Mars 2020 Rover Mission (M2020)

Software Interface Specification

Interface Title: **PIXL Instrument Experiment Data Record (EDR) Data Products for Non-Imaging Components**

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Signatures

IDS Generating Elements:

Instrument Data System (IDS)
Doug Alexander

Subsystem Lead Date

Science Receiving Elements:

M2020 Deputy Project Scientist
########

Deputy Project Scientist Date

IDS Receiving Elements:

M2020 IDS System Engineer
############

System Engineer Date

M2020 IDS IPE System Engineer
############

Subsystem Lead Date

Concurrence:

M2020 ############ Investigation Scientist
Abigail Allwood

Investigation Scientist Date

Instrument Ground System Lead
Payam Zamani

Instrument Ground System Lead Date

PDS Program Manager
############

Manager Date

PDS Geosciences Node Manager
Raymond E. Arvidson

Manager Date

PDS Discipline Node Manager
############

Manager Date

Mars 2020 Rover Mission Project

Software Interface Specification (SIS)

PIXL
Experiment Data Record (EDR)
Data Products for Non-Imaging Components

Version 1.0

Custodians:
Deborah Padgett, Stirling Algermissen

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OPEN ISSUE ITEMS

REVISION	OPEN ISSUE	RESPONSIBLE PARTY	CLOSE
	Appendix B, mapping of ODL label keywords to PDS4 label attributes, is incomplete		

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ACRONYMS AND ABBREVIATIONS

ASCII	American Standard Code of Information Interchange
CODMAC	Committee on Data Management and Computation
DPO	Data Product Object
EDR	Experiment Data Record
GV	Global Variable; area of PIXL Instrument Flight Software memory where parameters are stored
IDPH	Instrument Data Product Header
IDS	Instrument Data System, part of the Mission GDS
iFSW	Instrument Flight Software
iSDS	Instrument Science Data Systems
JPL	Jet Propulsion Laboratory
MCC	PIXL Micro-Context Camera
MIPL	Multi-mission Instrument Processing Laboratory
ODL	Object Description Language
PDP	Onboard PIXL Data Product, created by iFSW
PDS	Planetary Data System
PIQUANT	Spectroscopy software package from U. of Washington. TBR
PIXL	Planetary Instrument for X-ray Litho-chemistry
PMC	PIXL Motion Counter records changes to the PIXL Hexapod position
PSDD	Planetary Science Data Dictionary
RDR	Reduced Data Record
SLI	Structured Light Ilumination
XRF	X-ray fluorescence

1 INTRODUCTION

1.1 Purpose and Scope

The purpose of this Data Product Software Interface Specification (SIS) is to provide consumers of PIXL instrument Experiment Data Record (EDR) data products with a detailed description of the products and how they are generated, including data sources and destinations. Content in this document supports Experiment Data Record (EDR), data products generated by the Mars 2020 Instrument Data System (IDS) for the non-imaging components of the PIXL instrument. Specifically, this includes the spectroscopic products of the X-ray fluorescence system and instrument state-of-health and other engineering data packaged as EDRs.

Data products from the PIXL micro-context camera (MCC) are described in a separate document, D-99960 *Camera Instrument EDR/RDR Data Products*, along with all other imaging systems in the Mars 2020 rover science payload.

The users for whom this SIS is intended include IDS, users and developers of Science Operations Analysis Software (SOAS), member scientists of the project's Science Team who will analyze the data, and other scientists in the general planetary science community.

In this document, the EDR data product is the raw, uncalibrated, uncorrected data acquired by PIXL.

1.2 Contents

This Data Product SIS describes how the EDR data product is produced by PIXL and how it is processed, formatted, labeled, and uniquely identified by the IDS. The document discusses standards used in generating the product and software that may be used to access the product. The EDR data product structure and organization is described in sufficient detail to enable a user to read the product. Finally, examples of composite EDR labels are provided, along with the definitions of the keywords in the label.

1.3 Constraints and Applicable Documents

This SIS is meant to be consistent with the contract negotiated between the M2020 Project and the M2020 Principal Investigators (PI) for PIXL, in which experiment data records and documentation are explicitly defined as deliverable products. Because this SIS governs the specification of data products used during mission operations, any proposed changes to this SIS must be impacted by all affected software subsystems observing this SIS in support of operations (e.g., RPS, IDS, SOAS).

Product label keywords may be added to future revisions of this SIS. Therefore, it is recommended that software designed to process EDRs specified by this SIS should be robust to (new) unrecognized keywords. Similarly, entirely new products may be added over time.

This Data Product SIS is responsive to the following M2020 and PDS documents:

Mars 2020 CEDL and Surface PIXL Functional Design Description (FDD), “Baseline Release, Rev A”, , Joan Ervin,JPL D-95857
Mars 2020 Flight-Ground Interface Control Document (FGICD), “Volume 1, Downlink, Rev A, Version 1.0”, Biren Shah, JPL D-95521, October 3, 2017
Mars 2020 “PIXL Instrument Flight Software User’s Manual, Rev H”, Robert Denise, JPL D-94135
Mars 2020 “Mars 2020 SIS for PIXL RDRs”, Jimmie Young, JPL D-105236

Table 1-1 Establishing documents for the PIXL Instrument FSW

Document Identifier	Title	Revision as of release of this Document
D-94108	PIXL iFSW Software Development Plan	Rev-B, Jan 24, 2017
D-94125	PIXL Cmd/Tlm Dictionary	Rev-G, Sep 4, 2019
D-94116	PIXL iFSW Requirements Document	Rev-A, June 28, 2017
D-79821	Mars Surface Mission 2020 Preliminary Instrument Standard Electrical and Software Interface Specification.	Rev -: Sept 18, 2013
Drawing 10464005	Planetary Instrument for X-Ray Lithochemistry (POXL) Configuration	A1
D-94166	Detector Signal Processing Chain Field Programmable Gate Array Design Specification	Rev A, Mar 28, 2018
D-94140	PIXL-to-DTU Telemetry and Telecommand Interface Control Document	PIXL-DTU-ICD-3004 DTU v1.4 - March 14, 2019

D-94140 supporting file	Micro Context Camera PIXL User's Manual	PIXL-DTU-MA-3001 DTU v1.5 – March 14, 2019

Additionally, this SIS is consistent with the following Planetary Data System documents. These documents are subject to periodic revision. The most recent versions may be found at https://pds.nasa.gov/datastandards/documents/. The PDS products described in this SIS have been designed based on the versions current at the time, which are those listed below.

Planetary Data System Standards Reference, version 1.14.0.0, May 22, 2020.
Planetary Data System Data Provider's Handbook, version 1.14.0.0, May 19,2020.
PDS4 Common Data Dictionary, Abridged, version 1.14.0.0, March 23, 2020.
PDS4 Information Model Specification, version 1.14.0.0, March 23, 2020.

Finally, this SIS makes reference to the following documents for technical background information:

Sensing and Perception Research for Space Telerobotics at JPL, D. Gennery et al., *Proceedings of the IEEE Intern. Conf. on Robotics and Automation,* March 31 - April 3, 1987.
Anderson, R.C., et al., Mars Science Laboratory Participating Scientists Program Proposal Information Package, December 14, 2010.
Mars Exploration Rover (MER) Project ICER User's Guide, Aaron Kiely, MER 420-8-0538, JPL D-22103, January 5, 2004.
Malvar, H.S., Li-Wei He, and R. Cutler, "High-quality linear interpolation for demosaicing of Bayer-patterned color images", Proceedings, IEEE Intl. Conf. on Acoustics, Speech, and Signal Processing (ICASSP), doi: 10.1109/ICASSP.2004.1326587, 2004.
Maki, J.N., et al., The Mars 2020 Engineering Cameras and Microphone on the Perseverance Rover: A Next-Generation Imaging System for Mars Exploration, Manuscript Draft for Space Science Reviews, 2020.

1.3.1 Relationships with Other Interfaces

Changes to this EDR data product SIS document affect the following products, software, and/or documents.

Table 1-2 Interface relationships

Name	Type P = product S = software D = document	Owner
IDS database schema	P	IDS (JPL)
M2020EDRGEN	S	IDS (JPL)
M2020 PIXL Non-imaging Instrument EDRs	P	IDS (JPL)
RSVP	S	RSVP Dev Team (JPL)
ASTTRO	S	ASTTRO Dev Team (JPL)
RGIS	S	RGIS Dev Team (JPL)

2 PIXL Instrument Overview

PIXL (Planetary Instrument for X-ray Lithochemistry) is a microfocus X-ray fluorescence instrument that measures elemental chemistry at sub-millimeter scales. This is achieved by focusing an X-ray beam to a small spot ~ 150 um, scanning the surface with this beam, and then measuring the induced X-ray fluorescence. Since PIXL also contains a micro-context camera (MCC) it correlates sub-mm scale geochemistry with surface texture.

PIXL is mounted on the rover's robotic arm, allowing it to be placed in close proximity to the surface of selected science targets. For additional precision in placement, and to correct for drift in the robotic arm positioning, PIXL's mounting to the arm includes an articulated hexapod system, allowing PIXL's position in space to be finely adjusted.

In addition to the PIXL Sensor Assembly mounted on the robotic arm, the instrument includes its own electronics system with an instrument computer and memory module, mounted inside the rover body. PIXL is also furnished with a calibration target, mounted externally to the rover in reach of the arm.

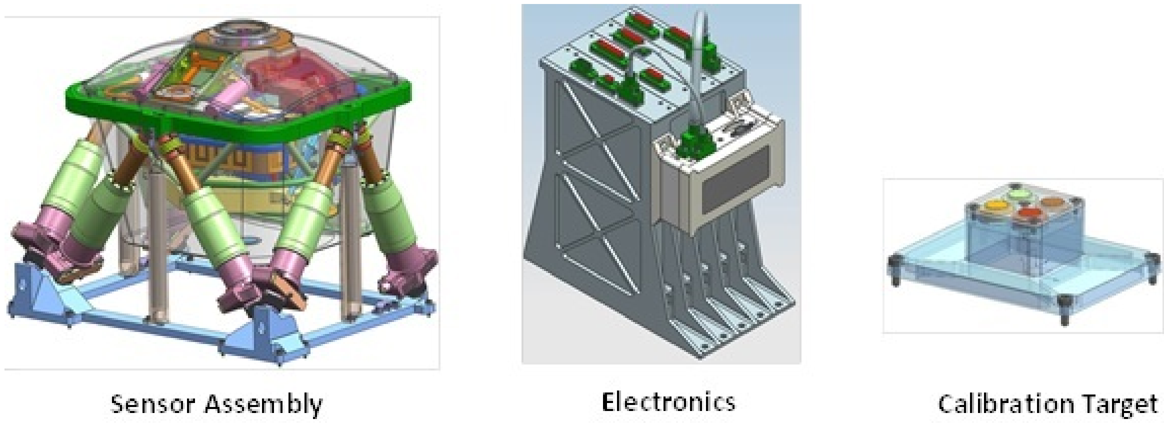


Figure 1 PIXL hardware. PIXL is composed of three primary components: the sensor assembly, mounted on the rover arm; the control electronics, mounted within the rover body; and the calibration target which is mounted externally within arm reach on the rover

PIXL observations consist of a suite of X-ray fluorescence measurements, context images, and metadata. The XRF measurements can be executed in a variety of geometries depending on target type and available observation time, and are accompanied by a set of images documenting the target and its position relative to the instrument.

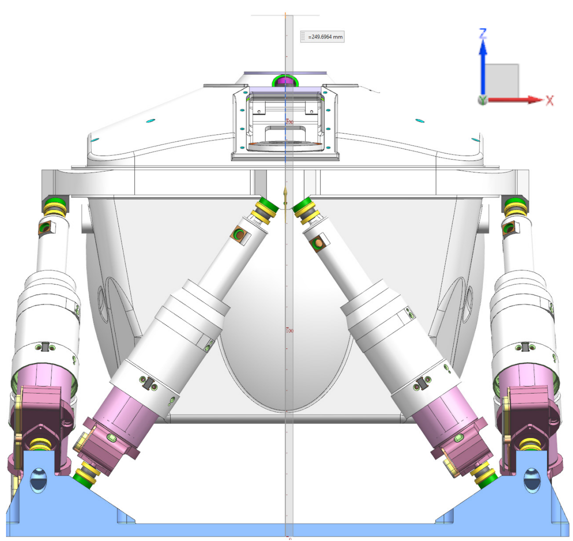


Figure 2 The Sensor Assembly. Shown are 4 of the 6 articulation sliders. Not pictured are the ones which oppose the sliders at the far left/right. At upper right is the definitions of the x, y, z axes.

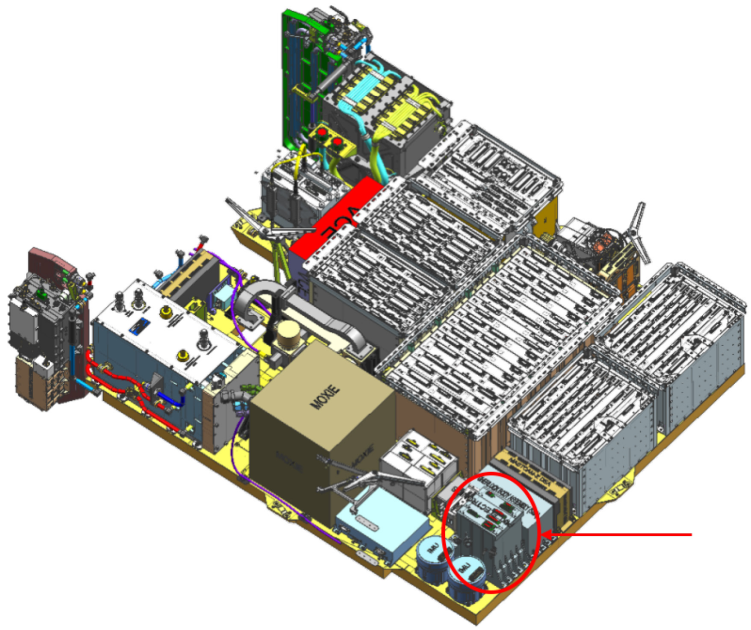


Figure 3 PIXL electronics location on the RAMP. The electronics consists of an instrument computer and memory module, mounted inside the rover body.

The PIXL Electronics Box is located inside the Rover on the RAMP, the PIXL Sensor Assembly is located on the Rover Turret, and the PIXL Calibration Target is located on the RA shoulder azimuth joint.

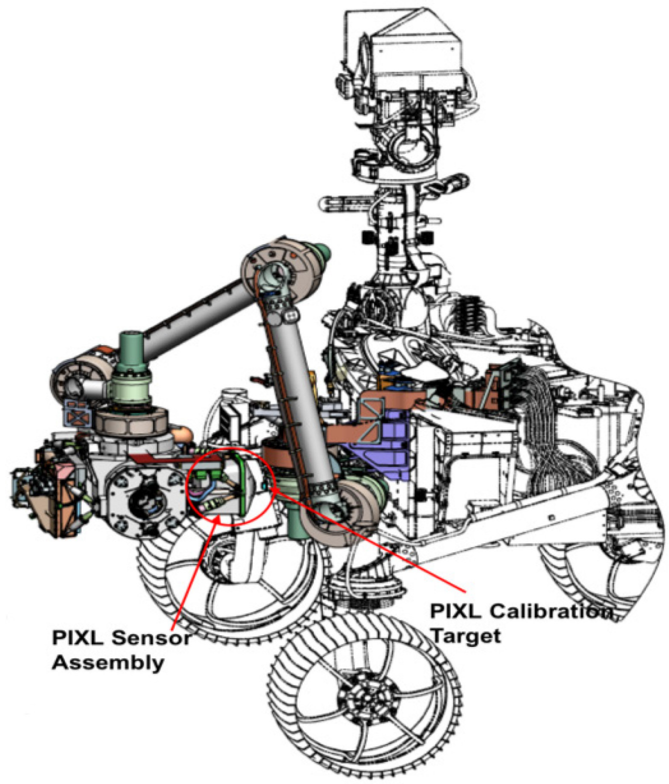


Figure 4 PIXL Sensor assembly and Calibration Target locations on the robotic arm.

2.1 PIXL Sensor Assembly

The PIXL Sensor Assembly houses the primary sensors, detectors and X-ray source used for PIXL science. Specifically, the Sensor Assembly houses the 28 kV High Voltage Power Supply (HVPS) which contains both a High voltage Multiplier Module (HVMM) and a Low Voltage Control Module (LVCM). This system energizes the X-ray tube which focuses the resultant X-rays through the X-ray optic and on to the target surface. Two Silicon Drift Detectors (SDD) collect the X-rays fluoresced from the target, enabling chemical analysis of the surface. A key metric for interpreting fluoresced flux and focusing the X-ray spot onto the surface is a distance measurement to the surface. The PIXL Optical Fiducial system (OFS) enables the measurement of surface distance. This system utilizes a coarse and fine structured light illuminator (SLI), which is a device that shines laser spots onto the target in a specific pattern (coarse or fine). A high resolution black and white camera - the micro context camera (MCC) - is then used to take a picture of the surface with the laser pattern illuminating the surface. The PIXL Instrument Flight Software (iFSW) uses this information to determine the distance to the target surface at the location of the X-ray spot. The sensor head is mounted onto the turret with isolation struts and 6 active struts that provide x, y, and z motion completing the sensor assembly (sensor head + active hexapod). The active hexapod is driven by the needs to: scan the surface for a map, correct for any placement errors or drift errors from the Robotic Arm, and to focus the X-ray spot on the surface based on the distance to the target. The sensor assembly also has a dust cover that is controlled with a motor very similar to the motor used in the active struts (just smaller).

PIXL has a set of heaters on the Sensor Assembly. The survival heaters continually cycle to keep the HVMM within its required temperature limits. These heaters are on two circuits, and one is always asserted on. One is primary, and one is redundant. A PIXL temperature control board is used to cycle the heaters and, as a fall back, the heaters are controlled with mechanical thermostats. Other heaters for pre-warming the LVCM and the AFE are activated to bring the devices up into operational AFT limits.

PIXL's robust science operations are enabled by the PIXL iFSW. The PIXL iFSW controls all mapping, imaging, hexapod movement - basically all PIXL functions. So, the computing for PIXL operations is performed internally by PIXL, and the rover FSW will essentially send pass through i-commands with arguments that define what the PIXL iFSW will do.

2.2 The PIXL Optical Fiducial System (OFS)

[Source: Allwood, Wade, Clark, Elam, Flannery, Foote, Hurowitz, Knowles, “Texture-specific elemental analysis of rocks and soils with PIXL: The Planetary Instrument for X-ray Lithochemistry on Mars 2020”, *IEE Aerospace Conference Proceedings*, June 2015, DOI: 10.1109/AERO.2015.7119099]

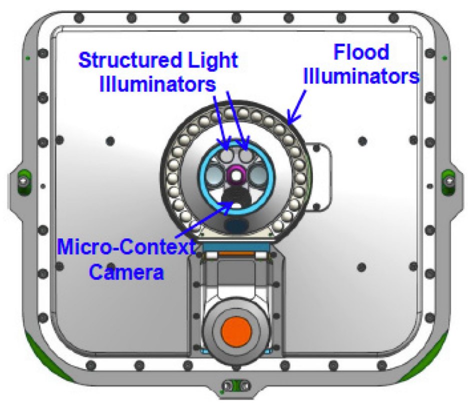


Figure 5 The location of the OFS components in the head of the PIXL Sensor Assembly.

To ensure the measured chemistry is unambiguously tied to the textural features in the targets, PIXL has an optical fiducial system (OFS) co-aligned with the X-ray beam. The OFS consists of a micro-context camera, multi-color flood illuminator, and an LED illuminator that projects reference spots onto the target. The arrangement of color LEDs in the Illuminator are shown in . Together these are used to acquire visible images of the sample and enable visual registration of the position of the X-ray beam. The Micro-Context Camera has spatial resolution of 50 microns per pixel and a field of view of 29 x 36mm. This allows observation of textural features and microstructures as small as PIXL's X-ray beam, across an area of similar size to an abraded patch produced by a surface preparation tool on the rover. While an image is being taken, an array of light spots will be projected onto the sample surface. The spot array has a fixed geometric relationship to the X-ray beam, to provide a means of spatially correlating measured chemistry to observed visual features as well as making a map of the rock topography.

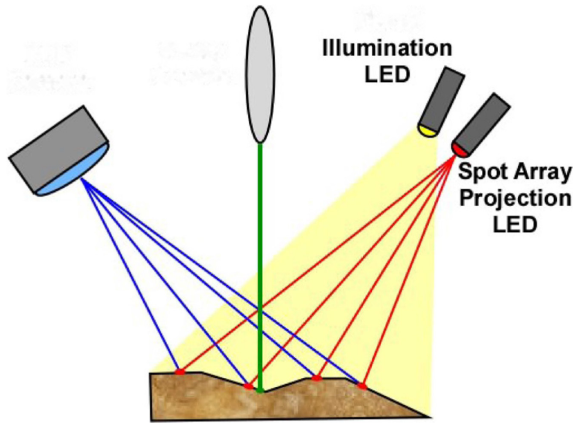


Figure 6 Alignment of the OFS (MCC in blue, Spot LED in red) with the PIXL X-ray beam (green).

Color	String	LED ID	Sys param 406	Sys. Param 408
Red	FLIE A 1	R1, R3, R5	0x0300	
	FLIE B 1	R2, R4, R6		0x0300
	ALL (6xLEDs)	ALL R	0x0300	0x0300
Green	FLIE A 3	G1	0x3000	
	FLIE B 3	G2		0x3000
	FLIE B 4	G3		0xC000
	FLIE A 4	G4	0xC000	
	FLIE B 5	G5		0x0003
	FLIE B 6	G6		0x000C
	ALL (6xLEDs)	ALL G	0xF000	0xF00F
Blue	FLIE A 5	B1, B4	0x0003	
	FLIE A 7	B2, B5	0x0030	
	FLIE B 7	B3, B6		0x0030
	ALL (6xLEDs)	ALL B	0x0033	0x0030
UV	FLIE A 6	UV1, UV4	0x000C	
	FLIE A 8	UV2, UV5	0x00C0	
	FLIE B 8	UV3, UV6		0x00C0
	ALL (6xLEDs)	ALL UV	0x00CC	0x00C0
White	ALL	ALL R, G, B, UV	0xF3FF	0xF3FF

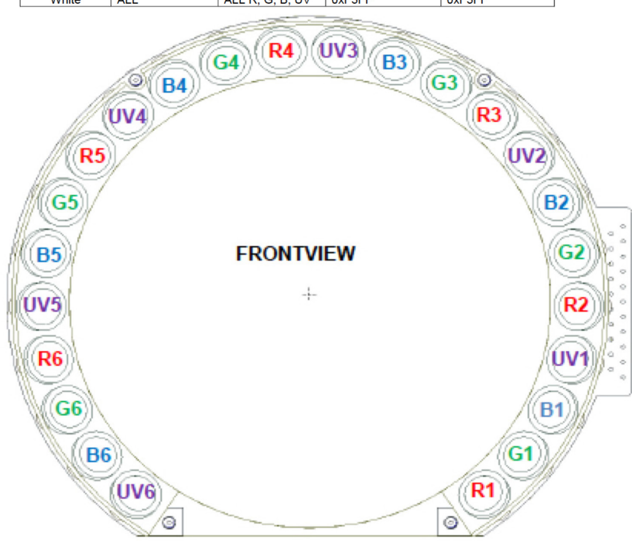


Figure 7 Color arrangement within the flood illuminator

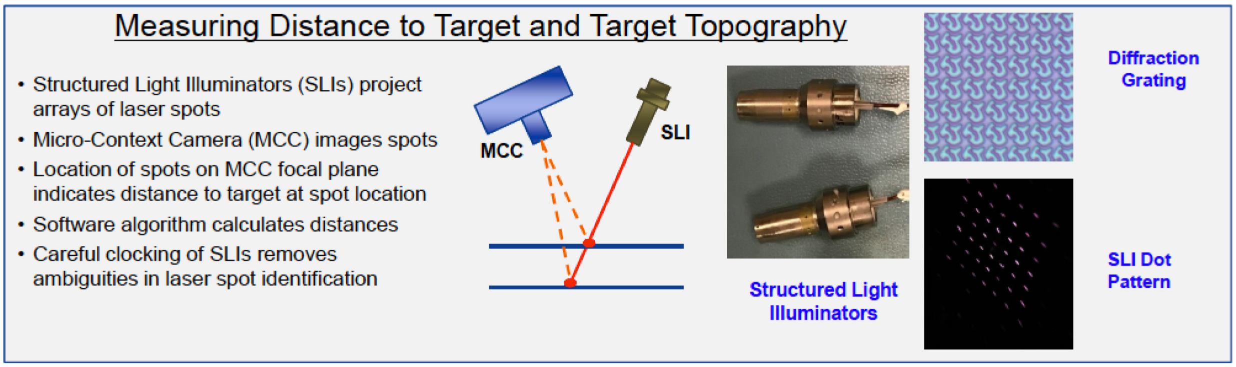


Figure 8 Overview of the OFS process to determine target distances/topography.

2.3 PIXL Electronics

The PIXL electronics contain 3 FPGAs and a LEON3 processor. While the RCE has the ability to send basic commands to PIXL by sending a limited number of pass through commands to the FPGA (typically only in iFSW fault cases), nominally all commanding and functions will be controlled with PIXL via the iFSW and the FPGA. Therefore, RCE commanding is quite limited and straight forward. Most RCE commanding will be done using the SEND_DATA and ACQUIRE_DATA. Note that the MCC camera electronics are inside the Rover as well and mate directly to the PIXL Electronics. The algorithms for localization reside on the MCC electronics but interface back to the PIXL iFSW. PIXL generates a large amount of data during operations and while not all of this data will get sent to the Rover and back to earth, it is all stored internally within PIXL. PIXL has 8GB of flash which is likely sufficient to store all observations for the life of the mission.

2.4 PIXL Calibration Target

The PIXL calibration target contains 4 samples that PIXL will scan approximately once a month to enable recognition and correction for contamination in the instrument (dust, spacecraft materials, etc.), avoid misidentification of peaks due to energy shift in the spectrum, maintain quantitative accuracy, and check detectability and sensitivity. The samples are as follows (clockwise, starting from the lower left of **Figure 7.**):

1. A Polytetrafluoroethylene (PTFE) disk to provide broadband X-ray backscatter for verifying the stability of the X-ray source spectrum and X-ray detection (or, if any changes occur, for tracking those changes and any effects of dust on the target).

2. A glass version of the United States Geological Survey (USGS) basaltic standard BHVO-2, which was specially-prepared by the USGS as a large glass piece by melting and then rapidly quenching powdered BHVO-2 in a platinum boat.

3. A disk of the National Institute of Standards and Technology NIST-610 glass donated by Clay Davis at NIST from their collection.

4. The mineral scapolite, which was donated by G. Rossman of the California Institute of Technology and embedded in epoxy by the PIXL team.

The target at center with a metal cross (a chromium line in one axis and a nickel line in the other axis, each 200 μm in width) is used to precisely locate the X-ray beam with respect to the camera. Lastly there is a pseudo-random distribution of 100 black dots against a light background, divided between two surfaces separated by 5 mm in depth. MCC images of these dots allow an accurate estimation of the PIXL sensor head position with respect to the calibration target for checking accuracy of distance measurements made by the SLIs. The target is a passive element that requires no heating.

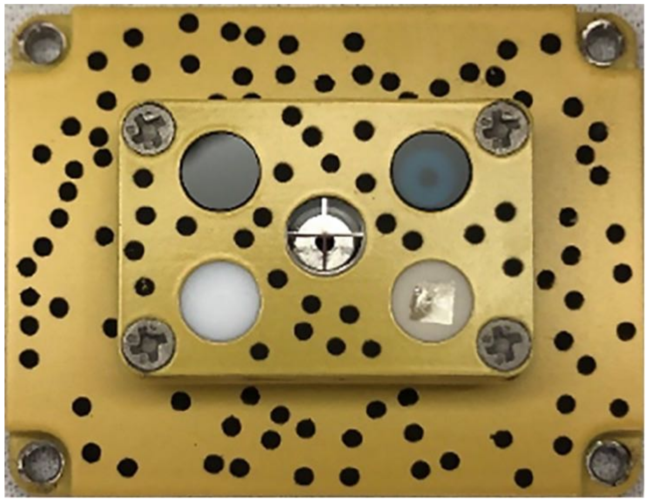


Figure 9 The PIXL Calibration Target

The calibration target is located at the base of the Rover's arm turret, as shown in Figure 10.

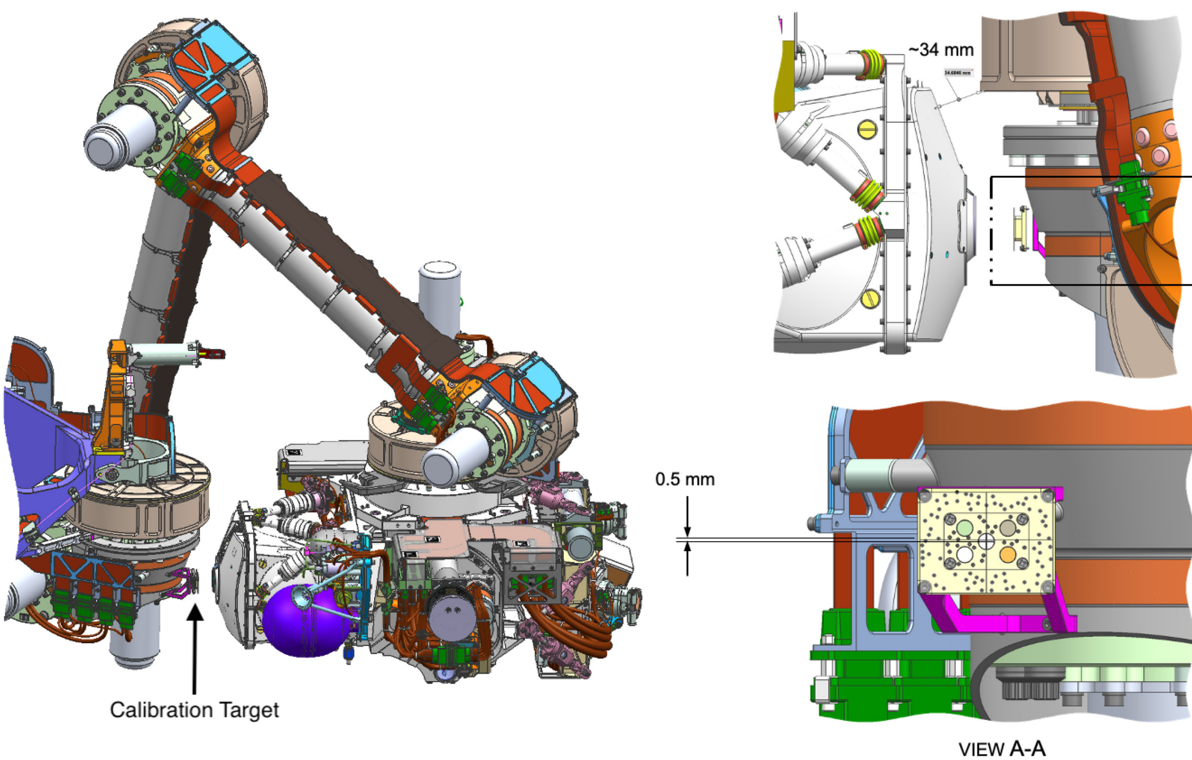


Figure 10 The location of the PIXL calibration target.

3 GENERAL DATA PRODUCT OVERVIEW

3.1 Data Processing Levels

This documentation uses the "Committee on Data Management and Computation" (CODMAC) data level numbering system. The M2020 instrument EDRs referred to in this document are considered "Level 2" or "Edited Data" (equivalent to NASA Level 0). The EDRs are to be reconstructed from "Level 1" or "Raw Data", which are the telemetry packets within the project specific Standard Formatted Data Unit (SFDU) record. They are to be assembled into complete data products (typically spectra), but will not be radiometrically or geometrically corrected.

The PDS4 archive standard does not use CODMAC data processing level numbers. Instead, it recognizes five data processing level terms: telemetry, raw, partially processed, calibrated, and derived. Table 3-1 PDS4 processing levels for instrument Experiment Data Sets shows the definitions of these processing levels.

Table 3-1 PDS4 processing levels for instrument Experiment Data Sets

Processing Level for PDS4 Archive	Operations Data Product Name	Description
Telemetry	n/a	An encoded byte stream used to transfer data from one or more instruments to temporary storage where the raw instrument data will be extracted. PDS does not archive telemetry data.
Raw	EDR (Experiment Data Record, heritage term based on MSL mission)	Original data from an instrument. If compression, reformatting, packetization, or other translation has been applied to facilitate data transmission or storage, those processes will be reversed so that the archived data are in a PDS approved archive format. For Mars 2020, these are the original products. However for M2020, the product ID field in the EDR filenames have a variety of 3 character codes beginning with "E" to distinguish between many types of Surface EDRs
Partially Processed	EDR FDR (Fundamental Data Record) RDR (Reduced Data Record)	Data that have been processed beyond the raw stage, but which have not yet reached calibrated status. For Mars 2020 imaging, these are the decompanded and debayered EDRs, the FDRs, and a few RDRs. These do not apply to M2020 non-imaging data
Calibrated	RDR	Data converted to physical units, which makes values independent of the instrument.
Derived	RDR	Results that have been distilled from one or more calibrated data products (for example, maps, gravity or magnetic fields, or ring particle size distributions). Supplementary data, such as calibration tables or tables of viewing geometry, used to interpret observational data should also be

Processing Level for PDS4 Archive	Operations Data Product Name	Description
		classified as “derived” data if not easily matched to one of the other three categories.

3.2 Product Label and Header Descriptions

3.2.1 Overview of Labels

Mars 2020 PIXL non-imaging products consist of two files: the instrument data file in CSV or binary format, and a detached PDS4 label file in XML format. The PDS4 label incorporates most of the information from the ODL label used by M2020 operations.

The detached PDS4 label is a separate file with the same base name as the image file, with a ".XML" extension. The detached label ceces the EDR filename via an XML attribute. This label is fully compliant with all PDS archive standards.

3.2.2 ODL Labels

As implied in the previous section, the EDRs described in this document have a detached ODL label and a detached PDS4 label. Each institution is responsible for converting PDS-formatted products to be compatible with their own software systems (such as VICAR, IDL, ISIS, etc.).

The attached ODL label starts with the keyword assignment:

ODL_VERSION_ID = ODL3

An ODL label is object-oriented and describes the objects in the data file. The ODL label contains keywords for product identification, along with the data object definition containing descriptive information needed to interpret or process the data in the file.

ODL label statements have the form of "keyword = value". Each label statement is terminated with a carriage return character (ASCII 13) and a line feed character (ASCII 10) sequence to allow the label to be read by many operating systems. Pointer statements with the following format are used to indicate the location of data objects in the file:

^object = location

where the carat character (^, also called a pointer) is followed by the name of the specific data object. The location is the 1-based starting record number for the data object within the file. Alternatively, it could be the 1-based byte location within the file if it includes a <bytes> unit tag. Pointers are used to define the locations of the binary instrument data itself (^IMAGE for image data), the VICAR header in the case of images (^IMAGE_HEADER), and non-imaging binary data.

3.2.2.1 PDS Local Data Dictionaries

The PDS4 label includes many XML classes and attributes defined in the PDS Common Data Dictionary, the PDS Mars 2020 Mission Dictionary, and other PDS data dictionaries. The dictionaries are represented by XML schema, which are listed at the top of every PDS4 label. Current and older versions of all PDS dictionaries are available at https://pds.nasa.gov/datastandards/dictionaries/.

3.2.2.2 Keyword Length Limits

All ODL keywords are limited to 31 characters in length. Therefore, software that reads M2020 ODL labels must be able to ingest keywords up to 31 characters in length.

For image RDR-producing institutions wishing to accommodate the VICAR mapping of ODL keywords that use a <*unit*> tag after the value, such keywords must be limited to 25 characters in length to accommodate the "__UNIT" suffix. Otherwise, those keywords will not be transcoded from the ODL label into a VICAR label.

3.2.2.3 Data Type Restrictions

In order to accommodate VICAR dual-labeled files, 16-bit data must be stored as signed data. Unsigned 16-bit data are not supported. 12-bit unsigned data from the cameras are stored in a 16-bit signed value. 8-bit data are unsigned.

3.2.2.4 Interpretation of N/A, UNK, and NULL

During the completion of data product ODL labels, one or more values may not be available for some set of required data elements. In this case the literals "N/A", "UNK", and "NULL" are used, each of which is appropriate under different circumstances. As a note, if any one of these three symbolic literals are used in place of a keyword value that is normally followed by a Unit Tag(s) (e.g., "<*value*>"), the Unit Tag(s) is <u>removed</u> from the label.

- "N/A" ("Not Applicable") indicates that the values within the domain of this data element are not applicable in this instance. For example, a label describing NAIF SPK kernels would contain the statement:

  INSTRUMENT_ID = "N/A"

  because this data set is not associated with a particular instrument.

"N/A" may be used as needed for data elements of any type (e.g., text, date, numeric, etc.).

- "UNK" ("Unknown") indicates that the value for the data element is not known and never will be. For example, in a data set comprising a series of images, each taken with a different filter, one of the labels might contain the statement:

  FILTER_NAME = "UNK"

  if the observing log recording the filter name was lost or destroyed and the name of the filter is not otherwise recoverable.

  "UNK" may be used as needed for data elements of any type.

- "NULL" is used to flag values that are *temporarily* unknown. It indicates that the data preparer recognizes that a specific value should be applied, but that the true value was not readily available. "NULL" is a placeholder. For example, the statement:

  DATA_SET_RELEASE_DATE = "NULL"

  might be used in a data set catalog file during the development and review process to indicate that the release date has not yet been determined.

  "NULL" may be used as needed for data elements of any type.

  Note that all "NULL" indicators should be replaced by their actual values prior to final archiving of the associated data.

Unlike earlier missions, some effort has been expended to reduce the number of UNK, N/A, and NULL values appearing in the label, since they can cause difficulties with the Velocity technology used to create PDS4 labels. Therefore, while these values are possible, they should be rare.

3.2.2.5 ODL Label Constructs "Class", "Object", and "Group"

For the EDRs and RDRs described in this document, the ODL label includes the following constructs:

- *Class* - The Class construct resides in a ODL label as a grouping of keywords that are thematically tied together. Classes are usually preceded by a label comment, although it is not required. ODL label comments are character strings bounded by "/* */" characters.

  In the M2020 non-imaging ODL label a Class of keywords will be preceded by a comment string as follows:

  /* *comment string* */

keyword = *keyword value*
keyword = *keyword value*

- *Object* - The Object construct is a set of standard keywords used for a particular data product. In the M2020 non-imaging ODL label an Object's set of keywords is specified as follows:

```
OBJECT      =  Object identifier
   keyword  =  keyword value
   keyword  =  keyword value
END_OBJEC   =  Object identifier
```

- *Group* - The Group construct is a grouping of keywords that are not components of a larger Object. Group keywords may reside in more than one Group within the label. In the M2020 non-imaging ODL label, a Group's set of keywords is specified as follows:

```
GROUP       =  Group identifier
   keyword  =  keyword value
   keyword  =  keyword value
END_GROUP   =  Group identifier
```

3.2.3 PDS4 Label

The PDS4 label is a separate file with the same base name and an extension of ".xml". It is in XML format whose content is controlled by the PDS Information Model and PDS core, discipline, and mission data dictionaries. The PDS4 label contains the same semantic information as the VICAR label, although the format is quite different. For FITS files (ending in ".fits"), the label removes the fits extension and replaces it with ".xml". For other files, the ".xml" extension is added to the end of the complete filename, for example ".TXT.xml" or ".obj.xml". Appendix B contains tables mapping between ODL keywords and their corresponding PDS4 construct.

3.2.4 PIXL CSV Files

PIXL comma-separated value (CSV) files are ASCII format files used for the EDR science data product instrument data. The structure for the files varies according to the instrument mode, as detailed in Section 4.2.

3.3 Binary Data Storage Conventions

Most PIXL EDR data products archived in PDS are CSV files, but some M2020 PIXL engineering data are stored as binary data. For the binary non-image EDRs, the data formats include rescaled 8-bit integers stored in an unsigned byte, as well as 10-bit to 13-bit integers stored in signed 16-bit integers. The PDS labels are stored as ASCII text.

4 EDR Product Specification

M2020 instrument EDRs described in this document will be generated by JPL's Multimission Instrument Processing Laboratory (MIPL) under the IDS subsystem of the M2020 GDS element. Other RDRs described in this document will be generated by the PIXL Science Team.

The EDR consists of unprocessed experiment data stored in the CSV ASCII format . The EDR structures defined in this document vary depending on instrument, with all containing attached metadata labels.

For PIXL/M2020, with the exception noted in Section 1.3, the spectrometer EDRs are the fundamental non-imaging instrument data archive product. They will be generated as "raw" uncalibrated data within an automated pipeline process managed by IDS under GDS at JPL. The size of the EDRs varies with select instrument modes. The size of an image EDR data product is approximately 8 MB, while the size of a spectrum EDR is approximately 700 KB.

EDRs are versioned on M2020. When updated telemetry is received a new version of the EDR will be generated. Updated telemetry is possible when missing packets are retransmitted and/or telemetry is reflowed through the Ground Data System (GDS).

4.1 EDR General Processing

The EDR processing begins with the reconstruction of packetized telemetry data resident on the TDS by the Mission data Processing and Control Subsystem (MPCS) into a binary ".dat" data product and associated ".emd" Earth metadata file. The data product and metadata are written by MPCS to the Operations Cloud Store (OCS) and messages are generated on a Java Message Server (JMS) bus, where they are ingested by MIPL's EDR generation software "m2020edrgen" and processed with SPICE kernels provided by NAIF. The EDR will be generated after the notification describing the OCS location of the respective the binary data product and associated Earth metadata file has been received by the IDS pipeline system. The data flow from instrument to data product is illustrated in Figure 11 Instrument Data Flow to .

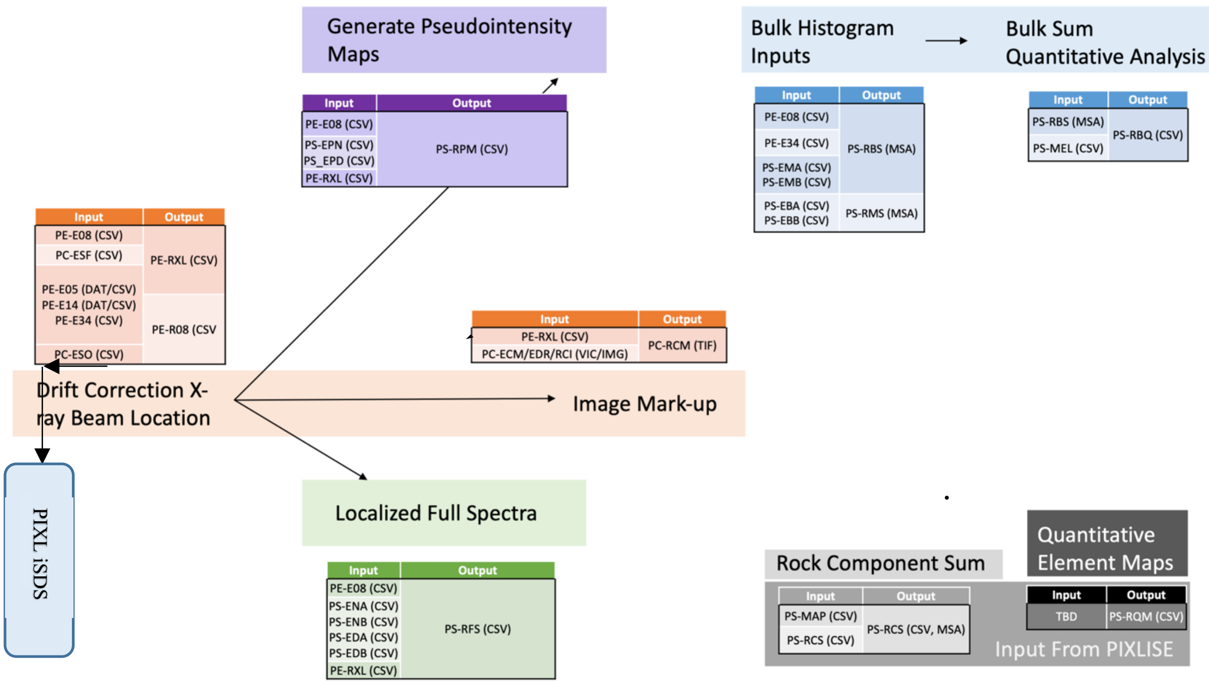


Figure 11 Instrument Data Flow to PIXL data products

In all EDR cases, missing packets will be identified and reported for retransmission to the ground as "partial datasets". Prior to retransmission, the missing EDR data will be filled with zeros. The EDR data will be reprocessed only after all "partial datasets" are retransmitted and received on the ground. In these cases, the EDR version will be incremented so as not to overwrite any previous EDR versions.

4.2 EDR Product Types and Structure

Descriptions for the various EDR product types are provided in this section. They are broken down into three groupings: a) Spectra and b) Spectral Support, and c) State of Health/Housekeeping. Refer also to Table 4.1 for a mapping between the source M2020 instrument and the EDR product type. Note that the tables listed in the subsections describe the mapping of parameters in the initial binary file. In the ASCII *.CSV product files which make up the bulk of the PDS PIXL data products, the parameters described will be found in the same sequence in files with up to 4096 bins or elements. This section has been updated as of E. Song's spreadsheet 10/10/2019.

PIXL data products are the quanta of information generated by the PIXL iFSW. There are three ways that PIXL Data Products are transmitted to the Ground.

1. 1) In response to a SEND_DATA I-Cmd, the iFSW generates PIXL Data Products and place them directly into the Science Data Frame being sent back to the RCE. These are encapsulated in Immediate Data Field Pieces as defined above.
2. 2) In response to a TRANSMIT_DATA I-Cmd, the iFSW reads PIXL Data Products from Non-Volatile Memory for subsequent transmission in response to a TRANSMIT_DATA command. These are encapsulated in Retrieved Data Field Pieces as defined above. For PIXL Data Products smaller than 4000 bytes, the “content” portion of the Data Field Piece is the same for Immediate Data Field Pieces, and Retrieved Data Field Pieces. The Retrieved Data Field Piece has a few extra bytes of piece header information, but the content is the same.
3. 3) The Do_BIST command, like the SEND_DATA command, generates a Science Data Frame containing Immediate Data Field pieces.

For PIXL Data Products larger than 4000 bytes, the Immediate Data Field Piece in the response to the SEND_DATA command will be one contiguous whole. That is, the PIXL data product will be transmitted to the ground as a single piece. But the same PIXL Data Product will be split into two or more Retrieved Data Field Pieces in response to the TRANSMIT_DATA command. This is because the PIXL iFSW has to break the PIXL Data Product into chunks that each fit into a single page when storing the data to NVM. On retrieval of the data from NVM, the iFSW merely moves the data into the SDF and allows the reconstitution of the PIXL Data Product into its original form to take place in the Ground Software.

The PIXL Data Product Definitions below are for the CONTENT portion of the Immediate Data Field Pieces and Retrieved Data Field Pieces. Each Data Field Piece has header information that is defined above. The characters in parentheses is the Product ID, which is a three character code which is unique per EDR type for the instrument.

Table 4-1 PIXL EDR Product IDs

Product ID	Name	Extension	PDS Archive Product?
E01	EVR Bundle	.CSV	no
E02	FSW SOH	.CSV	no
E03	FPGA Param Dump	.dat	no
E04	DPCFS Part Ready	.dat	no
E05	GV Report Lo-Priority	.dat	no
E06	SeqLib Load Table	.dat	no
E07	FDT Dump	.dat	no
EHK	HK Frame (standalone)	.CSV	no
E08	HK Frame	.CSV	yes
E09	CPU Mem Dump		no
E10	File Dump Data		no
E11	Raw Flash Page		no

E12	Remark	.dat	no
E13	FPGA Diagnostic Dump	.dat	no
E14	GV Report Hi-Priority	.dat	no
E15	PIXL Proximity	.dat	no
ENA	Histogram Normal A	.CSV	yes
ENB	Histogram Normal B	.CSV	yes
EDA	Histogram Dwell A	.CSV	yes
EDB	Histogram Dwell B		yes
EPN	PseudoIntensity Normal	.CSV	yes
EPD	PseudoIntensity Dwell	.CSV	yes
EMA	Hist Max Val A	.CSV	yes
EMB	Hist Max Val B	.CSV	yes
EBA	Hist Bulk Sum A	.CSV	yes
EBB	Hist Bulk Sum B	.CSV	yes
EHR	DSPC Register Dump	.dat	no
E33	Sentry HK Frame	.CSV	no
E34	Scan Log	.CSV	yes
E48	MCC Telemetry Status Report NVM	.dat	no
E49	MCC Telemetry Status Report RAM	.dat	no
ESO	MCC OLM TRN Estimate	.CSV	yes
ESF	MCC SLI Estimate	.CSV	yes
ESC	MCC Centroid	.CSV	no
ESA	MCC Circle Centroid	.dat	no
ESR	MCC Image ROI	.dat	no
EDR	MCC Image	.VIC	yes (see M2020 Image SIS)
RCI	MCC image (corrected)	VIC	yes
EV1	Intermediate EVR Bundle		no
E98	Anomalous Retrieved Piece		no
E99	Transmit Data Inventory	.txt (binary)	no
EPS	Adaptive Sampling Param Dump		no

4.2.1 Data Product: EVR Bundle (PE/E01) – not archived

The EVR Bundle Data Product conveys event information to the ground. During the processing of a SEND_DATA command, or a D0_BIST command, events that are generated are added to the Science Data Frame on one of three conditions

1. 1) When adding another EVR to the current bundle would push the Bundle larger than the maximum size
2. 2) When the SEND_DATA, or Do_BIST script is complete
3. 3) When an ABORT is received that causes pre-mature termination of the script.

EVR Bundles that are extracted from NVM in response to a TRANSMIT_DATA command will be aggregated to include as many EVR's as can be included in a 4-Kbyte NVM packet.
An EVR Bundle consists of one or more EVR Entries. Each entry has the following format. Note that the length of each EVR Entry ranges from 8 to 68 bytes and is determined by the number of arguments associated with the EVR. Each argument is a 4-byte numeric value.

Content	
SCLK value when the EVR occurred	Repeated for each of EVR in the bundle
Library Descriptor Word-2 Bit 31 – 24 = Module ID Bit 23 – 16 = EVR ID Bit 15 – 12 = Argument Count <-- **determines total length of this EVR** Bit 11 – 0 = EVR Counter	
EVR Argument 1 (if Argument Count >= 1)	
EVR Argument 2 (if Argument Count >= 2)	
EVR Argument 3 (if Argument Count >= 3)	
EVR Argument 4 (if Argument Count >= 4)	
EVR Argument 5 (if Argument Count >= 5)	
EVR Argument 6 (if Argument Count >= 6)	
EVR Argument 7 (if Argument Count = 7)	

Produced by iFSW in response to SEND_DATA, or TRANSMIT_DATA command
Since a NVM page can hold up to 4000 bytes of data, one EVR bundle can to hundreds EVR's. The iFSW will close a EVR Bundle DP when any one of several triggers occur. These include nominal conclusion of an ACQUIRE_DATA script, or when the next EVR generated would push the size over the maximum that can be accommodated in a

single NVM page. The EVR bundles are also closed and saved to NVM on erroneous termination of a script, or on receipt of an ABORT I-Cmd.

4.2.2 Data Product: iFSW State of Health (PE/E02) – not archived

The State of Health Data Product (SOH) provides insight into the current state of the iFSW. This Data product contains the following pieces of information:

Content
The git Hash associated with the currently loaded iFSW
The User Info Breadcrumb value. (Can be set by the iFSW Script to convey specific information to the ground)
The number of chunks yet to be inventoried by "MountDP" Phase-II. Once MountDP Phase-II has completed, this value will be zero.
The chunk number in NVM that represents the next-write pointer.
The oldest SCLK value discovered by MountDP Phase-II. (Remember that Mount-DP Phase-II works backwards through NVM. Thus until MountDP Phase-II is complete, this value represents the earlieset PIXL Data Product that can be retrieved, and included in a TRANSMIT_DATA command)
The lowest USN counter yet encountered by MountDP Phase-II.
The Highest USN counter yet encountered by MountDP Phase-II. Nominally this is the last product written.
The SCLK value when the DP Partition became "Ready"

4.2.3 Data Product: FPGA Parameter Dump (PE/E03) – not archived

The FPGA Parameter Dump Data Product documents the current content of the FPGA Parameter Registers at the time the Data Product was produced.

Content
First Parameter Register Value as defined in Telemetry and Command Dictionary (D-94125)
Second Parameter Register Value as defined in Telemetry and Command Dictionary (D-94125)
Etc…
Eightieth Parameter Register Value as defined in Telemetry and Command Dictionary (D-94125

4.2.4 Data Product: GV Report A – Low Priority/Scan Log (PE/E05) – not archived

Reports on the content of a portion of GV Space. The GV Report Data Product takes one of two forms; Simple, or Labeled. The simple form consists of one part; the GV area content. The Labeled form consists of three parts; the Label Part, the Source Address Part, and the GV area content Part. When the DP consists of multiple parts, they will one upon the next with no interleaved space. All parts will always be modulo-4 bytes. **This product is archived at the PDS**.

The part definitions are as follows:

Content
0x00 Start Address in GV space whence the data came (ADDR)
GV space content (NBYTES is determined by DP length less four bytes)

ORIGINAL FORMAT

Content
Start Address in GV space whence the data came
GV space content (where “N” is the “number of bytes” argument to the ReportGV

Produced by: Sub-command ReportGV Sub-command.

***Labeled** Form **Label** Part Definitions:*

Content
0x50 Length of the Label (LBYTES) -- always modulo 4.
GV Area Label (Helps identify the content of the GV Report)

***Labeled** Form **Source Address Part** Part Definitions:*

Content
0xA0 0x000004 (Address part is always four bytes long)
(ADDR) Start Address in GV Space whence the data came.

Labeled Form GV area Part Definitions:

Content
"0" Start Address in GV space whence the data came (NBYTES)
GV space content

Produced by: Sub-command ReportGV Sub-command.

4.2.5 Data Product: Housekeeping Frame (PE/E08) – Archived

The Housekeeping Frame Data Product documents the content of the Housekeeping Data at the time the DP was created. This file will be stored as ASCII *.CSV format. **This data product will be archived by the PDS. Note that the EHK frame is also a Housekeeping frame and requires conversion from DN**

Data Product: Housekeeping Frame – REQUIRES CONVERSION FROM DN (HK details sourced fom D-94125 REV F, 05/2019)

Name	Data format	Type	Conversion
HK_FCNT	U16	Frame Counter	N/A
HK_PIXL_ANALOG_FPGA	U16	Temperature 1K PRT, 2-wire	C = DN * 0.0320719 - 262.454
HK_PIXL_CHASSIS_TOP	U16	Temperature 1K PRT, 2-wire	C = DN * 0.0320719 - 262.454

HK_PIXL_CHASSIS_BOTTOM	U16	Temperature 1K PRT, 2-wire	C = DN * 0.0320719 - 262.454
HK_PIXL_AFT_LOW_CAL	U16	845 Ohm resistor	DN = -40.408C
HK_PIXL_AFT_HIGH_CAL	U16	1180 Ohm resistor	DN = +47.600C
HK_PIXL_MOTOR_V+	S16	V, motor, pos	V = DN / 1000
HK_PIXL_MOTOR_V-	S16	V, motor, neg	V = ((DN+16384)/992) - (DN_3.3V/200) *where DN_3.3V is "HK_PIXL_+3.3V" (byte offset 20) – UPDATED IN D-94125 RevF*
HK_PIXL_SDD1	S16	V, bias, neg	V = (49152 - DN) * 250/16383
HK_PIXL_SSD2	S16	V, bias, neg	V = (49152 - DN) * 250/16383
HK_PIXL_+3.3V	S16	V, system, pos	V = DN / 1000
HK_PIXL_ANA_+1.8V	S16	V, DSPC, pos	V = DN / 1000
HK_PIXL_DSPC_V+	S16	V, DSPC, pos	V = DN / 1000
HK_PIXL_DSPC_V-	S16	V, DSPC, neg	V = ((DN+16384)/992) - (DN_3.3V/200) *where DN_3.3V is "HK_PIXL_+3.3V" (byte offset 20) – UPDATED IN D-94125 RevF*
HK_PIXL_PRT_I+	S16	V, 1.25mA Isrc, pos	V = DN / 1000
HK_PIXL_ARM_RESISTANCE	U16	Ohms	R = DN / 100 - 100
HK_SH_SDD1	U16	Temperature 10K YSI SDD "B"	C = 1/(1.129241E-3 + 2.341077E-4 * ln(DN * 73.4236) + 8.775468E-

			8 * (ln(DN * 73.4236)) ^3) - 273.15
HK_SH_SDD2	U16	Temperature 10K YSI SDD "B"	C = 1/(1.129241E-3 + 2.341077E-4 * ln(DN * 73.4236) + 8.775468E-8 * (ln(DN * 73.4236)) ^3) - 273.15
HK_SH_AFE	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_LVCM	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_HVMM	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_BIPOD1	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_BIPOD2	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_BIPOD3	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_COVER	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_HOP	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_FLIE	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_TEC1	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_TEC2	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_XRAY	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454

HK_SH_YLLW	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_SH_MCC	U16	Temperature 1K PRT, 4-wire	C = DN * 0.0320719 - 262.454
HK_HVPS_FVMON	U16	Filament Volage Monitor	V = DN * 5 / 4095
HK_HVPS_FIMON	U16	Filament Current Monitor	V = DN * 5 / 4095
HK_HVPS_HVMON	U16	HV Voltage Monitor	KV = DN * 33 / 4095
HK_HVPS_HIMON	U16	HV Current Monitor	µA = DN * 25/ 4095
HK_HVPS_+13V	S16	V, HVPS, pos	V = DN * 15 / 4095
HK_HVPS_-13V	S16	V, HVPS, neg	V = DN * 15 / 4095 (signed)
HK_HVPS_+5V	S16	V, HVPS, pos	V = DN * 15 / 4095
HK_HVPS_LVCM	U16	Temperature 10K YSI LVCM "H"	C = 1/(1.032797E-3 + 2.385758E-4 * ln(DN * 29400/(4095 - DN)) + 1.583187E-7 * (ln(DN * 29400/(4095 - DN)) ^3)) - 273.15 – UPDATED IN D-94125 RevF - added close-parenthesis ")"
HK_VALID_CMDS	U16	Counter	# of valid commands received (CF CC=1)
HK_CRF_RETRY_CMDS	U16	Counter	# of valid commands received (CF CC=2)
HK_SDF_RETRY_CMDS	U16	Counter	# of valid commands received (CF CC=18)
HK_REJECTED_CMDS	U16	Counter	# of invalid commands received (CRF CC<>1)
HK_SIDE	hex16	RCE CMD Source	0 = primary side A 1 = redundant side B
[unused]	hex16	*Unused*	

HK_MOTOR_POS1	S16	Strut 1 position	Relative steps from specified position 0
HK_MOTOR_POS2	S16	Strut 2 position	Relative steps from specified position 0
HK_MOTOR_POS3	S16	Strut 3 position	Relative steps from specified position 0
HK_MOTOR_POS4	S16	Strut 4 position	Relative steps from specified position 0
HK_MOTOR_POS5	S16	Strut 5 position	Relative steps from specified position 0
HK_MOTOR_POS6	S16	Strut 6 position	Relative steps from specified position 0
HK_MOTOR_POS7	S16	*Unused*	
HK_MOTOR_POS8	S16	Cover position	Relative steps from specified position 0
HK_MOTOR_SENSE	S16	8 Hall-effect sensors	0 = north detected; 1 = south detected
HK_FLASH_STATUS	hex16	4 flash status bits	0 = no error
[unused]	hex16	*Unused*	
HK_VERSION	hex32	FPGA Version	
HK_TIME	U32	Counter	seconds from POR or 2000-Jan-01 1:58:55 UTC
HK_POWER	hex32	12 status bits	0 = off, 1 = on

FSW_0	hex32	breadcrumb register	Defined by FSW
FSW_1	hex32	breadcrumb register	Defined by FSW
FSW_2	hex32	breadcrumb register	Defined by FSW
FSW_3	hex32	breadcrumb register	Defined by FSW
FSW_4	hex32	breadcrumb register	Defined by FSW
FSW_5	hex32	breadcrumb register	Defined by FSW

Produced by: Sub-command FetchHK

4.2.6 Data Product: HK Frame Standalone PixlUtility DPO (PE/EHK) Same as E08 – not archived

The Housekeeping Frame Data Product documents the content of the Housekeeping Data at the time the DP was created. This file is in ASCII *.CSV format. **This data product will not be archived by PDS.** The content of the HK frame is the same as EDR E08 (Section 4.2.8), but this standalone type is generated via the PIXL_SEND_HK_DATA command instead of a scan observation. This means they will not have the Data Field Piece header, and therefore will have no associated RTT or PMC. EDR filename will use null char in RTT & PMC fields ("-" or "_").

4.2.7 Data Product: Remark (PE/E12) – not archived

The Remark Data Product provides a mechanism for clearly identifying the output from a given script by inserting a brief ASCII character string directly in the output stream. The “Content” field in the following structure contains a string of bytes as provided by the Remark subcommand defined above. The length of the string is 4 – 252 bytes (modulo 4). This is a *.txt ASCII file. **This data product will not be archived by PDS.**

Data Product: Remark

Content
Content of the Remark sub-command

Produced by: Sub-command Rem

4.2.8 GV Report B – High Priority (PE/E14) – not archived

The form of the GV Report – High Priority has the same content and layout as the GV Report Low Priority E05 (Section 4.2.5). Two different DP categories are defined to help manage downlink of on-board data. This file is in binary *.dat format. **This data product is not archived by PDS.** See GV Report B – Low Priority (PE/E05).

4.2.9 Data Product: PIXL Proximity (PE/E15) – not archived

The Surface Proximity Data Product documents the knowledge in the iFSW concerning the surface in front of the Sensor Head. This product is generated based on the SLI Centroids returned form the MCC. The DP contains the location in the PIXL Base Frame of:

1. The center of the cloud of centroids returned from the MCC
2. The unit normal vector of to the approximated surface through that point based on the cloud of centroids
3. The point in the cloud that is closest to the Instrument Base.

Data Product: PIXL Proximity (*RCE-only DP) – CLARIFIED FORMAT IN REV H

Content
X-value of Center of Known Surface in the PIXL Base Frame. IEEE-754 Floating Point format in meters.
Y-value of Center of Known Surface in the PIXL Base Frame. IEEE-754 Floating Point format in meters.
Z-value of Center of Known Surface in the PIXL Base Frame. IEEE-754 Floating Point format in meters.

X-value of the Unit Normal Vector for the approximation for the plan determined by the SLI data. IEEE-754 Floating Point format in radians.
Y-value of the Unit Normal Vector for the approximation for the plan determined by the SLI data. IEEE-754 Floating Point format in radians.
Z-value of the Unit Normal Vector for the approximation for the plan determined by the SLI data. IEEE-754 Floating Point format in radians.
X-value of point in the cloud that is closest to the Instrument Base. IEEE-754 Floating Point format in meters.
Y-value of point in the cloud that is closest to the Instrument Base. IEEE-754 Floating Point format in meters.
Z-value of point in the cloud that is closest to the Instrument Base. IEEE-754 Floating Point format in meters.

Produced by: Sub-command GenPixlProximity

4.2.10 Data Product: Normal Duration Histogram - A (PS/ENA) - Archived

This Data Product contains the Normal Duration Histogram from Detector A. The PIXL Data Product consists of some header fields followed by the Histogram encoded by the Dragonfly compression algorithm. Details of the Dragonfly output format are available in the PIXL iFSW Software Design Document (D-94113). These files are in ASCII *.CSV format. **These data products are archived by PDS.**

Data Product: Normal Duration Histogram - A
Data Product: Normal Duration Histogram - B
Data Product: Dwell Duration Histogram - A
Data Product: Dwell Duration Histogram - B

Content
Run Status
DPP Status
Real Time in 500 ns units – Low order 16 bits
Real Time in 500 ns units – Middle 16 bits
Real Time in 500 ns units – High order 16 bits
Live Time in 500 ns units – Low Order 16 bits
Live Time in 500 ns units – Middle 16 bits
Live Time in 500 ns units – High Order 16 bits
Number of Events in the Histogram – Low order 16 bits
Number of Events in the Histogram – High order 16 bits
Number of Triggers (threshold crossings) detected. – Low order 16 bits
Number of Triggers (threshold crossings) detected. – High order 16 bits
Number of Overflows detected – Low order 16 bits
Number of Overflows detected – High order 16 bits
Number of Underflows detected – Low order 16 bits
Number of Underflows detected – High order 16 bits
Number of Base Events detected – Low order 16 bits
Number of Base Events detected – High order 16 bits
Number of Preamp resets detected – Low order 16 bits
Number of Preamp resets detected – High order 16 bits
Number of Excursions above ADCMAX – Low order 16 bits
Number of Excursions above ADXMAX – High order 16 bits
Number of bins in the Histogram

Number of bytes in the data portion to follow
Product from the Dragonfly compression algorithm (to 4096)

4.2.11 Data Product: Normal Duration Histogram - B (PS/ENB) - Archived

This Data Product contains the Normal Duration Histogram from Detector B. The PIXL Data Product consists of some header fields followed by the Histogram encoded by the Dragonfly compression algorithm. Details of the Dragonfly output format are available in the PIXL iFSW Software Design Document (D-94113). These files are in ASCII *.CSV format. **These data products are archived by PDS.**

The content/format of this PIXL Data is the same as the A-side Normal Duration Histogram. See section 4.2.10 of this document.

4.2.12 Data Product: Dwell Duration Histogram – A (PS/EDA) - Archived

This Data Product contains the Dwell Duration Histogram from Detector A. The PIXL Data Product consists of some header fields followed by the Histogram encoded by the Dragonfly compression algorithm. Details of the Dragonfly output format are available in the PIXL iFSW Software Design Document (D-94113). These files are in ASCII *.CSV format. **These data products are archived by PDS.**
The content/format of this PIXL Data is the same as the A-side Normal Duration Histogram. See section 4.2.10 of this document.

4.2.13 Data Product: Histogram Dwell B (PS/EDB) - Archived

This Data Product contains the Dwell Duration Histogram from Detector B. The PIXL Data Product consists of some header fields followed by the Histogram encoded by the Dragonfly compression algorithm. Details of the Dragonfly output format are available in the PIXL iFSW Software Design Document (D-94113). These files are in ASCII *.CSV format. **These data products are archived by PDS.**
The content/format of this PIXL Data is the same as the A-side Normal Duration Histogram. See section 4.2.10 of this document.
Produced by: CollectHistogram

4.2.14 Data Product: Pseudo Intensity Data Product; Normal Duration (PS/EPN) - Archived

Pseudo Intensity Data Product Format is a series of 32 Adaptive Channel values whose interpretation is subject to the Adaptive Sampling Parameters in place when the data was acquired. These files are in ASCII *.CSV format. The discussion of which channels are incorporated in the Adaptive Sampling Parameters can be found in the PIXL RDR SIS. **These data products are archived by PDS.**

Data Product: PseudoIntensity Data Product; Normal Duration – NEW TO REV H
Data Product: PseudoIntensity Data Product; Dwell Duration – NEW TO REV H

Content
Adaptive Sampling Channel 1
Adaptive Sampling Channel 2
Adaptive Sampling Channel 3
Adaptive Sampling Channel 4
Adaptive Sampling Channel 5 – 31
Adaptive Sampling Channel 32

Produced by: GenerateMaxValHistogram AdsampUpdateNormal
Produced by: GenerateMaxValHistogram AdsampUpdateDwell

4.2.15 Data Product: Pseudo Intensity Data Product; Dwell Duration (PS/EPD) - Archived

Pseudo Intensity Data Product for the Dwell Duration scan has the same format as the Normal Duration Scan. The content/format of this PIXL Data is the same as the Normal Duration Pseudo intensity. See section 4.2.14 of this document. These files are in ASCII *.CSV format. The discussion of which channels are incorporated in the Adaptive Sampling Parameters can be found in the PIXL RDR SIS. **These data products are archived by PDS.**

Produced by: Adaptive Sampling on a DWELL Histogram

4.2.16 Data Product: Max Value Histogram – A (PS/EMA) - Archived

This Data Product contains the Max Value Histogram from Detector A. The PIXL Data Product consists of the encoded output of the Dragonfly compression algorithm. Details of the Dragonfly output format are available in the PIXL iFSW Software Design Document (D-94113). These files are in ASCII *.CSV format. **These data products are archived by PDS.**

Content
PMC – PIXL Motion Counter
Real Time (Sum for all points in Scan) – Float
Live Time (Sum for all points in Scan) – Float
Number of Events (Sum for all points in Scan) -- Integer
Triggers (Sum for all points in Scan) – Integer
Overflows (Sum for all points in Scan) – Integer
Underflows (Sum for all points in Scan – Integer
Base Events (Sum for all points in Scan) – Integer
Preamp Resets (Sum for all points in Scan -- Integer
Excursions above ADCMAX (Sum for all points in Scan – Integer
Number of bins in Histogram
Number of bytes in data portion
Output Product from DragonFly compression of the Max Value buffer

ORIGINAL FORMAT

Content
Number of bins in the Histogram
Number of bytes in the data portion to follow
Output Product from the Dragonfly compression algorithm.

Produced by: GenerateMaxValHistogram
Produced by: GenerateBulkSumHistogram

Note that the number of bins in the Histogram can not be greater than 4096, thus the first 32-bits of the DP definitely identify whether the DP is of the old format, or the new.

4.2.17 Data Product: Max Value Histogram – B (PS/EMB) - Archived

This Data Product contains the Max Value Histogram from Detector B. The PIXL Data Product consists of the encoded output of the Dragonfly compression algorithm. Details of the Dragonfly output format are available in the PIXL iFSW Software Design Document (D-94113). These files are in ASCII *.CSV format. **These data products are archived by PDS.** The content/format of this PIXL Data is the same as the A-side Max Value Histogram. See section 4.2.16 of this document.

4.2.18 Data Product: Bulk Sum Histogram – A (PS/EBA) - Archived

This Data Product contains the Bulk Sum Histogram from Detector A. The PIXL Data Product consists of the encoded output of the Dragonfly compression algorithm. Details of the Dragonfly output format are available in the PIXL iFSW Software Design Document (D-94113). These files are in ASCII *.CSV format. **These data products are archived by PDS.** The content/format of this PIXL Data is the same as the A-side Max Value Histogram. See section 4.2.16 of this document.

4.2.19 Data Product: Bulk Sum Histogram – B (PS/EBB) - Archived

This Data Product contains the Bulk Sum Histogram from Detector B. The PIXL Data Product consists of the encoded output of the Dragonfly compression algorithm. Details of the Dragonfly output format are available in the PIXL iFSW Software Design Document (D-94113). These files are in ASCII *.CSV format. **These data products are archived by PDS.** The content/format of this PIXL Data is the same as the A-side Max Value Histogram. See section 4.2.16 of this document.

4.2.20 Data Product: DSPC Register Dump (PS/EHR) – not archived

This Data Product contains the Register Dump from the DSPC.

Offset: Content
0x00: DSPC FPGA Version – A
0x00: DSPC FPGA Version – B

0x01: Variant – A
0x01: Variant – B
0x08: Run Control – A
0x08: Run Control – B
0x09: Run Preset Register – A
0x09: Run Preset Register – B
0x0A: Preset Length, Low order 16 bits – A
0x0A: Preset Length, Low order 16 bits – B
0x0B: Preset Length, Middle 16 bits – A
0x0B: Preset Length, Middle 16 bits – B
0x0C: Preset Length, High order 16 bits – A
0x0C: Preset Length, High order 16 bits – B
0x10: DPP Control Word – A
0x10: DPP Control Word – B
0x11: PA – A
0x11: PA – B
0x12: PB – A
0x12: PB – B
0x13: PG – A
0x13: PG – B
0x14: PC – A
0x14: PC – B
0x15: PD – A
0x15: PD – B
0x16: PCS – A
0x16: PCS – B
0x17: PE – A
0x17: PE – B
0x18: PF – A
0x18: PF – B
0x19: PH – A
0x19: PH – B
0x1A: PBLD – A
0x1A: PBLD – B
0x1B: PKINT – A
0x1B: PKINT – B

0x1C: PKSAM – A
0x1C: PKSAM – B
0x1D: MAXWID – A
0x1D: MAXWID – B
0x1E: ADCMIN – A
0x1E: ADCMIN – B
0x1F: ADCMAX – A
0x1F: ADCMAX – B
0x20: RESETINT – A
0x20: RESETINT – B
0x21: FTHRESH – A
0x21: FTHRESH – B
0x22: BTHRESH – A
0x22: BTHRESH – B
0x23: ETHRESH – A
0x23: ETHRESH – B
0x24: FSCALE – A
0x24: FSCALE – B
0x25: FBLAVGDIV – A
0x25: FBLAVGDIV – B
0x26: BLAVGDIV – A
0x26: BLAVGDIV – B
0x27: BLCUTVAL – A
0x27: BLCUTVAL – B
0x28: MCAGAIN – A
0x28: MCAGAIN – B
0x29: MCAGAINEXP – A
0x29: MCAGAINEXP – B
0x2A: MCALIMLO – A
0x2A: MCALIMLO – B
0x2B: MCALIMHI – A
0x2B: MCALIMHI – B
0x2C: NBLANKINT – A
0x2C: NBLANKINT – B
0x30: RCIGSCOEFF – A
0x30: RCIGSCOEFF – B

0x31: RCIGSEXP – A
0x31: RCIGSEXP – B
0x32: RCILSCOEFF – A
0x32: RCILSCOEFF – B
0x33: RCILSEXP – A
0x33: RCILSEXP – B
0x34: RCITSCOEFF – A
0x34: RCITSCOEFF – B
0x35: RCITSEXP – A
0x35: RCITSEXP – B
0x36: RCSGSCOEFF – A
0x36: RCSGSCOEFF – B
0x37: RCSGSEXP – A
0x37: RCSGSEXP – B
0x38: RCSLSCOEFF – A
0x38: RCSLSCOEFF – B
0x39: RCSLSEXP – A
0x39: RCSLSEXP – B
0x3A: RCSTSCOEFF – A
0x3A: RCSTSCOEFF – B
0x3B: RCSTSEXP – A
0x3B: RCSTSEXP – B
0xC0: FPGA_ID – A
0xC0: FPGA_ID - B
0xC1: TEC_SET – A
0xC1: TEC_SET – B
0xC2: DAC_OVR – A
0xC2: DAC_OVR – B
0xC3: TEC_FB_GAIN – A
0xC3: TEC_FB_GAIN – B
0xC4: TEC_FB_MAX_STEP – A
0xC4: TEC_FB_MAX_STEP – B
0xC5: TEC_SRC_STATUS – A
0xC5: TEC_SRC_STATUS – B
0xC6: TEC_PRT_VALUE – A
0xC6: TEC_PRT_VALUE – B

0xD0: HV_DAC – A
0xD0: HV_DAC – B
0xD1: HV_CLK_PER – A
0xD1: HV_CLK_PER – B
0xF0: FPGA_DATE_YYMM – A
0xF0: FPGA_DATE_YYMM – B
0xF1: FPGA_DATE_DD_VER – A
0xF1: FPGA_DATE_DD_VER – B

4.2.21 Data Product: Scan Parameters (iFSW v7) (PS/E16) – not archived

This Data Product contains the parameters that are in place when the Scan was initiated.

Content	
Reserved Field – All zeros	
Number of points in the Scan – Integer	
Number of Points in the Log – Integer	
X-component of center of the Scan in Base Frame (meters) – Float	
Y-component of center of the Scan in Base Frame (meters) – Float	
Z-component of center of the Scan in Base Framd (meters) – Float	
X-component of Pivot Point (meters) – Float	
Y-component of Pivot Point (meters) – Float	
Z-component of Pivot Point (meters) – Float	
Rfocus value (meters) – Float	
X-component of Scanned Point (meters) – Float	Repeated for each point in the log
Y-component of Scanned Point (meters) – Float	
Z-component of Scanned Point (meters) – Float	
Mask of Collected Data – Integer	
X-component of Accumulated Correction (meters) – Float	

Y-component of Accumulated Correction (meters) – Float	
Z-component of Accumulated Correction (meters) – Float	
PIXL Motion Counter – Integer	

Produced by: GenerateScanParams

4.2.22 Data Product: Scan Log (iFSW v7) (PS/E34) - Archived

This Data Product contains the summary of results of the Scan. The Scan Log DP is produced in the following conditions:

1. Nominal conclusion of a Scan
2. Off-nominal termination of a Scan, if the number of points in the Scan Log is greater than zero.
3. ABORT during a Scan, if the number of points in the Scan Log is greater than zero.

Content	
Reserved Field – All zeros	
Number of points in the Scan – Integer	
Number of Points in the Log – Integer	
X-component of center of the Scan in Base Frame (meters) – Float	
Y-component of center of the Scan in Base Frame (meters) – Float	
Z-component of center of the Scan in Base Framd (meters) – Float	
X-component of Pivot Point (meters) – Float	
Y-component of Pivot Point (meters) – Float	
Z-component of Pivot Point (meters) – Float	
Rfocus value (meters) – Float	
X-component of Scanned Point (meters) – Float	Repeated for each point in the log
Y-component of Scanned Point (meters) – Float	
Z-component of Scanned Point (meters) – Float	
Mask of Collected Data – Integer	
X-component of Accumulated Correction (meters) – Float	

Y-component of Accumulated Correction (meters) – Float	
Z-component of Accumulated Correction (meters) – Float	
PIXL Motion Counter – Integer	

Note: The **Mask of Collected Data** field is a 32-bit value wherein the bits in the mask indicate what actions were taken at each point in the Log. The bit masks values have the following meaning:

Mask	Meaning
0x00000001	Histogram acquired
0x00000002	OFS Correction occurred
0x00000004	TRN Correction occurred
0x00000008	Pause occurred for Metrology (only meaningful for ATLO Ops)
0x00000010	JPG Context Image was acquired
0x00000020	JPG Periodic Image was acquired
0x00000040	JPG Special Planned Image was acquired
0x00000080	Uncompressed Image was acquired
0x00000100	JPG Image with SLI-A was acquired
0x00000200	JPG Image with SLI-B was acquired
0x00000400	SLI-A Struct was acquired
0x00000800	SLI-B Struct was acquired
0x00001000	ROI Image with SLI-Awas acquired
0x00002000	ROI Image with SLI-B was acquired
0x00004000	Centroid Image with SLI-A was acquired
0x00008000	Centroid Image with SLI-B was acquired
0x00010000	Point was unreachable due to End of Travel limit
0x00020000	Point was unreachable due to NTE violation
0x00040000	Unused
	Remaining bit unused

Produced by: GenerateScanLog

4.2.23 Data Product: EVR Bundle Low Priority (iFSW v7) (PS/E35) – Not Archived

Content	
SCLK value when the EVR occurred	

Library Descriptor Word-2 Bit 31 – 24 = Module ID Bit 23 – 16 = EVR ID Bit 15 – 12 = Argument Count <-- **determines total length of this EVR** Bit 11 – 0 = EVR Counter	
EVR Argument 1 (if Argument Count >= 1)	Repeat for all EVRs in bundle
EVR Argument 2 (if Argument Count >= 2)	
EVR Argument 3 (if Argument Count >= 3)	
EVR Argument 4 (if Argument Count >= 4)	
EVR Argument 5 (if Argument Count >= 5)	
EVR Argument 6 (if Argument Count >= 6)	
EVR Argument 7 (if Argument Count = 7)	

4.2.24 Data Product: PIXL Tunable Scan Parameters (iFSW v7) (PS/E36) – Not Archived

Content	GV Name root
Version Hard-coded to 0x01000000	Version
Selected Column represents the Pixel of the “interesting point” in the Source Image (integer)	Selected_Col
Selected Row represents the Pixel of the “interesting point” in the Source Image (integer)	Selected_Row
Source File ID (integer)	FileID
Columns in the rectangular scan (count)	Cols
Rows in the rectangular scan (count)	Rows
Distance between columns (meters)	col_spacing
Distance between rows (meters)	row_spacing
Boolean 0 = Columns first then Rows 1 = Rows first then Rows	direction_flag

Clock angle between the "row orientation" and the X-axis in the Base Frame (radians)	radian_angle
X-coordinate in the Base Frame of the center of the Scan (meters).	Center_X
Y-coordinate in the Base Frame of the center of the Scan (meters)	Center_Y
Z-coordinate in the Base Frame of the center of the Scan (meters)	Center_Z
X-Unit Vector of the Normal to the plan to be generated (unitless)	Normal_X
Y-Unit Vector of the Normal to the plan to be generated (unitless)	Normal_Y
Z-Unit Vector of the Normal to the plan to be generated (unitless)	Normal_Z
Specification of which Detectors to use.	DSPC_Usage
Theremal Set Point for LVCM when powered (DN Counts)	LVCM_Temp_SetPoint
Thermal Set Point for TEC_A when powered. (DN Counts)	TEC_A
Thermal Set Point for TEC_B when powered. (DN Counts)	TEC_B
HVPS Voltage Set Point (DN Counts)	HV_Voltage
HV Bias Voltage for Detector in use (DN Counts)	HV_Bias_In_Use
HV Bias Voltage for Detectors not in use (DN Counts)	HV_Bias_Fallow
HC DAC current (DN Counts)	DAC_Current
Minimum number of Centroids that must match valid SLI's for an OFS measurement to deemed valid. (count)	min_sli_matches
Current value for SLI's (amps/3)	sli_current
Offset from the top corner of the Scan for acquisition of first Histogram (spots)	Histogram_offset
Offset from the top corner of the Scan for acquisition of first OFS Correction (spots)	OFS_offset
Offset from the top corner of the Scan for acquisition of first TRN Correction (spots)	TRN_offset
Offset from the top corner of the Scan for acquisition of first pause for Metrology (spots)	Metrology_offset
Offset from the top corner of the Scan for acquisition of first JPEG Context Image (spots)	JPG_Context_offset

Offset from the top corner of the Scan for acquisition of first Periodic Image (spots)	Periodic_Img_offset
Offset from the top corner of the Scan for acquisition of first ROI image (spots)	ROI_Image_offset
Offset from the top corner of the Scan for acquisition of first SLI A Struct (spots)	SLI_A_Image_offset
Offset from the top corner of the Scan for acquisition of first SLI B Struct (spots)	SLI_B_Image_offset
Offset from the top corner of the Scan for acquisition of first (spots)	SLI_A_Struct_offset
Offset from the top corner of the Scan for acquisition of first (spots)	SLI_B_Struct_offset
Period for Histogram collection (spots)	Histogram_period
Period for OFS correction (spots)	OFS_period
Period for TRN correction (spots)	TRN_period
Period for Pause for Metrology (spots)	Metrology_period
Period for JPG context image collection (spots)	JPG_Context_period
Period for Periodic image collection (spots)	JPG_Periodic_period
Period for ROI image collection (spots)	ROI_Image_period
Period for image of SLI A collection (spots)	SLI_A_Image_period
Period for image of SLI B collection (spots)	SLI_B_Image_period
Period for SLI A struct collection (spots)	SLI_A_Struct_period
Period for SLI B struct collection (spots)	SLI_B_Struct_period
Specification of which SLI to use.	SLI_Select
Legitimate values are:	
0x0B0A = B for Approach, A for Scan	
0x0A0A = A for Approach, and Scan	
0x0B0B = B for Approach, and Scan	
Number of OFS retries before declaring failure	ofs_retry_limit
Number of TRN retries before declaring failure	trn_retry_limit
Duration of Normal Histogram integration (seconds)	Integration_Normal
Duration of Dwell Histogram integration (seconds)	Integration_Dwell
Threshold beneath which a TRN lateral correction will be deemed unnecessary (meters)	xy_correct_threshold
Threshold beneath which a Z-correction (for OFS Correction or TRN correction) will be deemed unnecessary (meters)	z_correct_threshold

Limit for proximity of the closest point on the target. If any point on the target has a lower Z-value than this, then it is not save to approach the target. (meters)	min_safe_Z
Maximum dynamic range of the target. If any point on the target is more than this value from the mean, then the target is not safe to approach. (meters)	Delta_Z_Limit
Sine value of the limit of the angle between the normal vector of the observed target plane, and the Base Frame Z-vector. If the sine of the angle is greater than this, the target is not safe to approach. See Note Below	Target_Tilt_Sine_Limit
Duration for Pause for Metrology	Pause_Duration
DN Value for the HV Set Point when the EM electronics is being driven to 20 kVolt (DN Count)	HV_Voltage_EM_at_20
DN Value for the DAC Current when the EM Electronics is being driven to 20 kVolt (DN Count)	DAC_Current_EM_at_20
DN Value for the HV Set Point when the EM electronics is being driven to 28 kVolt (DN Count)	HV_Voltage_EM_at_28
DN Value for the DAC Current when the EM Electronics is being driven to 28 kVolt (DN Count)	DAC_Current_EM_at_28
Distance from the X-Ray source to the Focus Point in front of the Sensor Head (Meters)	rfocus
X-coordinate in the Base Frame of the Pivot Point for the steering algorithm (meters)	Pivot_X
Y-coordinate in the Base Frame of the Pivot Point for the steering algorithm (meters)	Pivot_Y
Z-coordinate in the Base Frame of the Pivot Point for the steering algorithm (meters)	Pivot_Z
Boolean flag to enable Bore Sight Science if Landmark Detection fails to provide a solution	boresight_sci_enabled
Boolean flag to indicate whether to continue with an observation in the face of a failure of OFS corretion to converge.	continue_on_OFS_Failure
Offset from the top corner of the Scan for performing the first Min Safe Z check (spots)	safe_Z_check_offset
Period for performing min safe Z check (spots)	safe_Z_check_period

Boolean flag to indicate that Images of SLI spots should be stored as RAW form	SLI_Image_Raw
(Default is 0 = store as JPG)	
Boolean flag to indicate that Periodic Images during a Scan should be stored as RAW form	Periodic_Image_Raw
(Default is 0 = store as JPG)	
Maximum number of DWELL Duration Histograms to acquire durint a Scan	AdSamp_Budget
(Default is zero)	
Fallow Parameter.	unused_1
Bit-Mapped integer specifying which varieties of intermediate data should be dumped by ReportGV.	dump_mask

4.2.25 TRN Estimate (PC/ESO) – Archived

This Data Product contains the TRN data from the MCC. This capability will be part of the V6.4 iFSW release. MCC TM/TC ICD 10.8: "The OLM compression executes the autonomous terrain relative navigation algorithms by extracting and matching keypoints between successive images. Usage is described in the PIXL RDR SIS and M20 Camera SIS. The output TM packets or image data will be different depending on the configuration.

Content
34-byte image header* taken directly from the first TM packet from the MCC

<u> 34-byte MCC_header</u>*

From para 10.8 of the MCC TM/TC document: The OLM compression executes the autonomous terrain relative navigation algorithms by extracting and matching keypoints between successive images. Usage is described in RD1. The output TM packets or image data will be different depending on the configuration (see PIXL Specific System Parameters in Section 0*).	**PIXL Specific System Parameters list*
Meta Data (if any) as provided by MCC. Refer to Para 10.10* in the MCC TM/TC document	**MCC_metadata*

4.2.26 SLI Estimate (PC/ESF) - Archived

The SLI image compression structure contains the distance and plane solutions derived from the SLI measurements.

SLI taken after(+before?) as thermal drift correction.

Also used for Z-calc & terrain tracking

SLI_A = Fine/Dense SLI ; SLI_B = Coarse/Sparse SLI

MCC TM/TC ICD 10.9: "The SLI compression executes the SLI algorithm that acquires distances to the observed terrain, using the SLI pattern. Usage is described in the PIXL RDR SIS and M20 Camera SIS.

The SLI image compression structure contains the distance and plane solutions derived from the SLI measurements. It consist of a 26 bytes SLI header followed by N x 24 bytes CenSLI data listed sequentially."

"The SLI compression executes the SLI algorithm that acquires distances to the observed terrain, using the SLI pattern. The usage is described in RD1.
The SLI image compression structure contains the distance and plane solutions derived from the SLI measurements.
It consist of a ~~22 bytes~~ SLI header (26 bytes in TM/TC ICD v1.4) followed by N x 24 bytes CenSLI data listed sequentially."

Content
34-byte image header taken directly from the first TM packet from the MCC
The content of this DP is a SLI Structure. See para 10.9 of the MCC TM/TC document.
Meta Data (if any) as provided by MCC. Refer to Para 10.10 in the MCC TM/TC document

SLI Header Struct):
Description
Number of following centroids (N)
Number of SLI matches
RMSE on matched centroids [unit: tenth of a pixel]
Reserved
Plane normal. The estimated plane normal of the surface. The three first elements of STRUCT_PLANE
Plane Distance. The estimated distance to the plane along boresight [unit: microns]. Last element of STRUCT_PLANE
Plane RMSE [microns]
Reserved
Warning flag (details below)
Error flag (details below)
CenSLI Struct (24 Bytes each):
Description
** Centroid X, raw ucorrected for distortion * The X and Y centroids are coded as 4 byte unsigned longs. In order to convert to image coordinates, these integers must be divided by 5000000.*

** Centroid Y, raw ucorrected for distortion * The X and Y centroids are coded as 4 byte unsigned longs. In order to convert to image coordinates, these integers must be divided by 5000000.*
The intensity of the centroid
3D Position (X, Y, Z) [Unit microns]
SLI ID tag of the matched SLI beam (details below)
SLI Residual [Unit: tenth of a pixel]

For non-matched centroids the SLI ID tag has a reserved value of 0xFF.
For a successful match the SLI ID is labelled as in the table below. Note that the estimated plane distance and normal is solely based on unique matches

Description
SLI ID. Unique ID tag of each individual SLI beam that the centroid is matched to. Ambiguity Flag. 0: The SLI beam is uniquely matched 1: The SLI beam match is ambiguous, linked in second matching iteration

Warning Flag (Byte 24 of SLI Header): *The warning flags associated to SLI compression format are decoded according to the following table, where the bits are ordered and transmitted from the highest to the lowest:*

Description
No Centroids: 0: At least 1 centroids is detected 1: No or more than 200 centroids are detected No SLI Match: 0: One or more centroids are matched to the SLI models 1: No centroids are matched to the SLI models

High Residual: 0: The residual from the centroids and SLI models is within nominal values 1: The residual from the matched centroids and SLI models is outside the nominal operational boundary No Plane: 0: Plane is estimated 1: No plane is estimated due to too few points. Reserved

Error Flag (Byte 25 of SLI Header): *The Error flags associated to SLI compression format are decoded according to the following table, where the bits are ordered and transmitted from the highest to the lowest:*

Description
No SLI Data: 0: The SLI model data bank is loaded successfully 1: The SLI model data bank is unsuccessfully loaded or no data is stored on the reserved data bank Reserved

Table 4-2 List of PIXL products to be archived

Product Name	NASA Level	Standard or Special	Description	Data Set Producer	Archive Volume Producer	PDS Curator
PIXL HK FRAME EDR	Raw	Standard	Engineering data at the time of each X-ray measurement (E08)	IDS	PIXL Team	Geosciences
PIXL GV REPORT B EDR	Raw	Standard	Scan Log that gives the actual (drift-corrected) hexapod coordinates for each X-ray measurement (E34)	IDS	PIXL Team	Geosciences
PIXL HISTOGRAM NORMAL A EDR	Raw	Standard	Regular histogram at nominal dwell time from X-ray detector A (ENA)	IDS	PIXL Team	Geosciences
PIXL HISTOGRAM	Raw	Standard	Regular histogram at nominal dwell time from X-ray detector B (ENB)	IDS	PIXL Team	Geosciences

NORMAL B EDR						
PIXL HISTOGRAM DWELL A EDR	Raw	Standard	Regular histogram at longer dwell time from X-ray detector A (EDA)	IDS	PIXL Team	Geosciences
PIXL HISTOGRAM DWELL B EDR	Raw	Standard	Regular histogram at longer dwell time from X-ray detector B (EDB)	IDS	PIXL Team	Geosciences
PIXL PSEUDOINTENSITY NORMAL EDR	Raw	Standard	Pseudointensity Data for each nominal-dwell X-ray histogram calculated onboard (32 channels of summed spectrum data) (EPN)	IDS	PIXL Team	Geosciences
PIXL PSEUDOINTENSITY DWELL EDR	Raw	Standard	Pseudointensity Data for each longer-dwell X-ray histogram calculated onboard (32 channels of summed spectrum data) (EPD)	IDS	PIXL Team	Geosciences
PIXL HISTOGRAM MAX VALUE A EDR	Raw	Standard	Max Value Histogram from Detector A (see definition under RDRs below) (EMA)	IDS	PIXL Team	Geosciences
PIXL HISTOGRAM MAX VALUE B EDR	Raw	Standard	Max Value Histogram from Detector B (EMB)	IDS	PIXL Team	Geosciences
PIXL HISTOGRAM BULK SUM A EDR	Raw	Standard	Bulk Sum Histogram from Detector A (EBA)	IDS	PIXL Team	Geosciences
PIXL HISTOGRAM BULK SUM B EDR	Raw	Standard	Bulk Sum Histogram from Detector B (EBB)	IDS	PIXL Team	Geosciences
PIXL MCC OLM TRN ESTIMATE EDR	Raw	Standard	Autonomous terrain relative navigation data from the MCC (used for thermal drift correction) (ESO)	IDS	PIXL Team	Geosciences
PIXL MCC SLI ESTIMATES EDR	Raw	Standard	Distance and plane solutions derived from the SLI measurements. (ESF)	IDS	PIXL Team	Geosciences
PIXL MCC JPEG IMAGE EDR	Raw	Standard	JPEG compressed context image (EDR)	IDS	PIXL Team	Geosciences
PIXL MCC RAW BIT-MAP IMAGE EDR	Raw	Standard	Uncompressed MCC images (raw bitmaps)	IDS	PIXL Team	Geosciences
PIXL LOCALIZED	Calibrated	Standard	XRF spectrum for each measured location on the target with energy	IDS	PIXL Team	Geosciences

FULL SPECTRA RDR			calibration, spatial location, and pixel location in context image			
PIXL MCC CONTEXT IMAGE RDR	Partially Processed	Standard	MCC Image context image (black-and-white image of target rock) with geometric and radiometric corrections applied	IDS	PIXL Team	Geosciences
PIXL MCC CONTEXT IMAGE WITH MARKUP RDR	Calibrated	Standard	Markup on MCC context image showing calculated X-ray measurement locations	PIXL Team	PIXL Team	Geosciences
PIXL DRIFT CORRECTED X_RAY BEAM LOCATIONS RDR	Calibrated	Standard	Location of each X-ray measurement in spatial coordinates and pixel location in context image, corrected for thermal drift of robotic arm position or other unexpected motion	PIXL Team	PIXL Team	Geosciences
PIXL BULK SUMMED SPECTRUM RDR	Calibrated	Standard	Bulk Sum Spectrum (one for each target, all PIXL point spectra for this target summed) with energy calibration	PIXL Team	PIXL Team	Geosciences
PIXL MAX VALUE SPECTRUM RDR	Calibrated	Standard	Max Value Spectrum (maximum measured value for each channel in the set of spectra for this target) with energy calibration	PIXL Team	PIXL Team	Geosciences
PIXL BULK QUANTITATIVE MEASUREMENT RDR	Derived	Standard	Quantification (element weight percents) for bulk sum spectrum	PIXL Team	PIXL Team	Geosciences
PIXL PSEUDOINTENSITY RDR	Derived	Standard	Pseudointensity values (as computed onboard) with measurement locations in spatial coordinates and pixel locations in context image	PIXL Team	PIXL Team	Geosciences
PIXL ROCK COMPONENT SUMS RDR	Derived	Special	Rock Component Sum (if components can be identified and associated in spectrum maps), including summed spectrum, net intensities, and quantification	PIXL Team	PIXL Team	Geosciences
PIXL CALIBRATION Document	Derived	Standard	Elemental and geometric calibration package	PIXL Team	PIXL Team	Geosciences

4.3 EDR Product Validation

Validation of the M2020 EDRs will fall into two primary categories: automated and manual. Automated validation will be performed on every EDR product produced for the mission. Manual validation will only be performed on a subset.

Automated validation will be performed as a part of the archiving process and will be done simultaneously with the archive volume validation. Validation operations performed will include such things as verification that the checksum in the label matches a calculated checksum for the data product (i.e., that the data product included in the archive is identical to that produced by the real-time process), a validation of the PDS syntax of the label, a check of the label values against the database and against the index tables included on the archive volume, and checks for internal consistency of the label items. The latter include such things as verifying that the product creation date is later than the earth received time, and comparing the geometry pointing information with the specified target. As problems are discovered and/or new possibilities identified for automated verification, they will be added to the validation procedure.

Manual validation of the data will be performed both as spot-checking through-out the life of the mission, and comprehensive validation of a sub-set of the data (for example, a couple of days' worth of data). These products will be viewed by a human being. Validation in this case will include inspection of the spectra or other data object for errors (like missing lines) not specified in the label parameters, verification that the target shown / apparent geometry matches that specified in the labels, verification that the product is viewable using the specified software tools, and a general check for any problems that might not have been anticipated in the automated validation procedure.

5 Standards Used in Generating Products

5.1 File Naming Standards

5.1.1 EDR Filename

Each M2020 EDR data product can be uniquely identified by incorporating into the product filename at minimum the Instrument ID, SCLK (or UTC), Product Type identifier, and Version number. The convention is illustrated in Figure 12 PIXL spectroscopy filename example.below. Note that the PIXL non-imaging products discussed in this SIS do not use the camera specific fields “geometry”, “thumbnail”, and “camera specific”, so the first two fields are incorporated into the “product id” field, increasing it to five characters.

The file naming scheme has been relieved of the string length constraint imposed by the Level II 36.3 filename standard used in PDS3. In the PDS4 standard the path and filename together are essentially limited to a character string length of 255. This is a change from the 36.3 convention that M2020 was constrained to using. Use of three-character extensions, such as “.IMG” for image EDRs and “.DAT” or “.CSV” for spectrum EDRs and state-of-health EDRs, is consistent with the PDS4 standard.

There are three file naming schemes adapted for the M2020 image and non-image data products. The first applies to the EDR data product. The second applies to all Mosaic RDR data products. The third applies to Terrain products.

The primary attributes of the filename nomenclature are:

a) Uniqueness - It must be unique unto itself without the file system’s directory path. This protects against product overwrite as files are copied/moved within the file system and external to the file system, if managed correctly.

b) Metadata - It should be comprised of metadata fields that keep file bookkeeping and sorting intuitive to the human user. Even though autonomous file processing will be managed via databases, there will always be human-in-the-loop that puts a premium on filename intuition. Secondly, the metadata fields should be smartly selected based on their value to ground processing tools, as it is less CPU-intensive to extract information from the filename than from the label.

NOTE: Metadata information in the filename also resides in the product label.

The metadata fields have been selected based on MER and Phoenix lessons learned. In general, the metadata fields are arranged to achieve:

a) Sortability - At the beginning of the filename resides a primary time-oriented field such as Spacecraft Clock Start Count (SCLK). This allows for sorting of files on the M2020 file system by spacecraft data acquisition time as events occurred on Mars.

b) Readability - An effort is made to alternate Integer fields with ASCII character fields to optimize differentiation of field boundaries for the human user.

5.1.2 PIXL Non-Imaging EDR Filename Specifics

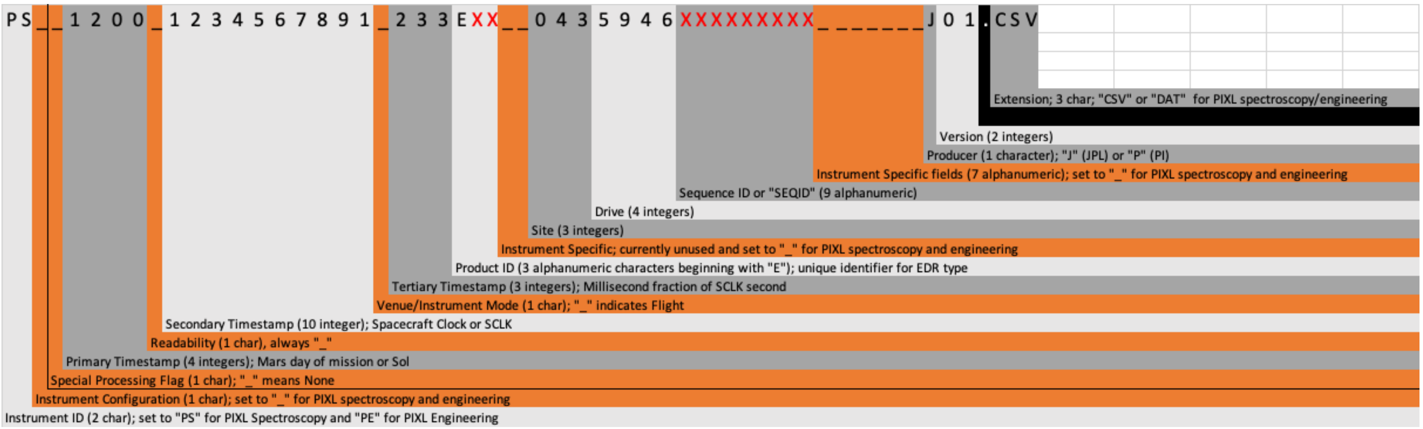
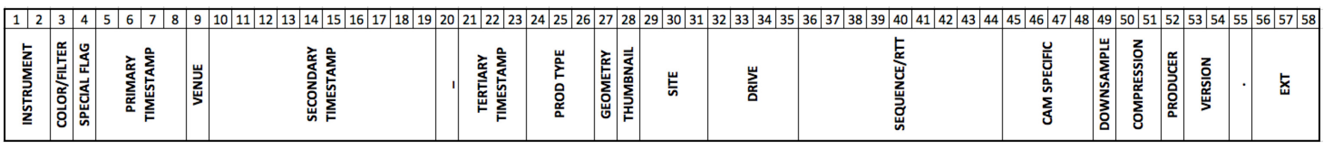


Figure 12 PIXL spectroscopy filename example.

Table 5-1 M2020 Instrument EDR filename fields



Field	Position (size, type)	Description
Instrument	01 (2, a)	Instrument Identifier: • FL : Front Hazcam Left (RCE-A) • FR : Front Hazcam Right (RCE-A) • FA : Front Hazcam Anaglyph (RCE-A) • FC : Front Hazcam Colorglyph (RCE-A) • BL : Front Hazcam Left (RCE-B) • BR : Front Hazcam Right (RCE-B) • BA : Front Hazcam Anaglyph (RCE-B) • BC : Front Hazcam Colorglyph (RCE-B) • CC : Cache Cam • EA : EDL Parachute Uplook Cam A (PUC-A) • EB : EDL Parachute Uplook Cam B (PUC-B) • EC : EDL Parachute Uplook Cam C (PUC-C) • ED : EDL Rover Downlook Cam (RDC) • EL : EDL Lander Vision System (LVS) • ES : EDL Descent Stage Downlook Cam (DSD) • EU : EDL Rover Uplook Cam (RUC)

INSTRUMENT	COLOR/FILTER	SPECIAL FLAG	PRIMARY TIMESTAMP	VENUE	SECONDARY TIMESTAMP	_	TERTIARY TIMESTAMP	PROD TYPE	GEOMETRY	THUMBNAIL	SITE	DRIVE	SEQUENCE/RTT	CAM SPECIFIC	DOWNSAMPLE	COMPRESSION	PRODUCER	VERSION	.	EXT
1 2	3	4	5 6 7 8	9	10 11 12 13 14 15 16 17 18 19	20	21 22 23	24 25 26	27	28	29 30 31	32 33 34 35	36 37 38 39 40 41 42 43 44	45 46 47 48	49	50 51	52	53 54	55	56 57 58

Field	Position (size, type)	Description
		• HN : Mars Helicopter Navigation Cam • HS : Mars Helicopter Scout Cam • ZL : Mastcam-Z Left • ZR : Mastcam-Z Right • ZA : Mastcam Anaglyph ZC : Mastcam Colorglyph • WS : MEDA Skycam • NL : Navcam Left • NR : Navcam Right • NA : Navcam Anaglyph • NC : Navcam Colorglyph • PC : PIXL Micro Context Cam (MCC) • RL : Rear Hazcam Left • RR : Rear Hazcam Right • RA : Rear Hazcam Anaglyph • RC : Rear Hazcam Colorglyph • SC : SHERLOC Context Imager (ACI) • SI : SHERLOC Imaging (Watson) • IA : SHERLOC Imaging (Watson) Anaglyph (<G6.3) • SA: SHERLOC Imaging (Watson) Anaglyph (G6.3+) • IC : SHERLOC Imaging (Watson) Colorglyph (<G6.3) • SC: SHERLOC Imaging (Watson) Colorglyph (G6.3+) – what about ACI SC? • IL : Watson treated as left-eye (<G6.3) • SL: Watson treated as left-eye (G6.3+) • IR : Watson treated as right-eye (<G6.3) • SR: Watson treated as right-eye (G6.3+) • LR : Supercam RMI Non-imaging instrument identifiers (not described in this SIS): • ME : MEDA Environment • OX : MOXIE • PE : PIXL Engineering • PS : PIXL Spectrometer • LS : SuperCam Spectrometers/Diagnostic/Generic/LIBS/Mineral/Passive (G6.3+) • SS : SHERLOC Spectrometer • XM : RIMFAX Mobile

1 2	3	4	5 6 7 8	9	10 11 12 13 14 15 16 17 18 19	20	21 22 23	24 25 26	27	28	29 30 31	32 33 34 35	36 37 38 39 40 41 42 43 44	45 46 47 48	49	50 51	52	53 54	55	56 57 58
INSTRUMENT	COLOR/FILTER	SPECIAL FLAG	PRIMARY TIMESTAMP	VENUE	SECONDARY TIMESTAMP	_	TERTIARY TIMESTAMP	PROD TYPE	GEOMETRY	THUMBNAIL	SITE	DRIVE	SEQUENCE/RTT	CAM SPECIFIC	DOWNSAMPLE	COMPRESSION	PRODUCER	VERSION	.	EXT

<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td>

- XS : RIMFAX Stationary

</td></tr>
<tr><td>Color/Filter</td><td>03 (1, i/a)</td><td>

Color flag (see CAM SIS):

- E : Raw Bayer pattern
- M : Grayscale image (Monochrome/Panchromatic)
- A : Upper green bayer cells
- D : Lower green bayer cells
- O : Other
- _ : N/A (non-imaging)

For all color cameras, the flag is set based on the color space depending on whether the product is a 3-band product, or an individual band.

Color Type	3-Band	Band 1	Band 2	Band 3
RGB	F	R	G	B
XYZ	T	X	Y	Z
xyY	C	J	K	L
HSI	P	H	S	I

For certain instruments, this flag may take on additional values indicating illumination or filter:

For PIXL, the flag can be set based on the LEDs used to illuminate the target.

LED Color	Flag
Red	R
Green	G
Blue	B
Multiple	W
UV	U
Off	_

For MCZ and SHERLOC Imaging the flag can be filter or cover state.

Instrument	Filters	Description

</td></tr>
</table>

Positions	1–2	3	4	5–8	9	10–19	20	21–23	24–26	27	28	29–31	32–35	36–44	45–48	49	50	51	52–53	54	55–58
Field	INSTRUMENT	COLOR/FILTER	SPECIAL FLAG	PRIMARY TIMESTAMP	VENUE	SECONDARY TIMESTAMP	_	TERTIARY TIMESTAMP	PROD TYPE	GEOMETRY	THUMBNAIL	SITE	DRIVE	SEQUENCE/RTT	CAM SPECIFIC	DOWNSAMPLE	COMPRESSION	PRODUCER	VERSION	.	EXT

<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>Mastcam-Z</td><td>0 – 7</td><td>See section on MCZ filters in CAM SIS</td></tr>
<tr><td>SHERLOC</td><td></td><td>See section on SHERLOC filters in CAM SIS</td></tr>
</table>

Other color flags may be defined in the future.

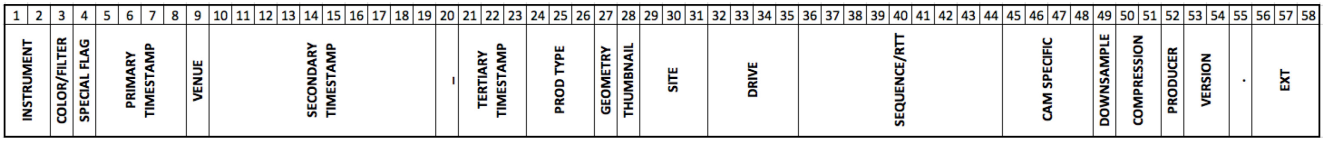
Only “E”, “F”, or “M” or Filter/LED can appear in EDRs.</td></tr>
<tr><td>Special flag</td><td>04 (1, a)</td><td>Special Processing flag, applicable to RDRs only. EDRs always have "_".

The special processing character is used to indicate off-nominal or special processing of the image. Examples include use of different correlation parameters, special stretches to eliminate shadows, reprocessing with different camera pointing, etc.

The meaning of any individual character in this field (other than "_" which means nominal processing) will be defined on an ad-hoc basis as needed during the mission. Within one Sol or a range of sols, the character will be used consistently. So, this field can be used to group together all derived products resulting from one kind of special processing. An attempt will be made to maintain consistency across different sols as well, but this may not always be possible; thus the meaning of characters may change across different individual or ranges of sols.

A database will be maintained containing all special processing designators that are used, the sols they relate to, and a description of the special processing that was done. This information will be included in the PDS archive.</td></tr>
<tr><td>Primary timestamp</td><td>05 (4, i/a)</td><td>Primary timestamp that is of coarser granularity than the Secondary timestamp. Value type is based on four scenarios:

<u>Flight Cruise</u>
Year-DOY (4 alphanumeric) - This field stores two metadata items in the order:
a) One alpha character in range “A-Z” to designate Earth Year portion of the UTC-like time value, representing Years 2017 to 2042
b) Three integers in range “001-365” representing Day-of-Year (DOY)
<u>Flight Surface</u>
Sol (4 integer) - This field stores the 4-integer Sol (Mars solar day) of the <u>first</u> (i.e., lowest Clock time) acquired instrument data.
<u>Ground Test in which SCLK in NOT reset</u>
When SCLK continuously increments and does NOT repeat, there are two variants:
a) Year-DOY (4 alphanumeric) - This field stores two metadata items in the order:
1. One alpha character in range “A-Z” to designate Earth Year portion of the UTC-like time value, representing Years 2017 to 2042
2. Three integers in range “001-365” representing Day-of-Year (DOY)
– OR –</td></tr>
</table>



Field	Position (size, type)	Description
		b) Sol (4 integer) - This field stores the 4-integer Sol (Mars solar day) of the <u>first</u> (i.e., lowest Clock time) acquired instrument data.

<u>Ground Test in which SCLK is reset</u>

When SCLK is reset and repeats, we lose time "uniqueness". So, we have to change from
SCLK to using "wall clock" derived from ERT and represent with a UTC-like format:

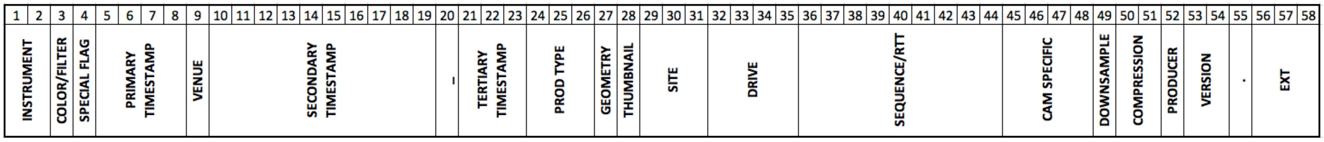
DOY-Year (4 alphanumeric) - This field stores two metadata items in reverse order compared to the previous "Year-DOY" cases, indicating that the Secondary Time field (described later) contains ERT

a) Three integers in range "001-365" representing Day-of-Year (DOY)

One alpha character in range "A-Z" to designate Earth Year portion of the UTC-like time value, representing Years 2017 to 2042

The valid values, in their progression, are as follows (non-Hex):

Scenario	Time Type	Value Format	Valid Values	Time Range
Flight Cruise	Year-DOY	[A-Z]<ddd>	"**A001**", "**A002**",…,"**A365**" "**B001**", "**B002**", **…** "**B365**" • • • "**Z001**", "**Z002**", **…** "**Z365**"	2017 - Days 1-365 2018 - Days 1-365 • • • 2042 - Days 1-365
		<aaaa>	"_ _ _ _" (4 underscores)	Value is out of range
Flight Surface	Sol	<nnnn>	"**0000**", "**0001**", **…** "**9999**"	0 thru 9999
		<aaaa>	"_ _ _ _" (4 underscores)	Value is out of range
Ground Test where SCLK is NOT reset	Year-DOY	(same as Flight Cruise)	(same as Flight Cruise)	(same as Flight Cruise)
	Sol	<nnnn>	"**0000**", "**0001**", **…** "**9999**"	0 thru 9999
		<aaaa>	"_ _ _ _" (4 underscores)	Value is out of range
Ground Test where SCLK is reset	DOY-Year	<ddd>[A-Z]	"**001A**", "**002A**", **…**,"**365A**", "**001B**", "**002B**",**…**, "**365B**", • • • "**001Z**", "**002Z**", **…** "**365Z**"	2017 - Days 1-365 2018 - Days 1-365 • • • 2042 - Days 1-365



<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td><table><tr><td></td><td></td><td><aaaa></td><td>"_ _ _ _" (4 underscores)</td><td>Value is out of range</td></tr></table></td></tr>
<tr><td>Venue</td><td>9 (1, a)</td><td>Mission venue identifier:
• _ : Flight (surface or cruise)
• A : AVSTB
• F : FSWTB
• M : MSTB
• S : "Scarecrow"
• V : VSTB

Other venue identifiers may be defined later.</td></tr>
<tr><td>Secondary timestamp</td><td>10 (10, i)</td><td>Secondary timestamp that is of finer granularity than the Primary timestamp. Value type is based on four scenarios:

<u>Flight Cruise</u>
SCLK – This field stores the 10-integer SCLK (seconds). Which specific SCLK count (Start
or End) is used depends on the instrument, but nominally it is the starting count of
the <u>first</u> (i.e., lowest Clock time) acquired instrument data.
<u>Flight Surface</u>
SCLK – Same as for "Flight Cruise"
<u>Ground Test in which SCLK in NOT reset</u>
SCLK – Same as for "Flight Cruise"
<u>Ground Test in which SCLK is reset</u>
ERT - This field stores the ERT time portions Month, Day-of-month, Hour and Seconds as
10 integers in a UTC-like format

The valid value formats are as follows:
<table><tr><th>Scenario</th><th>Time Type</th><th>Value Format</th><th>Valid Values</th><th>Time Range</th></tr><tr><td>Flight Cruise</td><td>SCLK</td><td><ssssssssss>
(Seconds)</td><td>"0000000000",
"0000000001",
•
•
•
"9999999999"</td><td>0 thru 9999999999</td></tr></table></td></tr>
</table>

1–2	INSTRUMENT
3	COLOR/FILTER
4	SPECIAL FLAG
5–8	PRIMARY TIMESTAMP
9	VENUE
10–19	SECONDARY TIMESTAMP
20	_
21–23	TERTIARY TIMESTAMP
24–26	PROD TYPE
27	GEOMETRY
28	THUMBNAIL
29–31	SITE
32–35	DRIVE
36–44	SEQUENCE/RTT
45–48	CAM SPECIFIC
49	DOWNSAMPLE
50–51	COMPRESSION
52	PRODUCER
53–54	VERSION
55	.
56–58	EXT

Field	Position (size, type)	Description

		<aaaaaaaaaa> (Alphabetic)	“__________” (10 underscores)	Value is out of range
Flight Surface	SCLK	(same as Flight Cruise)	(same as Flight Cruise)	(same as Flight Cruise)
Ground Test where SCLK is NOT reset	SCLK	(same as Flight Cruise)	(same as Flight Cruise)	(same as Flight Cruise)
Ground Test where SCLK is reset	ERT	<MMDDHHmmss> (Month, Day-of-month, Hour, Minute, Second)	“**0101010000**”, “**0101010001**”, • • • “**1231235959**”	January 1, 01:00:00 thru December 31, 23:59:59
		<aaaaaaaaaa> (Alphabetic)	“__________” (10 underscores)	Value is out of range

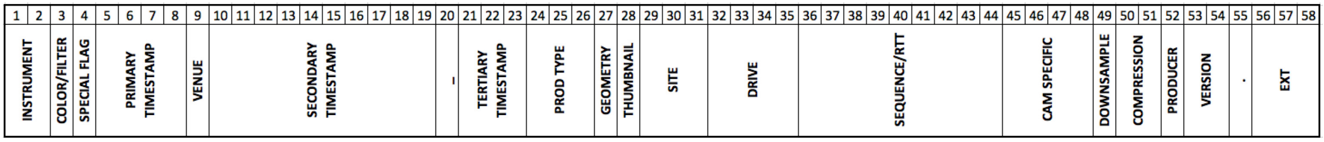
Example #1: (PIXL)
PE__0003_0667226295_000E12_N0010052000000453000000__J02.CSV

where,

instid = “**PE**” = PIXL Engineering
config = “_” = Standard for non-imaging
specflag = “_” = “_” = No special processing
time1 = “**0003**” = Sol 3
venue = “_” = Flight HW
time2 = “**0667226306**” = SCLK time of 667226306 (seconds)
_ = “_” = Standard underscore for spacing
prodid = “**000E12**” = E12 product ID type
= “**_**” = Standard for non-imaging
bitsamp = “N” = “Normal” (16-bit) sampling
site = “**001**” = Site 1
drive = “**0052**” = Drive 52
seqid = “**000000453**” = SeqID for PIXL observation
camspec = “**00000**” = Cam specific; “00000” for non-imaging
compress = “__” = Image compression; “__” non-imaging
provider = “**J**” = Product generated by IDS (JPL)

1–2	3	4	5–8	9	10–19	20	21–23	24–26	27	28	29–31	32–35	36–44	45–48	49	50	51	52–53	54	55–58
INSTRUMENT	COLOR/FILTER	SPECIAL FLAG	PRIMARY TIMESTAMP	VENUE	SECONDARY TIMESTAMP	_	TERTIARY TIMESTAMP	PROD TYPE	GEOMETRY	THUMBNAIL	SITE	DRIVE	SEQUENCE/RTT	CAM SPECIFIC	DOWNSAMPLE	COMPRESSION	PRODUCER	VERSION	.	EXT

Field	Position (size, type)	Description
		ver = "02" = Product version 1 ext = "**CSV**" = Comma-separated value file type
_	20 (1, a)	Underscore for readability. Always set to "_".
Milliseconds	21 (3, i)	Milliseconds of either the SCLK or UTC.
Product type	24 (3, a)	Product identifier. See Table 4-1 for details. This field may be extended to 5 characters in non-imaging EDRs.
Geometry	27 (1, a)	Linearization flag: • _ : Non-linearized (raw geometry) • L : Product has been linearized with nominal stereo partner • A : Product has been linearized with an actual stereo partner. • **Note**: This field may be subsumed into the product ID field in non-imaging EDRs Note that for the "A" case, an image can have multiple stereo partners and the linearized images will be different for each partner. A user will need to look in the ODL/VICAR label to determine which partner was used for linearization. All EDRs are Raw geometry ("_").
Thumbnail	28 (1, a)	Thumbnail flag: • T : Product is a thumbnail • N: Product is a non-thumbnail (full-frame, sub-frame, downsample) • _: PIXL non-imaging product **Note**: This field may be subsumed into the product ID field in non-imaging EDRs, such as for N : Product is a non-thumbnail (full-frame, sub-frame, downsample)
Site	29 (3, i/a)	Site identifier: Site location count from the RMC where the data was acquired. Values / Range: 000, 001, …, 999 — 0 thru 999 A00, A01, …, A99 — 1000 thru 1099 B00, B01, …, B99 — 1100 thru 1199 … — …



Field	Position (size, type)	Description
		(continued)

Z00, Z01, … Z99	3500 thru 3599
AA0, AA1, …, AA9	3600 thru 3609
AB0, AB1, …, AB9	3610 thru 3619
…	…
ZZ0, ZZ1, …, ZZ9	10350 thru 10359
AAA, AAB, …, AAZ	10360 thru 10385
ABA, ABB, …, ABZ	10386 thru 10411
…	…
ZZA, ZZB, …, ZZZ	27910 thru 27935
0AA, 0AB, …, 0AZ	27936 thru 27961
0BA, 0BB, …, 0BZ	27962 thru 27987
…	…
7CA, 7CB, …, 7CZ	32720 thru 32745
7DA, 7DB, …, 7DV	32746 thru 32767
_ _ _	Value out of range

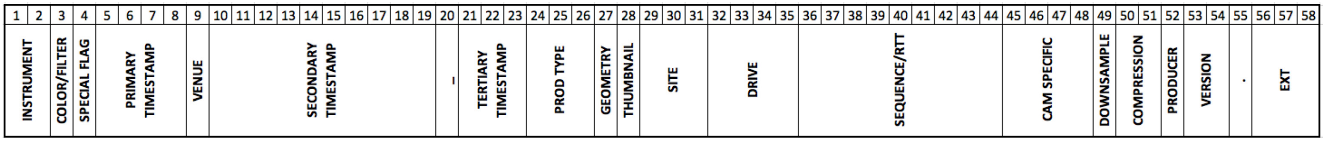
Field	Position (size, type)	Description
Drive	32 (4, i/a)	Drive identifier: Drive count (position within a Site location) from the RMC where the data was acquired.

Values	Range
0000, 0001, …, 9999	0 thru 9999
A000, A001, …, A999	10000 thru 10999
B000, B001, …, B999	11000 thru 11999
…	…
Z000, Z001, … Z999	35000 thru 35999
AA00, AA01, …, AA99	36000 thru 36099
AB00, AB01, …, AB99	36100 thru 36199
…	…
AZ00, AZ01, …, AZ99	38500 thru 38599
BA00, BA01, …, BA99	38600 thru 38699
BB00, BB01, …, BB99	38700 thru 38799

1–2	INSTRUMENT
3	COLOR/FILTER
4	SPECIAL FLAG
5–8	PRIMARY TIMESTAMP
9	VENUE
10–19	SECONDARY TIMESTAMP
20	_
21–23	TERTIARY TIMESTAMP
24–26	PROD TYPE
27	GEOMETRY
28	THUMBNAIL
29–31	SITE
32–35	DRIVE
36–44	SEQUENCE/RTT
45–48	CAM SPECIFIC
49	DOWNSAMPLE
50–51	COMPRESSION
52	PRODUCER
53–54	VERSION
55	.
56–58	EXT

<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>…</td><td>…</td></tr>
<tr><td>LJ00, LJ01, …, LJ35</td><td>65500 thru 65535</td></tr>
<tr><td>_ _ _ _</td><td>Value is out of range</td></tr>
</table>
</td></tr>
<tr><td>Seq-ID/RTT</td><td>36 (9, i/a)</td><td>Identifies sequence-ID or Round-Trip Tracking token (RTT).
• Sequence-ID : Identifier indicating the command sequenced the image was acquired from. Specific values will be assigned by the uplink team.
• RTT : Unique identifier used for tracking activities. Used in filename for PIXL ONLY.
Note: All cameras will have an RTT associated with their images but not included in the filename. PIXL is a special case where RTT and PMC are required for filename uniqueness.</td></tr>
<tr><td>Camera specific</td><td>45 (4, i/a)</td><td>Camera specific identifier. This will be “0000” for non-imaging EDRs.

Each instrument has a unique format:
<table>
<tr><th>Instrument</th><th>Format</th></tr>
<tr><td>ECAM Tile</td><td>STT_</td></tr>
<tr><td>ECAM Reconstructed</td><td>S0DR</td></tr>
<tr><td>MCZ</td><td>SZZZ</td></tr>
<tr><td>SCAM</td><td>SNNN</td></tr>
<tr><td>PIXL MCC</td><td>PPPP</td></tr>
<tr><td>SHERLOC
MEDA Skycam
EDL Cameras
HELI</td><td>S000</td></tr>
</table>
Format key:
• D : Single-resolution or multi-resolution downsampling (ECAM Reconstructed images only). Multi-resolution value represents the highest resolution tile(s) of the reconstructed image.
<table>
<tr><th>Valid values</th><th>Description</th></tr>
<tr><td>A</td><td>Single resolution (Alone)</td></tr>
</table>
</td></tr>
</table>



Field	Position (size, type)	Description

L	Multi-resolution 4x4 (Low-res)
M	Multi-resolution 2x2 (Med-res)
N	Multi-resolution 1x1 (No downsample)

- NNN : Observation counter (RMI only). Counter increments by one for each image command used in an RMI sequence (raster). Valid values are 000-999.
- PPPP : PIXL motion counter.
- R : Reconstruction counter (ECAM Reconstructed only). When a new tile is added that changes either the geometry or color of the reconstructed image, the counter increments by one. Valid values are 0-9, then A-Z.
- S : Stereo partner counter.

All EDRs are "_".

Valid values	Description
_	Nominal (synchronized) stereo or No nominal stereo partner
A-Z then 0-9	

- TT: Tile counter (ECAM Tile only). Identifies a unique tile within a reconstructed image. Valid values are 00-99.
- ZZZ : Focus value in millimeters (MCZ only). Valid values are 000-999.
- _ : Literal underscore. As last character of camera specific field, identifies an ECAM Tile.
- 0 : Literal zero. Undefined field placeholder.

Instrument teams with undefined ("0") fields may define values at a later date.

Downsample — 49 (1, i/a)

Downsample resolution identifier. This will be "_" in non-imaging modes unless downsample is feasible.

This value (n) indicates the level of downsampling applied to the image by the following equation:

Resolution = $2^n \times 2^n$

Valid values	Resolution
0	1x1

1–2	INSTRUMENT
3	COLOR/FILTER
4	SPECIAL FLAG
5–8	PRIMARY TIMESTAMP
9	VENUE
10–19	SECONDARY TIMESTAMP
20	_
21–23	TERTIARY TIMESTAMP
24–26	PROD TYPE
27	GEOMETRY
28	THUMBNAIL
29–31	SITE
32–35	DRIVE
36–44	SEQUENCE/RTT
45–48	CAM SPECIFIC
49	DOWNSAMPLE
50–51	COMPRESSION
52	PRODUCER
53–54	VERSION
55	.
56–58	EXT

Field	Position (size, type)	Description
		(continued)

1	2x2
2	4x4
3	8x8
…	...

For the case of reconstructed ECAM images, this value represents the highest resolution tile(s) in the reconstructed image (least amount of downsampling).

Compression — 50 (2, i/a)

Compression type identifier. This will be "__" in non-imaging modes

There are several modes of compression available, varying per instrument. The uplink team will decide which algorithm will provide the best results on a per sequence basis. For ECAM reconstructed images, compression value represents the compression level of the best tile(s) in the reconstruction.

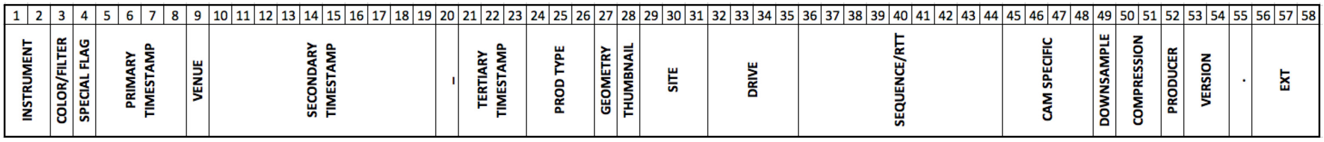
Type	Valid values	Description
JPEG (lossy)	00 01-99 A0	Thumbnail Jpeg quality level Jpeg quality level 100
ICER (lossy)	I1, I2, …, I8 I9	1 bpp, 2 bpp, …, 8 bpp Anything higher than 8 bpp
Lossless	LI LL LM LU	ICER LOCO Malin Uncompressed

Producer — 52 (1, a)

Identifier for the institution/team that created this product:

- J : JPL (IDS/MIPL)
- P : Principal investigator of instrument.

Instrument	PI
ECAM	JPL
MCZ	ASU (Tempe, AZ)
SCAM RMI	IRAP (France)
PIXL MCC	JPL
SHERLOC	JPL



<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>MEDA Skycam</td><td>Ministry of Education and Science (Spain)</td></tr>
<tr><td>EDL Cameras</td><td>JPL</td></tr>
<tr><td>HELI RTE/NAV</td><td>JPL</td></tr>
</table>

A – I, K – O, Q – Z : Co-I to be identified per instrument at the discretion of the instrument PI.
_ : undefined/other

Other producer codes will be added in the future.</td></tr>
<tr><td>Version</td><td>53 (2, a)</td><td>Product version number. Increments by one whenever a previously generated file with an otherwise identical filename exists.
<table>
<tr><th>Values</th><th>Range</th></tr>
<tr><td>00, 01, 02 …, 99</td><td>0 thru 99</td></tr>
<tr><td>A0, A1, …, A9</td><td>100 thru 109</td></tr>
<tr><td>AA, AB, …, AZ</td><td>110 thru 135</td></tr>
<tr><td>B0, B1, B2 …, B9</td><td>136 thru 145</td></tr>
<tr><td>BA, BB, …, BZ</td><td>146 thru 171</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>Z0, Z1, …, Z9</td><td>1000 thru 1009</td></tr>
<tr><td>ZA, ZB, …, ZZ</td><td>1010 thru 1035</td></tr>
<tr><td>_ _</td><td>Value is out of range</td></tr>
</table>
Every version need not exist. E.g. version 01, 02, and 04 may exist but not 03. In general, the highest-numbered version represents the best version of that product. This field increments independently of all fields.</td></tr>
<tr><td>.</td><td>55 (1, a)</td><td>Separator for filename and extension. Always set to “.”</td></tr>
<tr><td>Extension</td><td>56 (3, a)</td><td>File extension:

VIC : Used for VICAR files.
IMG : Same as .VIC with ODL label.
</td></tr>
</table>

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
INSTRUMENT		COLOR/FILTER	SPECIAL FLAG	PRIMARY TIMESTAMP				VENUE	SECONDARY TIMESTAMP										_	TERTIARY TIMESTAMP			PROD TYPE			GEOMETRY	THUMBNAIL	SITE			DRIVE				SEQUENCE/RTT									CAM SPECIFIC				DOWNSAMPLE	COMPRESSION		PRODUCER	VERSION		.	EXT		

Field	Position (size, type)	Description
		• TIF : TIFF formatted image file. (no label) • JPG : JPEG formatted image file. (no label) • PNG : PNG formatted image file. (no label) • TXT : ASCII text file. • iv : Inventor-format file • ht : Height-map file (VICAR format) • rgb : Skin file in SGI RGB format • obj: Mesh file in Wavefront OBJ format • mtl : OBJ Material file • png : Lower case for meshes • mlp : MeshLab project file • xml : PDS4 label file • DAT: Binary data file • CSV: ASCII data file • fits: SuperCam non-imaging FITS file Note: other file extensions to be added in the future

5.2 PDS Standards

The M2020 instrument EDR data product complies with Planetary Data System standards for file formats and labels, as specified in the PDS Standards Reference. See Section **3.2.** for a description of the PDS Label and the specific conventions adopted by M2020.

5.3 Time Standards

The EDR ODL labels use keywords containing time values. Each time value standard is defined according to the keyword description. See Appendix B.

5.4 Coordinate Frame Standards

The M2020 camera instrument EDR data product complies with Planetary Data System standards for file formats and labels, as specified in the PDS Standards Reference [Section 1.3]. See Section 3.2 for a description of the PDS Label and the specific conventions adopted by M2020.

5.4.1 Rover Navigation (Rover Nav) Frame

The Rover Nav frame (RNAV) is the one used for surface navigation and mobility. By definition, the frame is attached to the rover, and moves with it when the rover moves while on the surface. Its Y origin is centered on the rover and the X origin is aligned with the middle wheels' rotation axis for the deployed rover and suspension system on a flat plane. The Z origin is defined to be at the nominal surface, which is a fixed position with respect to the rover body. The actual surface will likely not be at exactly Z=0 due to the effects of suspension sag, rover tilt, rocker bogie angles, etc. The +X axis points to the front of the rover, +Y to the right side, and +Z down (perpendicular to the chassis deck).

A subset of these frames needed for a specific image or data set are defined by the *_COORDINATE_SYSTEM groups.

Note that the PLACES database [Ref X] maintains both telemetered and re-localized versions of the Site and Rover Nav frames at every available index.

Table 5-2 Coordinate Frames Used for M2020 Surface Operations

Frame Name (Label Keyword Value)	Short Name (SAPP FDD)	Reference Frame (Used to Define)	Coordinate Frame	
			Origin	Orientation
ROVER_NAV_FRAME	RNAV	Enclosing SITE_FRAME	Attached to rover	Aligned with rover
ROVER_MECH_FRAME	RMECH	Enclosing SITE_FRAME	Attached to rover	Aligned with rover
LOCAL_LEVEL_FRAME	LL	Enclosing SITE_FRAME	Attached to rover (coincident with Rover Nav Frame)	North/East/Nadir

Frame Name (Label Keyword Value)	Short Name (SAPP FDD)	Reference Frame (Used to Define)	Coordinate Frame	
			Origin	Orientation
SITE_FRAME	SITE(n)	Previous SITE_FRAME	Attached to surface	North/East/Nadir
RSM_HEAD_FRAME	RSM_HEAD	ROVER_NAV_FRAME	Attached to mast head	Aligned with pointing of mast head. This corresponds to RSM_HEAD in the Frame Manager
Arm Frames: ARM_BASE_FRAME ARM_TURRET_FRAME ARM_DRILL_FRAME ARM_GDST_ FRAME ARM_TOOL_FRAME ARM_WATSON_FRAME ARM_SHERLOC_FRAME ARM_PIXL_FRAME	Arm Frames: RA_BASE TURRET DRILL GDRT TOOL WATSON SHERLOC PIXL	ROVER_NAV_FRAME	Attached to the tool; see PPPCS for the specific tool frame.	Aligned with tool in some way; see PPPCS [Ref X] for the specific tool Frame.

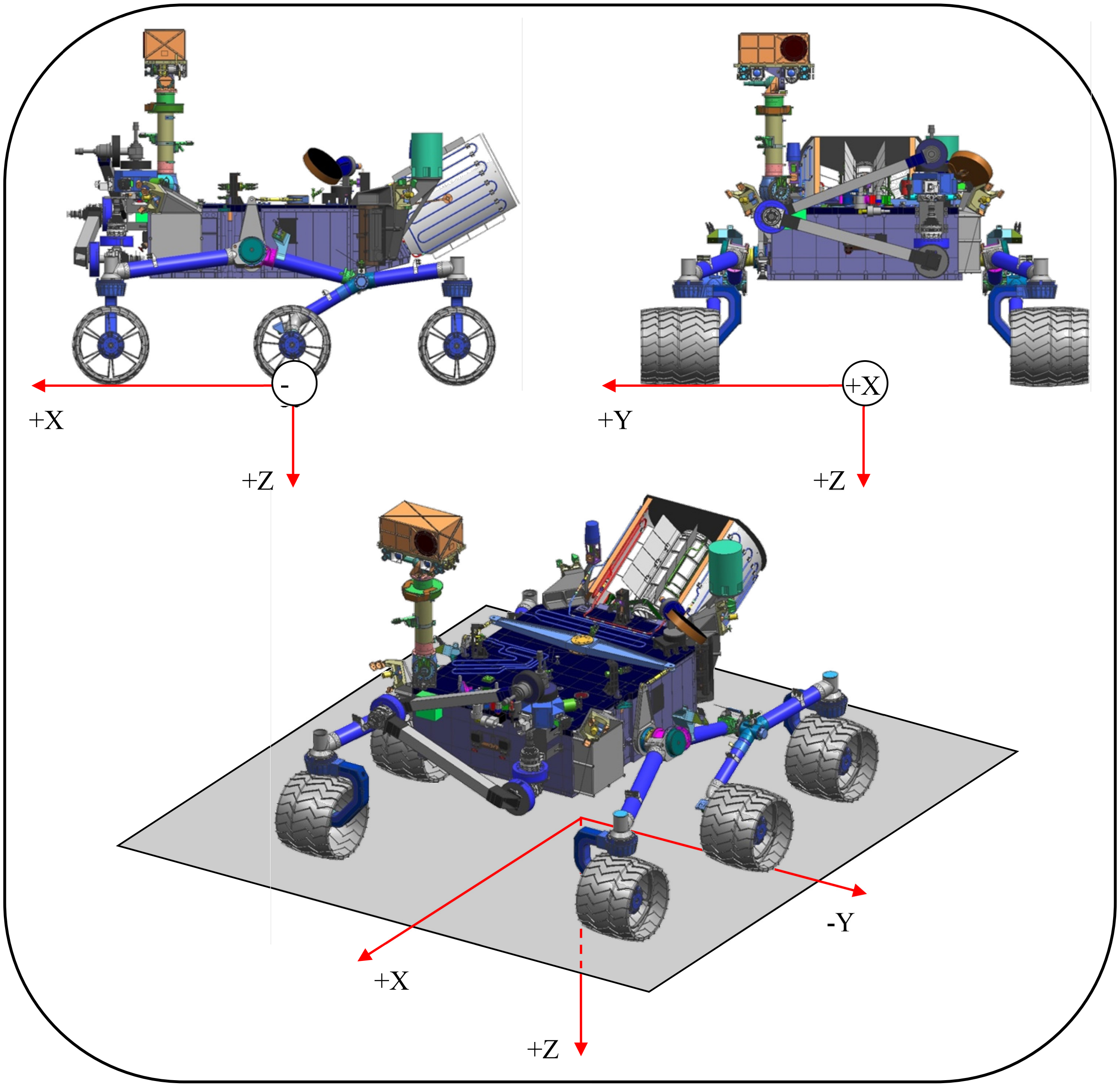


Figure 13 Rover Navigation (RNAV) Coordinate Frame

The Rover Nav frame is specified via an offset from the current Site frame, and a quaternion that represents the rotation between the two. A new instance of the Rover Nav frame, with a potentially unique offset/quaternion, is created every time the ROVER_MOTION_COUNTER increments.

Orientation of the rover (and thus Rover Nav) with respect to Local Level or Site is also sometimes described by Euler angles as shown in Figure 13, where ψ is heading, θ is attitude or pitch, and ϕ is bank or roll.

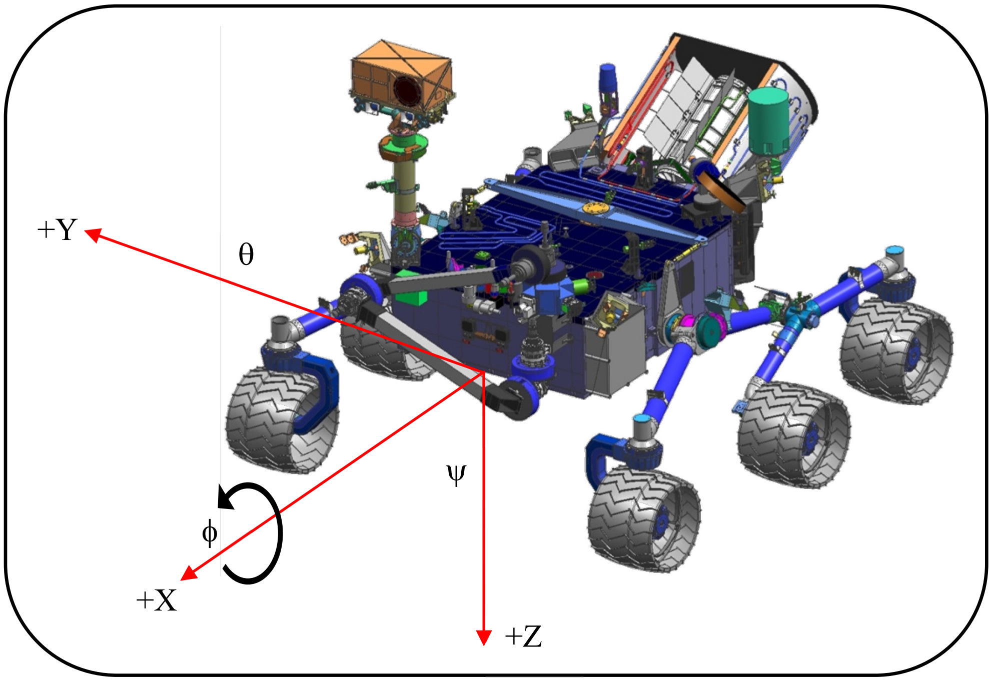


Figure 13 Yaw, Pitch, and Roll definitions

5.4.2 Rover Mechanical (Rover Mech) Frame

The Rover Mechanical (RMECH) frame is oriented identically to the Rover Nav frame. The origin is forward of Rover Nav by x=0.09002 meters. In other words, given a point expressed in Rover Mech, if you add (0.09002, 0.0, 0.0) you will get the same point expressed in Rover Nav. Rover Mech is not used by any nominal products (EDR or RDR) but could appear in certain special products, generally having to do with arm kinematics.

5.4.3 Local Level Frame

The Local Level frame is coincident with the Rover Nav frame, i.e. they share the same origin at all times. The orientation is different, however. The +X axis points North, +Z points down to nadir along the local gravity vector, and +Y completes the right-handed system. Thus the orientation matches the orientation of Site frames.

Local Level frames are defined by an offset from the current Site frame, with an identity quaternion.

5.4.4 Site Frame

Site frames are used to reduce accumulation of rover localization error. They are used to provide a common reference point for all operations within a local area. Rover Nav and Local Level frames are specified using an offset from this origin. When a new Site is declared, that becomes the new reference, and the offset is zeroed. In this way, long-term localization error is relegated to the offset between Sites, becoming irrelevant to local operations, because the positions are reset with each new Site.

When a Site frame is declared, it is identical to the Local Level frame, sharing both orientation and position. However, the Site frame is fixed to the Mars surface; when the rover moves, Local Level moves with it but Site stays put. Therefore, for the Site frame, +X points North, +Z points down to nadir along the local gravity vector, and +Y completes the right-handed system.

Sites are indexed, meaning there are multiple instances. Site 1 by definition represents the landing location. New Sites are declared as needed during operations, as the rover moves away from the local area. See Figure 14.

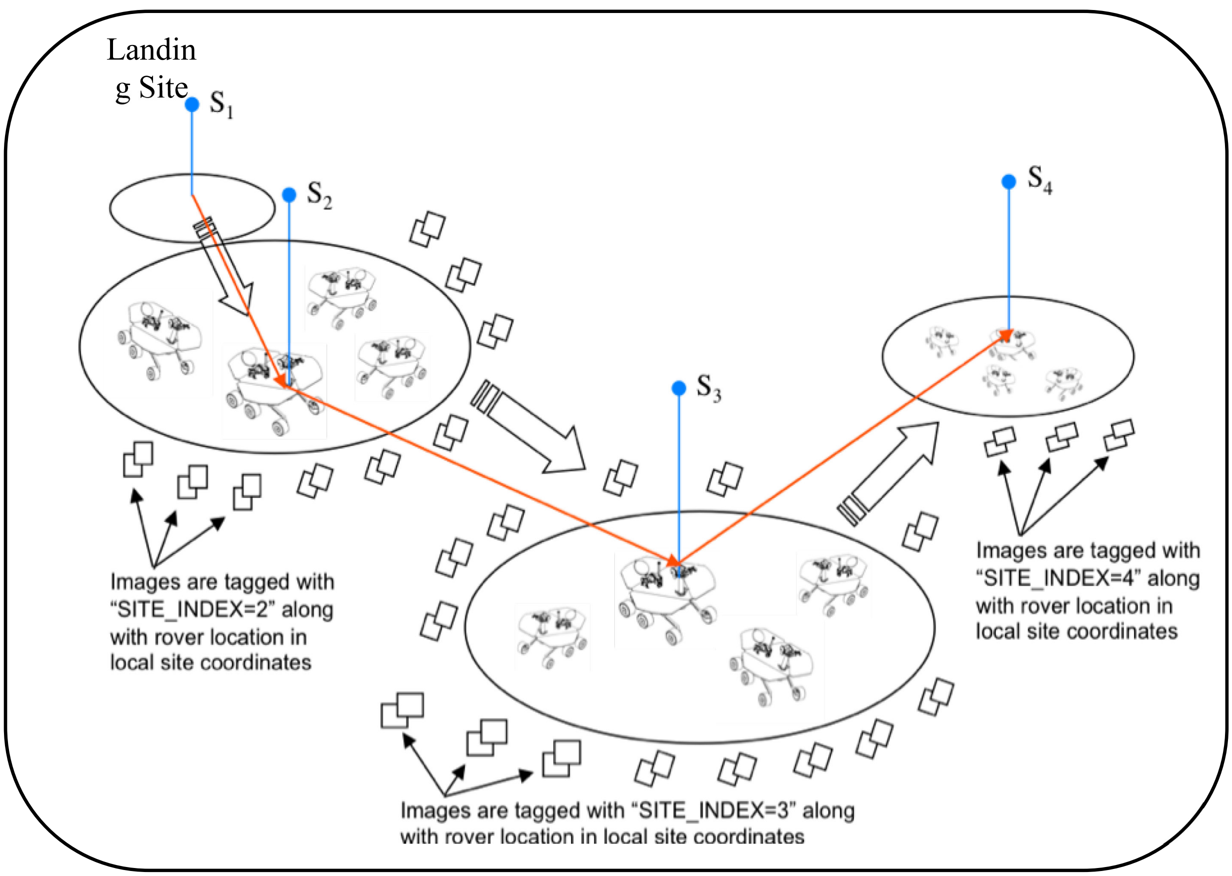


Figure 14 Rover and site frame examples

The PLACES database [Ref 10] stores the set of all site-to-site offsets; such offsets are not in every image label.

5.4.5 RSM Frame

The RSM frame is attached to the Remote Sensing Mast (RSM) camera head, and moves with it. See the PPPCS for specific definition. It is expressed as an offset and quaternion from the Rover Nav frame.

5.4.6 Arm Frames

The frame representing the currently selected arm tool is reported in the arm coordinate system group. The selected tool, given by ARTICULATION_DEV_INSTRUMENT_ID, is arbitrary for any given image and may be surprising; for example SHERLOC-WATSON may not be the selected tool for a SHERLOC-WATSON image. The various tool frames are attached to and aligned with the tool in some manner specific to that tool. See the PPPCS [Ref 1] for actual frame definitions.

6 Applicable Software

The instrument data downlink processing software is focused on rapid reduction, calibration, and visualization (in the case of images) of products in order to make discoveries, to accurately and expeditiously characterize the geologic environment around the rover, and to provide timely input for operational decisions concerning rover navigation and Arm target selection. Key software tools have been developed at JPL as part of the IDS and APSS subsystems, and at LANL/IRAP/CNES by the PIXL team. These toolsets can be used to process data to yield substantial scientific potential in addition to their operational importance.

6.1 Utility Programs

Table 6-1 lists (in no particular order) the primary software tools that will be used to process and manipulate downlinked M2020 instrument payload data. Instrument data processing software executed by teams working the IDS and APSS subsystems at JPL will be capable of reading and writing image and spectra data in PDS format. Within IDS, the "M2020edrgen" program will generate EDRs and the Mars Program Suite of VICAR programs will generate RDRs in PDS format. An IDS pipeline system will deliver the products to the FEI server for transfer to M2020's ODS as rapidly as possible after receipt of telemetry. Note that non-image data products for the most part will not use the image-based utility programs, but may use new programs not yet defined.

Table 6-1 Key Software Toolsets

Name	Description	Primary Development Responsibility
PIXL Ops Software	PIXL X-Ray and MCC software development is primarily performed in IDL code, with JPL as lead institute.	Luca Cinquini (JPL) Kyle Uckert (JPL)
M2020edrgen	Fetches the image Data Product Object (DPO) records from M2020 Data Product (DP) files, reconstructing the image file from the telemetry data into a PDS-labelled image EDR data product. VICAR code.	Hyun Lee, (JPL / MIPL)
Mars Program Suite	Stereo image processing software using EDRs or calibrated images (RDRs), image mosaicking software, 3-D terrain building software. VICAR code: • MARSCAHV – Generates a geometrically corrected version of the EDR, applying the C, A, H and V camera model vectors. • MARSRAD – Generates a radiometrically corrected image from a single input EDR. • MARSJPLSTEREO – Generates a disparity map from a stereo pair of input EDRs, applying a 1-D correlator (fast). • MARSCOR3 – Generates a disparity map from a stereo pair of input EDRs, applying a 2-D correlator (more robust). • MARSXYZ – Generates an XYZ image from an input disparity map. • MARSRANGE – Generates a range image from an input XYZ map.	Bob Deen (JPL / MIPL)

Name	Description	Primary Development Responsibility
	• M2020REACH – Generates an arm reachability map from an input XYZ map. • MARSINVERTER – Generates inverse lookup table (ILUT) products. • MARSDEBAYER – Generates de-Bayered images. • M2020ROUGH – Generates roughness maps. • MARSERROR – Generates XYZ and range error maps. • MARSSLOPE – Generates slope maps. • MARSBRT – Generates brightness/contrast correction file for mosaic processing. • M2020FILTER – Generates XML file for image mask files. • MARSFILTER – Generates image mask files. • MARSMASK – Applies image mask files to image files. • MARSDISPCOMPARE – Checks consistency for left-to-right and right-to-left stereo image correlations. • MARSUVW - Generates a surface normal image, wherein XYZ is computed normal to the surface. • MARSMAP – Generates a Cylindrical, Polar or Vertical projection mosaic from a list of input EDRs. • MARSMOS – Produces pinhole camera mosaics using uncorrected input images and CAHVOR camera model. • MARSMCAULEY – Generates a combination Cylindrical-Perspective projection mosaic from a list of input EDRs. • MARSTIE – Generates pointing corrections (tiepoint file) from an overlapping set of input EDRs. • MARSNAV – Generates an updated azimuth and elevation file based on comparison with existing image data that can be directly compared. • XVD – De facto image reader software capable of displaying VICAR-labeled image files.	
	• CRUMBS – 3-D terrain building software	Oleg Pariser (JPL / MIPL)
APSS / RSVP	Visualization, planning, and sequence generation software for use by Sequence Team to create Sol sequences based on activity lists generated by PSI during planning meetings. Java, C and C++ code.	Brian Cooper (JPL)

6.2 Applicable PDS Software Tools

PDS-labeled images and tables can be viewed with the program PDS4 Viewer, developed by the PDS and available for a variety of computer platforms from the PDS web site http://sbndev.astro.umd.edu/wiki/PDS4_Viewer. A Python library of PDS4 tools, from which the PDS4 Viewer is built, is available at http://sbndev.astro.umd.edu/wiki/Python_PDS4_Tools. There is no charge for this software.

6.3 Software Distribution and Update Procedures

The FEI distribution tool and Mars Image Processing Program Suite are available to researchers and academic institutions. Refer to the MIPL Web site at http://www-mipl.jpl.nasa.gov for contact information. FEI is described in detail at http://www-mipl.jpl.nasa.gov/MDMS.html

APPENDIX A. PRODUCT LABEL KEYWORD DEFINITIONS, VALUES, AND SOURCES

As described in the main text, there are three types of label keywords: VICAR, ODL, and PDS4. The VICAR and ODL labels are virtually identical and are referred to here collectively as "VICAR" labels.

This Appendix describes several tables that will be useful for understanding the details of these keywords. All of the tables are in separate files within the document collection, with names as described herein.

PDS4 Keyword Tables

This set of tables describes the PDS4 keywords (classes and attributes in PDS 4 parlance). They include pointers to the matching VICAR keywords, as well as both the generic (multimission) definition of the keyword, and the specific "nuance" or supplemental information that applies only to Mars 2020.

These tables are created by examining a set of sample labels (incorporating all types of products being created) in order to determine the PDS4 classes and attributes that are actually used by the products described in this SIS. This list is then cross-referenced against the PDS4 data dictionaries in order to find the definitions, children, valid values, and data types. This list is then augmented with "property maps" that provide the Mars 2020-specific valid values, and the "nuance" definitions.

These tables are thus much more useful for most purposes than looking at the PDS4 data dictionaries directly, because they contain *only* the keywords that are *actually* used.

The first column contains the name of the PDS4 attribute (keyword) or class (container), and the PDS4 dictionary it comes from. Along with that, when applicable, are the VICAR keyword and property name(s) from which the values are derived. The property name is the section of the VICAR label. Not every entry has a VICAR keyword; some entries are merely containers, others contain constants or values that are derived in other ways. Some of the VICAR keywords refer to the class rather than the attribute; for example a VICAR vector keyword will typically refer to the vector's class rather than the x,y,z attributes individually.

The second column contains the definition. There are two components to many definitions, as alluded to above. The first, which is always present, is the standard PDS4 definition that applies to all missions, from the PDS4 data dictionary. The second (in italics) is a Mars 2020-specific nuance to the definition, providing additional context that applies specifically to Mars 2020.

The third column is broken up into several pieces. The first is the XPath. This gives the "path" of where the item can be found in the label, tracing the hierarchy from the root (often but not always Product_Observational) down to the item itself. Each level in this hierarchy is a hyperlink, which can be clicked on to go directly to that items' definition.

Underneath the XPath is a field whose content varies based on the type. For attributes ("keyword"), this contains the valid values, when such are defined either by the PDS4 data dictionary or the Mars 2020-specific property maps. For classes (containers), the valid children are listed. Those that are blue hyperlinks are actually used by Mars 2020; clicking on them will go to that item's definition. Those that are not blue are defined by the PDS4 data dictionary but are not used by Mars 2020.

Finally, also underneath the XPath field is another column containing (for attributes only) the data type and units. All attributes should have a data type, but only some have units defined.

These label tables are the primary source of information regarding the metadata in the labels. The rest of this document describes things at a high level; the label tables (along with the ops label table, above) define specifically what each label item means.

There are two versions of the table: sorted by PDS4 name, and sorted by VICAR keyword. The tables can be used in either direction. Given a label item you don't understand, you can look it up in the table (sorted by either PDS or VICAR name, depending on which you're looking at) to find the definition. In some cases you may need to go up the hierarchy to find a meaningful definition (for example the definition for "x" is not particularly useful, but the parent or grandparent should describe what the full x,y,z value is being used for. Alternatively, given an item in the table, you can find the item in the label by following the XPath – looking down the hierarchy of elements until you find the item. Note that not all keywords are in any given label; the table encompasses image products, browse images, mosaics, meshes, calibration, and documentation files.

The cross-reference between PDS4 name and VICAR keyword can also be useful for comparing values across similar missions (MSL, MER, Phoenix, etc) that use PDS3 (the VICAR and PDS3 keywords are generally the same).

Each of the tables is provided in both HTML and PDF format. The files are:

Mars2020_PIXL_Labels_sort_pds.pdf
Mars2020_PIXL_Labels_sort_pds.html
Mars2020_PIXL_Labels_sort_vicar.pdf
Mars2020_PIXL_Labels_sort_vicar.html