Day of year, HH = Hour (00–23), MI = Minute, SS.SSSSSSS = Fractional seconds. Year, day of year, and spacecraft start time of either the first image data in the interval or the start of a WRS scene.
STOP_TIME	H5T_STRING(26)	= “YYYY:DDD:HH:MI:SS.SSSSSSS” Where YYYY = 4 digit year, DDD = Day of year, HH = Hour (00-23), MI = Minute, SS.SSSSSSS = Fractional seconds. The time format is the same as for Interval START_TIME, above.
SUBSETTER_VERSION_L0RP	H5T_STRING(10)	= "X.Y.Z": X, Y, Z are all numeric values X is the major release number Y is the minor release number Z is the patch (or engineering) release number
Version number of the Subsetter software in use when the L0Rp data request is processed. For L0Ra output, =“”. For L0Rp output, see Section 4.		
SUN_AZIMUTH	H5T_IEEE_F64LE	= -180.0 through +180.0 degrees A positive value (+) indicates angles to the East or clockwise from North. A negative value (-) indicates angles to the West or counterclockwise from North.
The Sun azimuth angle at the frame closest to the actual scene center.		
SUN_ELEVATION	H5T_IEEE_F64LE	= -90.0 through +90.0 degrees A positive value (+) indicates a daytime scene. A negative value (-) indicates a nighttime scene.
The Sun elevation angle at the frame closest to the actual scene center.		
TARGET_WRS_PATH	H5T_STD_U16LE	= 001–233
Nearest WRS path to the actual scene center. This is used primarily for scenes with off-nadir look angles. The center of the scene for off-nadir imaging may be several paths left or right of the orbital path and the center may even be off the WRS-2 grid when near the poles. This is an estimated value, for reference. For nadir scenes, the target path is generally the same as the orbital path (may vary due to spacecraft drift or variations in inclination angle near the poles).		
TARGET_WRS_ROW	H5T_STD_U16LE	= 001–248, 880–889, 990–999
Nearest WRS row to the actual scene center. This is used primarily for scenes with off-nadir look angles. The center of the scene for off-nadir imaging may be several rows above or below the orbital		

Parameter Name	HDF5 Type	Value, Format, Range, Units
row and the center may even be off the WRS-2 grid when near the poles. This is an estimated value, for reference. See subsection 3.2 for more information. For nadir scenes, the target row is generally the same as the orbital row (may vary due to spacecraft drift or variations in inclination angle near the poles).		
TIME_CODE_ERRORS	H5T_STD_U16LE	= 0--9999
The total number of OLI and TIRS frames detected with errors in their time code fields during processing of this scene.		
WRS_PATH	H5T_STD_U16LE	= 001–233
WRS-defined orbital Landsat satellite track.		
WRS_ROW	H5T_STD_U16LE	= 001–248
WRS-defined nominal Landsat satellite row, based on the latitudinal center frame of a Landsat image.		
WRS_SCENE_NUMBER	H5T_STD_U8LE	1–99
Sequence number of this scene within the interval. For LDCM, the largest interval is 77 full scenes.		

Table 2-31. Metadata File – Scene Metadata Parameters

2.4 Example Files

This subsection shows example file structure and data for various collections. The format is similar to the HDF h5dump utility output. The files, groups, datasets, and data have been rearranged for readability while displaying the same content. Underlines are added for readability.

2.4.1 Earth Imaging Interval

```
HDF5 "LC81640440442000248SGS00_B1.h5"
{
GROUP "/" {
   ATTRIBUTE "L0R Format Version" {
      DATATYPE  H5T_STD_U32LE
      DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
   }
   DATASET "Detector_Offsets" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 2, 494 ) / ( 14, H5S_UNLIMITED,
494 ) }
   }
   DATASET "Image" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 7484, 494 ) / ( 14,
H5S_UNLIMITED, 494 ) }
   }
   DATASET "VRP" {
      DATATYPE  H5T_STD_U16LE
      DATASPACE  SIMPLE { ( 14, 7484, 12 ) / ( 14, H5S_UNLIMITED,
12 ) }
   }
}
}

HDF5 "LC81640440442000248SGS00_B10.h5"
{
GROUP "/" {
```

```
      ATTRIBUTE "L0R Format Version" {
         DATATYPE  H5T_STD_U32LE
         DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
      }
      DATASET "Detector_Offsets" {
         DATATYPE  H5T_STD_U16LE
         DATASPACE  SIMPLE { ( 3, 2, 640 ) / ( 3, H5S_UNLIMITED, 640
   ) }
      }
      DATASET "Image" {
         DATATYPE  H5T_STD_U16LE
         DATASPACE  SIMPLE { ( 3, 2616, 640 ) / ( 3, H5S_UNLIMITED,
   640 ) }
      }
   }
   }
```

Figure 2-24. Example OLI & TIRS Band Files (Earth Imaging Interval)

```
   HDF5 "LC81640440442000248SGS00_ANC.h5"
   {
   GROUP "/" {
      ATTRIBUTE "L0R Format Version" {
         DATATYPE  H5T_STD_U32LE
         DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
      }
      GROUP "OLI" {
         DATASET "Image_Header" {
         }
         DATASET "Frame_Headers" {
         }
      }
      GROUP "Spacecraft" {
         GROUP "ACS" {
            DATASET "Attitude" {
            }
            DATASET "Attitude_Filter" {
            }
         }
         DATASET “Ephemeris”{
         }
         DATASET "GPS_Position" {
         }
         DATASET "GPS_Range" {
         }
         GROUP "IMU" {
            DATASET "Gyro" {
            }
            DATASET "Latency" {
            }
         }
         DATASET "Star_Tracker_Centroid" {
         }
         DATASET "Star_Tracker_Quaternion" {
         }
```

```
            GROUP "Temperatures" {
               DATASET "Gyro" {
            }
               DATASET "OLI_TIRS" {
            }
         }

         GROUP "Telemetry" {
            GROUP "OLI" {
               DATASET "Telemetry_Group_3" {
               }
               DATASET "Telemetry_Group_4" {
               }
               DATASET "Telemetry_Group_5" {
               }
            }
            GROUP "TIRS" {
               DATASET "TIRS_Telemetry" {
               }
            }
         }
         GROUP "TIRS" {
            DATASET "Frame_Headers" {
            }
         }
         }
```

Figure 2-25. Example Ancillary Data File (Earth Imaging Interval)

```
HDF5 "LC81640440442000248SGS00_MTA.h5"
{
ATTRIBUTE "L0R Format Version" {
   DATATYPE  H5T_STD_U32LE
   DATASPACE  SIMPLE { ( 1 ) / ( 1 ) }
}
DATASET "File" {
   DATATYPE  H5T_COMPOUND {
      H5T_ARRAY [32]H5T_STRING "ANCILLARY_FILE_NAME" {
          " LC81640440442000248SGS00_ANC.h5"
    }
      H5T_ARRAY [32]H5T_STRING "CHECKSUM_FILE_NAME" {
          " LC81640440442000248SGS00_MD5.txt"
    }
      H5T_ARRAY [32]H5T_STRING "FILE_NAME_BAND_1" {
          " LC81640440442000248SGS00_B1.h5"
    }

  --- Repeat FILE_NAME_BAND_X items for bands 2-17 ---

      H5T_ARRAY [32]H5T_STRING "FILE_NAME_BAND_18" {
          " LC81640440442000248SGS00_B18.h5"
    }
      H5T_ARRAY [32]H5T_STRING "METADATA_FILE_NAME" {
          " LC81640440442000248SGS00_MTA.h5"
    }
 }
```

```
   }
   DATASET "Interval" {
      DATATYPE  H5T_COMPOUND {
         H5T_ARRAY [26]H5T_STRING "ANCILLARY_START_TIME" {
             " 2000:248:07:02:13.7980382"
         }
         H5T_ARRAY [26]H5T_STRING "ANCILLARY_STOP_TIME"; {
             " 2000:248:07:03:39.7780363"
         }
         H5T_STD_U16LE "ATTITUDE_POINTS" {
             4300
         }
         H5T_STD_U16LE "ATTITUDE_POINTS_MISSING" {
             1
         }
         H5T_STD_U16LE "ATTITUDE_POINTS_REJECTED" {
             2
         }
         H5T_ARRAY { [50] H5T_STRING "COLLECTION_TYPE" {
             "EARTH_IMAGING"
         }
         H5T_IEEE_F64LE "CORNER_UL_LAT_OLI" {
             24.13886
         }
         H5T_IEEE_F64LE "CORNER_UL_LON_OLI" {
             47.92739
         }
         H5T_IEEE_F64LE "CORNER_UR_LAT_OLI" {
             23.76992
         }
         H5T_IEEE_F64LE "CORNER_UR_LON_OLI" {
             49.75465
         }
         H5T_IEEE_F64LE "CORNER_LL_LAT_OLI" {
             22.40772
         }
         H5T_IEEE_F64LE "CORNER_LL_LON_OLI" {
             47.52651
         }
         H5T_IEEE_F64LE "CORNER_LR_LAT_OLI" {
             22.03709
         }
         H5T_IEEE_F64LE "CORNER_LR_LON_OLI" {
             49.33001
         }
         H5T_IEEE_F64LE "CORNER_UL_LAT_TIRS" {
             23.82883
         }
         H5T_IEEE_F64LE "CORNER_UL_LON_TIRS" {
             47.87219
         }
         H5T_IEEE_F64LE "CORNER_UR_LAT_TIRS" {
             23.46549
         }
         H5T_IEEE_F64LE "CORNER_UR_LON_TIRS" {
             49.66577
         }
```

```
H5T_IEEE_F64LE "CORNER_LL_LAT_TIRS" {
    22.11394
}
H5T_IEEE_F64LE "CORNER_LL_LON_TIRS" {
    47.47567
}
H5T_IEEE_F64LE "CORNER_LR_LAT_TIRS" {
    21.75065
}
H5T_IEEE_F64LE "CORNER_LR_LON_TIRS" {
    49.24686
}
H5T_ARRAY [25]H5T_STRING "CPF_NAME" {
    " L8CPF20000701_20000930.01"
}
H5T_STD_U32LE "CRC_ERRORS_OLI" {
    0
}
H5T_STD_U32LE "CRC_ERRORS_TIRS" {
    0
}
H5T_ARRAY [20] H5T_STRING "DATA_TYPE" {
    "OLI_TIRS_LORA"
}
H5T_ARRAY [26] H5T_STRING "DATE_ACQUIRED" {
    "2000:248:07:02:13.9687660"
}
H5T_STD_U32LE "EPHEMERIS_POINTS" {
    86
}
H5T_STD_U32LE "EPHEMERIS_POINTS_MISSING" {
    0
}
H5T_STD_U32LE "EPHEMERIS_POINTS_REJECTED" {
    0
}
H5T_STD_U16LE "FRAMES_FILLED_OLI" {
    0
}
H5T_STD_U16LE "FRAMES_FILLED_TIRS" {
    0
}
H5T_ARRAY [20] H5T_STRING "HOSTNAME" {
    "hostname_ABC"
}
H5T_STD8LE "IMAGE_QUALITY_OLI" {
    9
}
H5T_STD8LE "IMAGE_QUALITY_TIRS" {
    9
}
H5T_STD_U8LE "INTERVAL_FILES" {
    21
}
H5T_STD_U32LE " INTERVAL_FRAMES_OLI" {
    7484
}
```

```
H5T_STD_U32LE " INTERVAL_FRAMES_TIRS" {
    2616
}
H5T_STD_U8LE "INTERVAL_NUMBER" {
    1
}
H5T_STD_U8LE "INTERVAL_VERSION" {
    0
}
H5T_ARRAY [10] H5T_STRING "IS_VERSION" {
    "3.0.0"
}
H5T_ARRAY [24] H5T_STRING "LANDSAT_CAL_INTERVAL_ID" {
    ""
}
H5T_ARRAY [24] H5T_STRING "LANDSAT_INTERVAL_ID" {
    "LC81640440442000248SGS00"
}
H5T_ARRAY [9] H5T_STRING "NADIR_OFFNADIR" {
    "NADIR"
}
H5T_ARRAY [50]H5T_STRING "QUALITY_ALGORITHM" {
    "2011012:LDCM_IMAGE_QUALITY:01.00.00"
}
H5T_IEEE_F32LE "ROLL_ANGLE" {
    -0.0003278
}
H5T_STD_U8LE "SATELLITE" {
    8
}
H5T_ARRAY [8]H5T_STRING "SENSOR_ID" {
    "OLI_TIRS"
}
H5T_ARRAY [9]H5T_STRING "SPACECRAFT_ID" {
    "LANDSAT_8"
}
H5T_ARRAY [26]H5T_STRING "START_TIME_OLI" {
    "2000:248:07:02:13.9687660"
}
H5T_ARRAY [26]H5T_STRING "START_TIME_TIRS" {
    "2000:248:07:02:15.7475200"
}
H5T_ARRAY [3]H5T_STRING "STATION_ID" {
    "SGS"
}
H5T_ARRAY [26]H5T_STRING "STOP_TIME_OLI" {
    "2000:248:07:02:45.6667540"
}
H5T_ARRAY [26]H5T_STRING "STOP_TIME_TIRS" {
    "2000:248:07:02:53.1054100"
}
H5T_STD_U32LE "TIME_CODE_ERRORS_OLI" {
    0
}
H5T_STD_U32LE "TIME_CODE_ERRORS_TIRS" {
    0
}
```

```
        H5T_STD_U32LE "DETECTOR_MAP_ID_TIRS" {
            0
        }
        H5T_STD_U8LE "WRS_ENDING_ROW" {
            45
        }
        H5T_STD_U8LE "WRS_SCENES" {
            3
        }
        H5T_STD_U8LE "WRS_SCENES_FULL" {
            0
        }
        H5T_STD_U8LE "WRS_SCENES_PARTIAL" {
            3
        }
        H5T_STD_U8LE "WRS_STARTING_PATH" {
            164
        }
        H5T_STD_U8LE "WRS_STARTING_ROW" {
            43
        }
        H5T_STD_U8LE "WRS_TYPE" {
            2
        }
    }
}
DATASET "Scenes" {
   DATATYPE  H5T_COMPOUND {
      H5T_STD_U16LE "ATTITUDE_POINTS" {
          4300,4300,4300
    }
      H5T_STD_U16LE "ATTITUDE_POINTS_MISSING" {
          0,0,0
    }
      H5T_STD_U16LE "ATTITUDE_POINTS_REJECTED" {
          0,0,0
    }
      H5T_IEEE_F64LE "CORNER_UL_LAT_OLI" {
          24.13886,24.11741,22.67601
    }
      H5T_IEEE_F64LE "CORNER_UL_LON_OLI" {
          47.92740,47.92241,47.58816
    }
      H5T_IEEE_F64LE "CORNER_UR_LAT_OLI" {
          23.76989,23.74849,22.30867
    }
      H5T_IEEE_F64LE "CORNER_UR_LON_OLI" {
          49.75482,49.74937,49.39584
    }
    H5T_IEEE_F64LE "CORNER_LL_LAT_OLI" {
          23.95107,22.50946,22.40771
    }
      H5T_IEEE_F64LE "CORNER_LL_LON_OLI" {
          47.88367,47.54985,47.52660
    }
      H5T_IEEE_F64LE "CORNER_LR_LAT_OLI" {
          23.57873,22.13870,22.03709
```

```
    }
      H5T_IEEE_F64LE "CORNER_LR_LON_OLI" {
          49.70762,49.35462,49.33001
    }
      H5T_IEEE_F64LE "CORNER_UL_LAT_TIRS" {
          0.00000,23.82884,23.15424
    }
      H5T_IEEE_F64LE "CORNER_UL_LON_TIRS" {
          0.00000,47.87219,47.71540
    }
      H5T_IEEE_F64LE "CORNER_UR_LAT_TIRS" {
          0.00000,23.46550,22.79166
    }
      H5T_IEEE_F64LE "CORNER_UR_LON_TIRS" {
          0.00000,49.66577,49.49998
    }
    H5T_IEEE_F64LE "CORNER_LL_LAT_TIRS" {
          0.00000,23.13278,22.11391
    }
      H5T_IEEE_F64LE "CORNER_LL_LON_TIRS" {
          0.00000,47.71018,47.47581
    }
      H5T_IEEE_F64LE "CORNER_LR_LAT_TIRS" {
          0.00000,22.76834,21.75065
    }
      H5T_IEEE_F64LE "CORNER_LR_LON_TIRS" {
          0.00000,49.49413,49.24690
    }

      H5T_STD_U32LE "CRC_ERRORS" {
          0,0,0,0
    }
      H5T_ARRAY [26] H5T_STRING "DATE_ACQUIRED" {
          "2000:248:07:02:13.9726354",
          "2000:248:07:02:29.1560955",
          "2000:248:07:02:45.6628846"
    }
      H5T_ARRAY [5]H5T_STRING "DAY_NIGHT" {
          "DAY","DAY","DAY","DAY"
    }
      H5T_STD_U16LE "EPHEMERIS_POINTS" {
          86,86,86
    }
      H5T_STD_U16LE "EPHEMERIS_POINTS_MISSING" {
          0,0,0
    }
      H5T_STD_U16LE "EPHEMERIS_POINTS_REJECTED" {
          0,0,0
    }
      H5T_ARRAY [7]H5T_STRING "FULL_PARTIAL_SCENE" {
          "PARTIAL","PARTIAL","PARTIAL"
    }
      H5T_ARRAY [20]H5T_STRING "HOSTNAME" {
          "hostname_ABC", "hostname_ABC","hostname_ABC"      }
      H5T_STD_I8LE "IMAGE_QUALITY" {
          9,9,9
    }
```

```
  H5T_ARRAY [21]H5T_STRING "LANDSAT_SCENE_ID" {
      "LC81640432000248SGS00",
      "LC81640442000248SGS00",
      "LC81640452000248SGS00"
}
  H5T_STD_U16LE "MISSING_FRAMES" {
      0,0,0
}
  H5T_ARRAY [9]H5T_STRING "NADIR_OFFNADIR" {
      "NADIR","NADIR","NADIR"
}
  H5T_IEEE_F32LE "ROLL_ANGLE" {
      -0.00033,0.00179,-0.00063
}
  H5T_IEEE_F64LE "SCENE_CENTER_LAT" {
      24.02305,23.10792,22.11233
}
  H5T_IEEE_F64LE "SCENE_CENTER_LON" {
      48.99363,48.77329,48.53640
}
  H5T_STD_I32LE "SCENE_CENTER_SHIFT" {
     -3646,-7270,-11358
}
  H5T_STD_U32LE "SCENE_START_FRAME_OLI" {
      1,85,5726
}
  H5T_STD_U32LE "SCENE_STOP_FRAME_OLI" {
      1445,7086,7484
}
  H5T_STD_U32LE "SCENE_START_FRAME_TIRS" {
      0,1,784
}
  H5T_STD_U32LE "SCENE_STOP_FRAME_TIRS" {
      0,1434,2616
}
  H5T_STD_U8LE "PRESENT_SENSOR_OLI" {
      "Y","Y","Y"
}
  H5T_STD_U8LE "PRESENT_SENSOR_TIRS" {
      "N","Y","Y"
}
  H5T_ARRAY [26] H5T_STRING "START_TIME" {
      "2000:248:07:02:13.9687660",
      "2000:248:07:02:14.3245900",
      "2000:248:07:02:30.8322820"    }
  H5T_ARRAY [26] H5T_STRING "STOP_TIME" {
      "2000:248:07:02:28.7990020",
      "2000:248:07:02:43.9808260",
      "2000:248:07:02:45.6667540"
}
  H5T_ARRAY [26] H5T_STRING "SUBSETTER_VERSION_L0RP" {
      "","",""
}
  H5T_IEEE_F64LE "SUN_AZIMUTH" {
      120.77365,119.17529,117.40026
}
  H5T_IEEE_F64LE "SUN_ELEVATION" {
```

```
                60.55819,60.88847,61.22126
        }
          H5T_STD_U16LE "TARGET_WRS_PATH" {
              164,164,164
        }
          H5T_STD_U16LE "TARGET_WRS_ROW" {
              43,44,45
        }
          H5T_STD_U16LE "TIME_CODE_ERRORS" {
              0,0,0
        }
          H5T_STD_U16LE "WRS_PATH" {
              164,164,164
        }
          H5T_STD_U16LE "WRS_ROW" {
              43,44,45
        }
          H5T_STD_U8LE "WRS_SCENE_NUMBER" {
              1,2,3
        }
    }
}
```

Figure 2-26. Example Metadata File (Earth Imaging Interval)

2.4.2 Calibration Interval

The metadata for the calibration interval have the same format as those described in the previous section for the Earth Imaging interval. The calibration interval is not framed to WRS2 scenes. Therefore, only the file and interval datasets are applicable for this data.

Section 3 Mission Data and L0Ra Data Notes

3.1 Image Data

The DPAS Ingest Subsystem reads LDCM mission data files and outputs L0Ra data files. The nomenclature used to describe the data formats is different for the two formats. Further information is found in LDCM-DFCB-001 Landsat Data Continuity Mission (LDCM) Mission Data Data Format Control Book (DFCB). See References.

Mission data are described in terms of Frames, Frame Headers, and Lines. A frame is a complete segment of image data. It consists of a series of consecutive image lines for a given duration with minimal header information. At the beginning of every line is a Line Header. For OLI data, the first line in the frame (line 0) is referred to as the Frame Header. Each image line contains data from all SCAs for the sensor (14 OLI, 3 TIRS). Four OLI Panchromatic lines exist (PAN 1 Odd, PAN 1 Even, PAN 2 Odd, and PAN 2 Even).

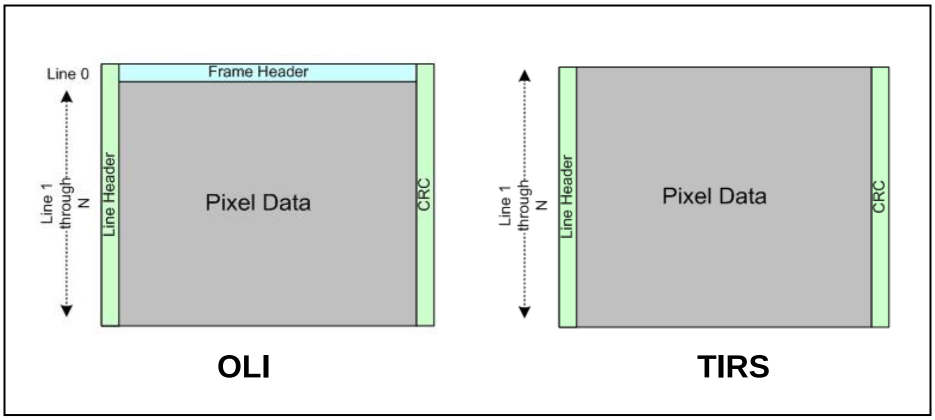

Figure 3-1. Mission Data Structure

L0Ra data are described in terms of Images, Bands, and Frames. An Image is the complete segment of imagery data, with the header data stripped off. The image data are separated into bands. The L0Ra Panchromatic band contains two mission data Panchromatic band lines (Pan 1 and Pan 2), each of which consists of two mission data Panchromatic band lines (Even and Odd detectors). The term ‘Video Frame’ describes this ‘group’ of mission data lines. For the other OLI bands and the TIRS bands, a mission data line and an L0Ra video frame contain the same data (pixels).

L0Ra band and Level 1 imagery are also described in terms of lines. For the Panchromatic band, each line has twice the number of pixels as the other OLI bands, and has twice as many lines as in the other OLI bands.

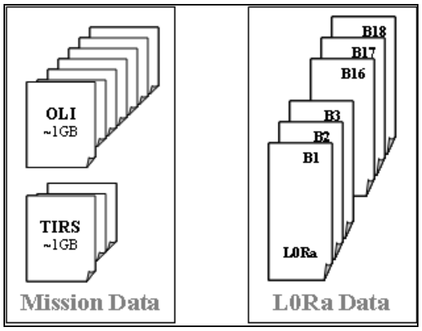

Figure 3-2. Mission Data Files and L0Ra Band Files

3.2 Off-nadir Scene Framing

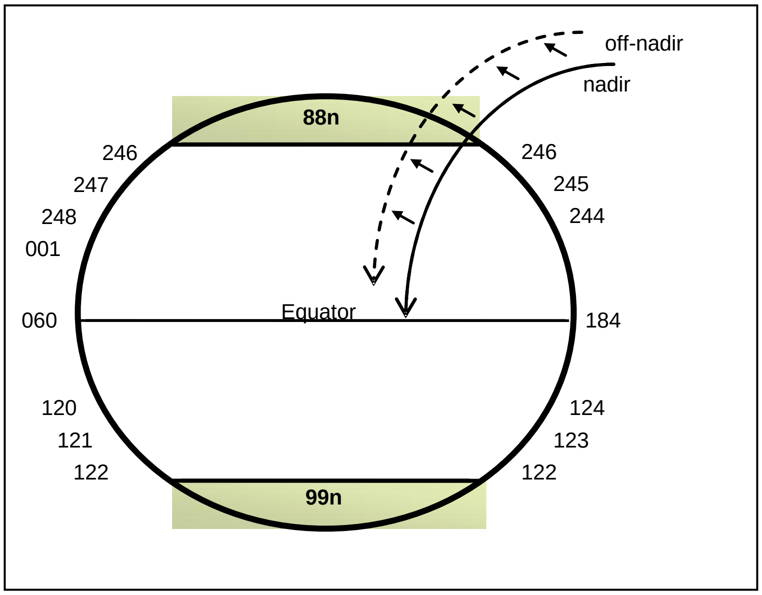

Figure 3-3. Off-nadir Scene Framing

For collections near the poles, it is possible to look off-nadir toward the pole, into an area not defined by the WRS-2 grid (above 82.61 degrees). To allow unique Target Row assignments, the North Pole area is assigned a row of 88n, and the South Pole area is assigned a row of 99n, where n is a sequential number. Up to seven scenes can be covered in these areas; therefore, the scenes are assigned row numbers 880 to 886, or 990 to 996.

3.3 Corner Coordinates

Corner coordinates for descending L0Ra scenes are determined as follows:

- UL - The upper left corner is based on the leading SCA upper left corner, corner point C1, at the scene start time.

- UR - The upper right corner is based on the top edge of the trailing odd SCA, corner point C2, and the upper right corner of the trailing SCA, corner point C3, at the scene stop time.
- LL - The lower left corner is based on the leading SCA, corner point C7, and the lower edge of the leading even SCA, corner point C6, at the scene stop time.
- LR - The lower right corner is based on the lower right corner of the trailing SCA at the scene stop time.

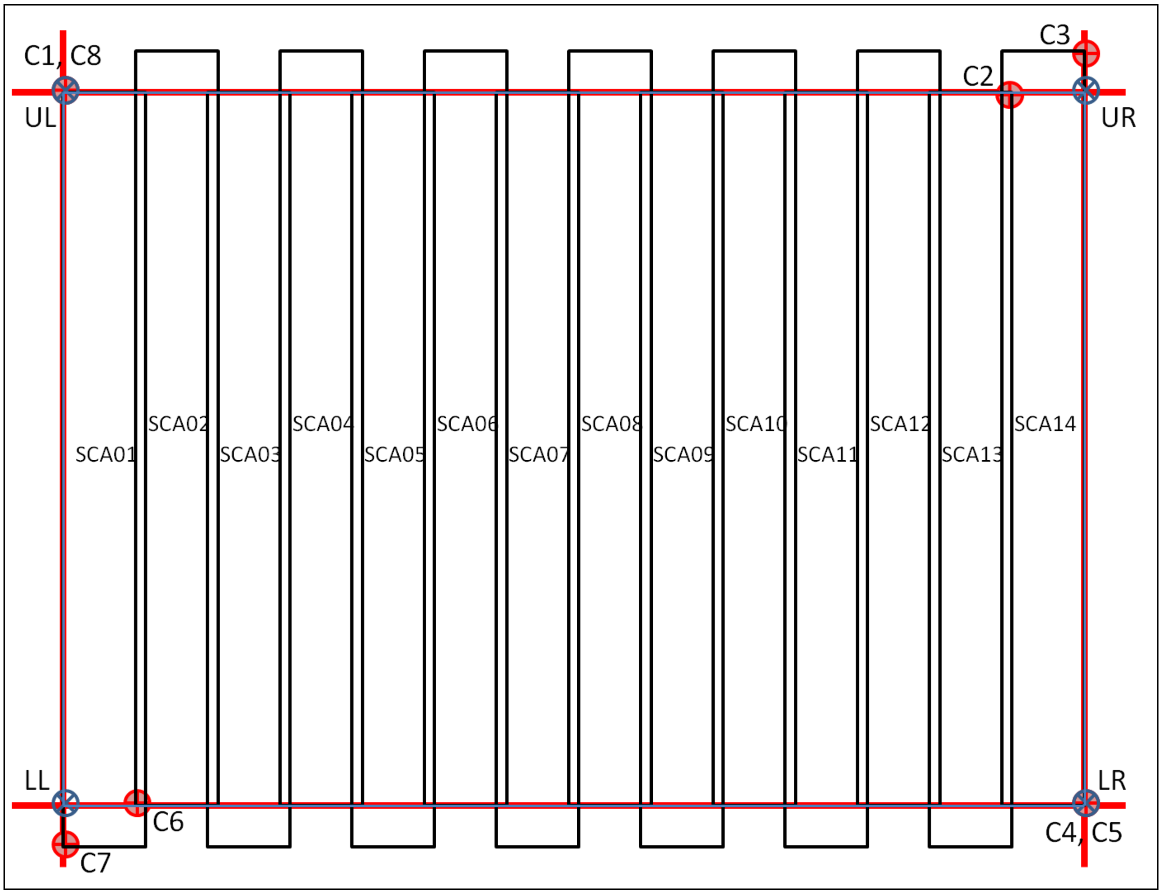

Figure 3-4. OLI Active Image Area

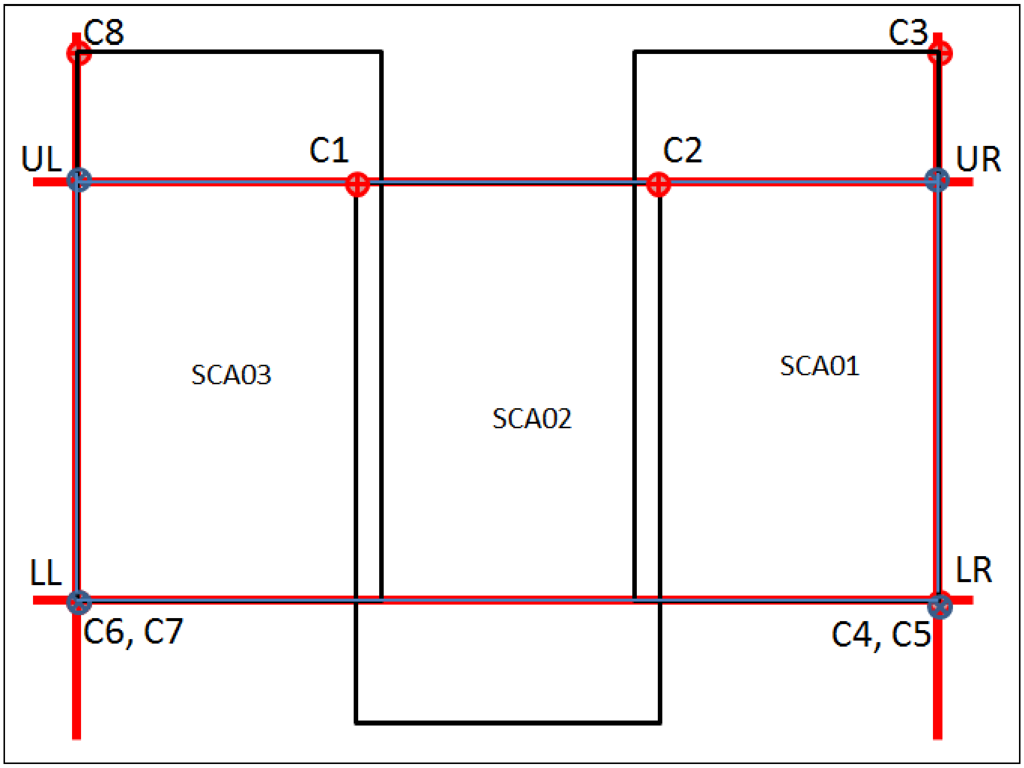

Figure 3-5. TIRS Active Image Area

Lower corner coordinates correspond to the leading edge (last line) of a scene, and upper coordinates correspond to the trailing edge (first line) of a scene. For the OLI corner calculation the Cirrus band is used and similarly the 10.8 µm band is used for TIRS.

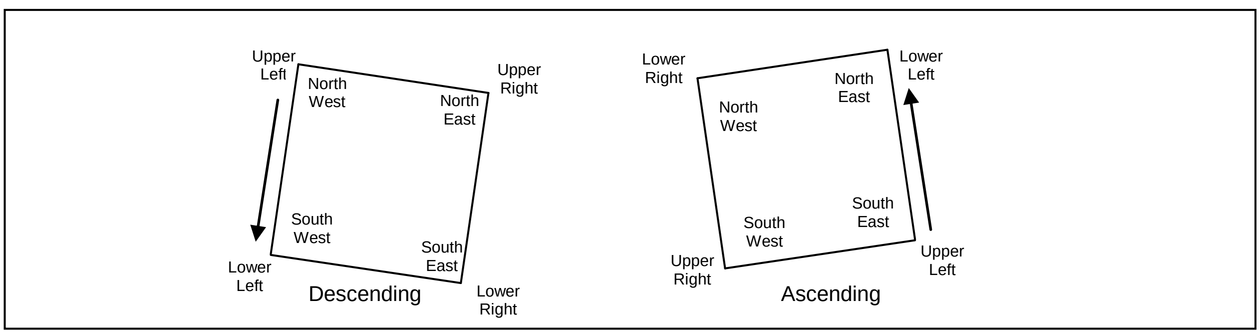

Figure 3-6. Landsat Image Corner Orientation

Section 4 L0Rp Processing, Product, and DFCB

The L0Rp files are in the same format as L0Ra files. The difference between L0Ra and L0Rp files is in the content of the data. L0Ra files contain an entire interval of imagery. The L0Rp files contain a smaller portion of that L0Ra data: a WRS-2 scene-based subset. The ancillary data file always contains the spacecraft and instrument ancillary data for the full interval, but only the header data from OLI and TIRS frames are present in the band files. The redundant TIRS bands (16, 17, and 18) are optional. No Quality Band or Browse files exist.

L0Ra → L0Rp document differences

- Title, File Properties, applicable Configuration Change Requests (CCRs), Document Control Number (DCN), Headers / Footers

L0Ra → L0Rp file changes during DPAS processing (Subsetter Subsystem)

- Metadata file (HDF5 format):
    - File Metadata
        - FILE_NAME_BAND_16–18 may be blank
        - INTERVAL_FILES updated
          (Total number of files included in this interval)
    - Interval Metadata (contains L0Ra interval parameters) except for:
        - DATA_TYPE OLI_L0RP, TIRS_L0RP, OLI_TIRS_L0RP
          (Data type identifier string for the interval)
    - Scene metadata (contains only the single-scene metadata)
        - SUBSETTER_VERSION_L0RP updated
          (Version number of the Subsetter software in use when the L0Rp data request is processed)
        - HOSTNAME updated
          (Hostname of the machine on which the data files for this scene were processed)
- Checksum file:
    - A new checksum file is created for the L0Rp files

L0Rp data → L0Rp product (LPGS Subsystem)

- The final output product is a tar.gz file. The files (band files (1–15 or 1–18), ancillary, metadata, L0Rp checksum) are written to a .tar file format. The tar file does not contain any subdirectory information; therefore, uncompressing (untarring) the file dumps all of the files directly into the current directory. The .tar file is compressed with the gzip application.
- A checksum file of the tar.gz file is created.

Position	Description
L	Landsat
S	Sensor of: O = OLI, T = TIRS, C = Combined TIRS and OLI Indicates which sensor collected data for this product
8	Landsat mission number
PPP	Satellite orbit location in reference to the WRS-2 path of the product
RRR	Satellite orbit location in reference to the WRS-2 row of the product
YYYY	Acquisition year of the image
DDD	Acquisition day of year
GGG	Ground Station ID
VV	Version (vv = 00–99)
_L0R	Designates an L0R product package
.FT	File type, where .FT equals tar (tar'd file), _MD5 equals checksum
.EXT	File extension, where .gz equals gzip compressed, .txt equals text

Table 4-1. L0Rp Product – File Naming Convention

Example: LC82220032014265LGN01_L0R.tar.gz
LC82220032014265LGN01_L0R_MD5.txt

Appendix A Glossary

<u>Collection</u>: The set of data received from an LDCM imaging period.

<u>LDCM Imaging Period</u>: The time duration between the start and end of an imaging operation by the instruments onboard the LDCM spacecraft.

<u>L0Ra Files</u>: Denotes the band, ancillary, metadata, and checksum files for a single interval.

<u>SCA</u>: One of the assemblies that comprise the focal plane of the imaging instruments.

<u>WRS Scenes</u>: Full and Partial, as follows:

- Full - A full WRS scene product with approximately ten percent overlap is defined as 180km. For OLI, this is 7001 frames (~28.86-meter MS lines) and for TIRS, this is 2801 frames (~86.91-meter lines).
- Partial – Considered less than a full scene.

Appendix B QUALITY ALGORITHM

The quality algorithm designated as '2011012:LDCM_IMAGE_QUALITY:01.00.00' is calculated by the following two formulas:

$$SIQS = 9 - \left\lfloor \frac{SNF}{ANF} * \left(\frac{NDF}{DFBP} + \frac{NCF}{CFBP} \right) \right\rfloor$$

$$IIQS = 9 - \left\lfloor \left(\frac{NDF}{DFBP} + \frac{NCF}{CFBP} \right) \right\rfloor$$

Where:

SIQS = Scene Image Quality Score
IIQS = Interval Image Quality Score
SNF = Standard number of video frames in a scene [7001 for OLI, 2801 for TIRS]
ANF = Actual number of frames in the scene / interval
NDF = Number of dropped frames in the scene / interval
DFBP = Dropped Frame Break Point: dropped frame count at which the quality score drops by one point. [2]
NCF = Number of video frame CRC failures in the scene / interval
CFBP = CRC Failures Break Point: Video frame CRC failure count at which the quality score drops by one point. [100]

Numbers in brackets are configurable. If changed, the quality algorithm version is updated and the new values documented.

References

See http://landsat.usgs.gov/tools_acronyms_ALL.php for a list of acronyms.

Ball Aerospace & Technologies Corp. Document No. 2339436. OLI FPE Time Tag Error Correction Algorithm.

National Aeronautics and Space Administration (NASA). TIRS-SE-REF-0060. Science Data Description Document.

Orbital Sciences Corporation (Orbital). 70-P58230P, Rev D. Spacecraft To Ground Interface Control Document (ICD).

EROS. LDCM-DFCB-001. Landsat Data Continuity Mission (LDCM) Mission Data Data Format Control Book (DFCB).

EROS. LDCM-DFCB-005. Landsat Data Continuity Mission (LDCM) Calibration Parameter File (CPF) Data Format Control Document (DFCB).

EROS. LS-IC-04. Landsat Ground Station (GS) Identifiers.

EROS. LS-DIR-05. Landsat Metadata Definition Document (LMDD), Version 8.1.