Mars 2020 Rover Mission (M2020)

Software Interface Specification

Interface Title: **SHERLOC Spectroscopy Experiment Data Record (EDR) Data Products**

Mission: M2020 Date: July 27, 2021

Module ID: D-99965

Module Type (REFerence Only or MISsion-specific info included): MIS

Reference Module ID: N/A Date: N/A

Signatures

GDS Generating Elements:

Instrument Data System (IDS)
Stirling Algermissen

____
Subsystem Lead Date

Science Receiving Elements:

MSL Deputy Project Scientist
Ken Williford

____
Deputy Project Scientist Date

GDS Receiving Elements:

M2020 GDS System Engineer
Maher Hanna

____
System Engineer Date

M2020 GDS System Engineer
Guy Pyrzak

____
Subsystem Lead Date

Concurrence:

M2020 SHERLOC Instrument Principal Investigator
Luther Beegle

____
Instrument Lead Date

M2020 SHERLOC Instrument Engineer
Kevin Hand

____
Instrument Engineer Date

PDS Program Manager
Tim McClanahan

____
Manager Date

PDS Geosciences Node Manager
Ray Arvidson

____
Manager Date

PDS Discipline Node Manager
Lisa Gaddis

____
Manager Date

Mars 2020 Rover Mission Project

Software Interface Specification (SIS)

Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) Spectroscopy Experiment Data Record (EDR) Data Products

Version 1.00

Custodians:
Deborah Padgett, Stirling Algermissen

JPL D-99965

July 27, 2021

Jet Propulsion Laboratory
California Institute of Technology

CHANGE LOG

DATE	SECTIONS CHANGED	REASON FOR CHANGE	REVISION
2017-01-09	• Template created	Initial	Version 0.0
2019-03-12	• All sections; first draft		Version 0.1
2019-05-07	• All sections G6.1		Version 0.2
2019-09-09	• Filename definitions G6.2		Version 0.3
2019-09-24	• Timestamp filename fields update	Format change	Version 0.4
2019-10-10	• Another timestamp filename fields update	More options	Version 0.5
2019-10-24	• Appendix B	Revised IDPH Keywords	Version 0.6
2020-02-02	• Revision for G6.4	G6.4	Version 0.7
2020-03-10	• Revision for G6.4.1, filename change	G6.4.1	Version 0.8
2020-04-01	• Revision for G6.5.0, metadata changes	G6.5(.1?)	Version 0.81
2020-04-13	• Revision for G6.5.0, metadata and filename changes	G6.5	Version 0.9
2020-05-14	• Revision for G6.5, Table for PDS, TOC update	G6.5	Version 0.91
2020-07-06	• Revision for G6.6, EDR types and keywords	G6.6	Version 0.92
2020-08-03	• Revision for G6.6, keywords and corrections	G6.6	Version 0.93
2020-08-09	• Revision for G6.6, keywords and EDR types	G6.6	Version 0.94
2020-09-10	• Revision for G6.6, overall formatting, all sections	G6.6	Version 0.95
2020-09-22	• Document name replacement, header	G6.6	Version 0.96
2020-09-30	• All sections	Team comments	Version 0.97
2020-10-09	• All sections	Team comments	Version 0.97 rev 10-08-20
2020-10-17	• All Sections	Team comments	Version 0.98 rev 10-17-20
2020-11-2	• All sections	PDS peer review	Version 0.98 rev 11-2-20
2020-12-15	• All sections	PDS peer review	Version 0.99 rev 12-15-20
2021-01-12	• All sections	PDS peer review	Version 0.99 rev 01-12-21 by S. Slavney
2021-01-26	• All sections	PDS peer review	Changes based on S.

DATE	SECTIONS CHANGED	REASON FOR CHANGE	REVISION
			Slavney comments
2021-02-02	• All sections	PDS peer review for bundle	Changes for S. Slavney
2021-05-10	• All sections	Liens from PDS review	Version 0.99 rev05-10-21
2021-05-25	• Section 2	Figure 3 update	v0.99_rev05-25-21
2021-06-21	• All sections	Final PDS input	V1.00
2021-07-21	• Appendix	PDOG table reference substituted for Appendix	V1.0 rev072721

OPEN ISSUE ITEMS

REVISION	OPEN ISSUE	CLOSED
v0.97	Appendix B, mapping of ODL label keywords to PDS4 label attributes, is incomplete	

Table of Contents

INTERFACE TITLE: SHERLOC SPECTROSCOPY EXPERIMENT DATA RECORD (EDR) DATA PRODUCTS 1

MISSION: M2020 DATE: JULY 27, 2021 1

SOFTWARE INTERFACE SPECIFICATION (SIS) 2

SCANNING HABITABLE ENVIRONMENTS WITH RAMAN & LUMINESCENCE FOR ORGANICS & CHEMICALS (SHERLOC) SPECTROSCOPY 2

EXPERIMENT DATA RECORD (EDR) 2

DATA PRODUCTS 2

VERSION 1.00 2

CHANGE LOG 2

OPEN ISSUE ITEMS 4

1 INTRODUCTION 12

1.1 PURPOSE AND SCOPE 12
1.2 CONTENTS 12
1.3 CONSTRAINTS AND APPLICABLE DOCUMENTS 13
1.3.1 RELATIONSHIPS WITH OTHER INTERFACES 14

2 INSTRUMENT OVERVIEW 15

2.1 INSTRUMENT FUNCTIONAL DESCRIPTION 24
2.1.1 GENERAL SCIENCE 24
2.1.2 MEASUREMENT DESCRIPTIONS 24
2.2 REFERENCES 25

3 GENERAL DATA PRODUCT OVERVIEW 25

3.1 DATA PROCESSING LEVELS 25

3.2 PRODUCT LABEL AND HEADER DESCRIPTIONS 27
3.2.1 OVERVIEW OF LABELS 27
3.2.2 ODL LABELS 27
3.2.3 PDS4 LABEL 30
3.3 CSV DATA STORAGE CONVENTIONS 31
3.3.1 BIT AND BYTE ORDERING 31

4 EDR PRODUCT SPECIFICATION 31

4.1 EDR GENERAL PROCESSING 35
4.2 EDR PRODUCT TYPES 37
4.3 EDR PRODUCT FORMAT 39
4.3.1 CRUISE: SPECTROMETER FAULT (EDF) 40
4.3.2 CRUISE: SPECTROMETER SCIENCE DATA FRAME (EDR) 40
4.3.3 SURFACE: SPECTROMETER STATE OF HEALTH IN SCIENCE MODE (EXS) 40
4.3.4 SURFACE: FULL RESOLUTION SPECTRA IN SCIENCE MODE (ERS) 40
4.3.5 SURFACE: SPECTROMETER STATE OF HEALTH IN CALIBRATION MODE (EXC) 40
4.3.6 SURFACE: FULL RESOLUTION SPECTRA IN CALIBRATION MODE (ECR) 40
4.3.7 SURFACE: SCANNER MIRROR POSITION IN AZ/EL (ESS) 40
4.3.8 SURFACE: PROCESSED DATA (EPD) 41
4.3.9 SURFACE: SPECTROMETER STATE OF HEALTH IN SCIENCE MODE (ESH) 41
4.3.10 SURFACE: SPECTROSCOPY STATE OF HEALTH IN CALIBRATION MODE (ECH) 41
4.3.11 SURFACE: SCANNER POSITION ARRAY (IN PIXEL) (EXH) 41
4.3.12 SURFACE: FULL RESOLUTION SPECTRA IN SCIENCE MODE (ERA) 41
4.3.13 SURFACE: FULL RESOLUTION BACKGROUND (DARK) SPECTRA IN SCIENCE MODE (ERB) .. 41
4.3.14 SURFACE: FULL RESOLUTION SPECTRA IN CALIBRATION MODE (ECA) 41
4.3.15 SURFACE: FULL RESOLUTION BACKGROUND (DARK) SPECTRA IN CALIBRATION MODE (ECB) 41
4.3.16 SURFACE: PHOTODIODE ARRAY (EPA) 41
4.3.17 SURFACE: SCANNER POSITION ARRAY (IN MILLIMETER UNITS OF MEASUREMENT) (ESP) ... 42
4.3.18 SURFACE: PROCESSED DATA (ERP) 42
4.3.19 SURFACE: ENGINEERING DATA IN FAULT (EDF) 42
4.3.20 SURFACE: ENGINEERING UTILITY TEST (EUT) 42
4.3.21 SURFACE: ENGINEERING DEBUG INFO (ED1) 42
4.3.22 SURFACE: ENGINEERING MEMORY PARAMETER DUMP (ED2) 42
4.3.23 SURFACE: ENGINEERING COMMAND HISTORY PARAMETER DUMP (ED3) 42
4.3.24 SURFACE: ENGINEERING DEBUG PARAMETER DUMP (ED4) 42
4.3.25 SURFACE: ENGINEERING ERROR LOG DUMP (ED5) 42
4.3.26 SURFACE: ENGINEERING MEMORY PARAMETER DUMP (ED6) 42
4.3.27 SURFACE: ENGINEERING BUILT-IN SELF-TEST (ED7) 43
4.3.28 SURFACE: ENGINEERING REGISTERS READOUT (ESR) 43
4.3.29 SURFACE: ENGINEERING POWER READOUT (ESE) 43
4.3.30 SURFACE: ENGINEERING INITIAL POWER ON READOUT (ESI) 43
4.3.31 SURFACE: ENGINEERING SPECTROSCOPY SOH READOUT (ESX) 43

4.4 EDR PRODUCT STRUCTURE 43
4.4.1 COMPONENT DPOS 45
THE COMPONENT DPOS ARE AS FOLLOWS: 45
4.4.2 EDR TYPES (UNPROCESSED) 60
4.5 EDR PRODUCT VALIDATION 64

5 STANDARDS USED IN GENERATING PRODUCTS 65

5.1 FILE NAMING STANDARDS 65
5.1.1 EDR FILENAME 66
5.2 PDS STANDARDS 81
5.3 TIME STANDARDS 81
5.4 COORDINATE FRAME STANDARDS 81
5.4.1 ROVER NAVIGATION (ROVER NAV) FRAME 82
5.4.2 ROVER MECHANICAL (ROVER MECH) FRAME 84
5.4.3 LOCAL LEVEL FRAME 85
5.4.4 SITE FRAME 85
5.4.5 RSM FRAME 86
5.4.6 ARM FRAMES 87

6 APPLICABLE SOFTWARE 88

6.1 UTILITY PROGRAMS 88
6.2 APPLICABLE PDS SOFTWARE TOOLS 89
6.3 SOFTWARE DISTRIBUTION AND UPDATE PROCEDURES 90

7 APPENDIX A – DATA PRODUCT NAMES FOR SHERLOC 91

8 APPENDIX B – PRODUCT LABEL KEYWORD DEFINITIONS, VALUES, SOURCES 96

9 APPENDIX C : SHERLOC SDF FORMAT 98

9.1.1 DATA OR COMMAND SEGMENT MARKER IN GENERIC SDS DATA STRUCTURE 99

APPENDIX C EDR STRUCTURE TABLE 106

LIST OF FIGURES

Figure 1 The SHERLOC Turret Assembly on the Perseverance robotic arm durnig the ATLO test with both spectroscopic ACI boresight (left) and WATSON boresight (right) visible [12]. 18
Figure 2 Example Ramen spectra of astrobiologically relevant minerals. 19
Figure 3 Example Raman and Fluorescence spectra of some important organic molecules. 22
Figure 4 Example of SHERLOC science on the Stelley Pool Stromatolite using the lab breadboard MOBIUS instrument (Beegle et al. 2015, IEEE; Abbey et al. 2017, Icarus, 390, 201). 22
Figure 5 Mars 2020 instruments PIXL, SuperCam, and SHERLOC incoporate cameras although they are not primarily imaging instruments. 35
Figure 6 Flow of M2020 data from instruments to IDS. 36
Figure 7 IDS EDR generation data flow 37
Figure 8 SHERLOC Spectroscopy EDR naming convention 66
Figure 9 Definition of Rover Nav coordinate frame 83
Figure 10 Rover Navigation (RNAV) Coordinate Frame .... **Error! Bookmark not defined.**
Figure 11 Site Frame definition 86

LIST OF TABLES

Table 1-1 M2020 SHERLOC Documents 14
Table 2-1 SHERLOC Spectroscopic Investigation Matrix. Mars 2020 Mission Goals and derived Mission Science Objectives are mapped into SHERLOC contributions and Data Products addressed by the SHERLOC investigation 24
Table 3-1 PDS4 Processing levels for Instrument Experiment Data Sets 26
Table 4-1 List of Mars 2020 Data Products to be Archived 32
Table 4-2 Product IDs for SHERLOC Spectroscopy 38
Table 5-1 M2020 EDR filename fields 66
Table 5-2 Coordinate Frames Used for M2020 Surface Operations 82
Table 6-1 Key Software Toolsets 88

ACRONYMS AND ABBREVIATIONS

ACI	Autofocus Context Imager
APSS	Activity Planning and Sequencing Subsystem
ATLO	Assembly, Test, and Launch Operations
BTU	Brassboard Test Unit
CNDH	Command and Data Handling
CODMAC	Committee On Data Management And Computation
CSV	Comma-Separated Value
DEA	Digital Electronics Assembly
EDR	Experiment Data Record
EECAMs	Enhanced Engineering Cameras
EM	Engineering Model
FM	Flight Model
IDS	Instrument Data Subsystem
iGDS	Instrument Ground Data System
iSDS	Instrument Science Data System
JPL	Jet Propulsion Laboratory
LANL	Los Alamos National Laboratory
M2020	Mars 2020
MAHLI	Mars Hand Lens Imager
MSL	Mars Science Laboratory
MSSS	Malin Space Science Systems
ORT	Operations Readiness Test
PDS	Planetary Data System
PI	Principal Investigator
POC	Point of Contact
RDR	Reduced Data Record
SAPP	Surface Attitude Position and Pointing
SOAS	Science Operations Analysis Software
SOWG	Science Operations Working Group
RSM	Remote Sensing Mast
SCS	Sampling and Caching System
SE	Spectrometer Electronic
SHERLOC	Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals
SIS	Software Interface Specification
SOH	State of Health
TBU	Testbed Unit
WATSON	Wide Angle Topographic Sensor for Operations and eNgineering

1 INTRODUCTION

1.1 Purpose and Scope

The purpose of this Data Product Software Interface Specification (SIS) is to provide consumers of SHERLOC 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 non-imaging EDR data products generated by the Instrument Data Subsystem (IDS) for the SHERLOC instrument.

The users for whom this SIS is intended include IDS, the Activity Planning and Sequencing Subsystem (APSS), users and developers of Science Operations Analysis Software (SOAS), member scientists of the project's Science Operations Working Group (SOWG) 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 spectrometer data in Planetary Data System (PDS)-compliant comma-separated value (CSV) format (and may include non-archived engineering data) acquired by the M2020 SHERLOC instrument. It may include decompression if there was data product compression performed onboard the rover by the instrument.

1.2 Contents

This Data Product SIS describes how the EDR data product is acquired by the M2020 SHERLOC instrument and how it is processed, formatted, labeled, and uniquely identified. 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 the SHERLOC instrument. 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., APSS, IDS, SOAS).

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

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

1. Mars 2020 CEDL and Surface SuperCam Functional Design Description (FDD), “Baseline Release, Rev A”, Ivair Gontijo, JPL D-95868
2. Mars 2020 Flight-Ground Interface Control Document (FGICD), “Volume 1, Downlink, Rev A, Version 1.0”, Biren Shah, JPL D-95521, October 3, 2017

Additionally, this SIS is also 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.

3. Planetary Data System Standards Reference, version 1.14.0.0, May 22, 2020.
4. Planetary Data System Data Provider’s Handbook, version 1.14.0.0, May 19,2020.
5. PDS4 Common Data Dictionary, Abridged, version 1.14.0.0, March 23, 2020.
6. 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:

7. 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.
8. Anderson, R.C., et al., Mars Science Laboratory Participating Scientists Program Proposal Information Package, December 14, 2010.
9. Mars Exploration Rover (MER) Project ICER User’s Guide, Aaron Kiely, MER 420-8-0538, JPL D-22103, January 5, 2004.

10. 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.
11. 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.
12. Bhartia, R. et al. “Perseverance’s Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) Investigation”, Draft for Space Science Reviews, 2020.

Table 1-1 M2020 SHERLOC Documents

Document Name	Doc ID (if applicable)	Official URL (to latest version)
SHERLOC Experiment Operations Plan (EOP) Feb 10, 2016		
Mars 2020 Project SHERLOC Interface Control Document (preliminary)	JPL D-93877	
SHERLOC Functional Requirements Description Document (FRDD)	JPL D-95109	https://cae-jazz.jpl.nasa.gov/rm/web#action=com.ibm.rdm.web.pages.showArtifact&artifactURI=https%3A%2F%2Fcae-jazz.jpl.nasa.gov%2Frm%2Fresources%2F_JcbgYSTWEeWLcJiLCPkL6Q&vvc.configuration=https%3A%2F%2Fcae-jazz.jpl.nasa.gov%2Frm%2Fcm%2Fstream%2F_ig_qEPAfEeaWgubEgqPLOQ
Mars 2020 SHERLOC Instrument Software User’s Guide, Los Alamos National Laboratory, May 5 2018		
SHERLOC IMAGERS Instrument-Command Definition, Mar 7 2018	JPL D-xxxxx	
SHERLOC SPECTROMETERS Instrument-Command Definition, Aug 16 2018	JPL D-xxxxx	

1.3.1 Relationships with Other Interfaces

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

Table 1.3.1 - Product and Software Interfaces to this SIS

Name	**Type** P = product S = software D = document	**Owner**
IDS database schema	P	IDS (JPL)
M2020EDRGEN	S	IDS (JPL)
M2020 Instrument EDRs • SHERLOC	P	IDS (JPL)
RSVP	S	RSVP Dev Team (JPL)
ASTTRO	S	ASTTRO Dev Team (JPL)
RGIS	S	RGIS Dev Team (JPL)

2 INSTRUMENT OVERVIEW

SHERLOC will assess the habitability potential of an ancient site including understanding its aqueous history. Identification of clay minerals, carbonates, sulfates, and halides in sedimentary units has shown that Mars hosted nearly a dozen different types of aqueous (alkaline, acidic, and saline lakes, hydrothermal deposits etc.) and other potentially habitable environments during its first billion years [1]. Some minerals are particularly indicative of environmental conditions such as serpentine (alkaline, reducing), sulfate (acidic, oxidizing), and carbonates (alkaline). Other phases are useful as environmental indicators though only when they are found in mineral assemblages where multiple phases collectively allow derivation of fluid geochemistry. By collecting point mineralogical data over an extended spatial scale in conjunction with texture, it is possible to discern whether aqueous minerals formed in sediments, hydrothermal precipitates, volcanic materials, or resulted from secondary overprinting by weathering or diagenesis. Measurements on these scales, achievable by SHERLOC can identify many important features including evidence of aqueous activity, through analysis of clasts, alteration amygdules, sedimentary laminae, melt pockets, or individual grains in conglomerates or breccias. SHERLOC measurements on the micron to multi-millimeter scale are an important size-step in the continuum of contextual investigations that make up the 2020 mission.

SHERLOC would assess the availability of key elements and energy source for life. Life on Earth is driven by oxidation-reduction reactions that form and transform organic matter and mineral substrates containing key elements such as C, H, N, O, P and S. The abundance and diversity of these substrates in a sedimentary environment are key measures of habitability. Analysis of these substrates in a given environment can identify sedimentary rocks that reflect the detrital component, a precipitated residue of the dissolved component, and post-depositional (diagenetic) alteration processes [2]. Transformation of minerals by biology or diagenesis has distinctive signatures that can be observed in assemblages of astrobiologically important minerals (e.g., carbonates, nitrates, phosphates, sulfates, etc.). The presence of such minerals, especially in association with organics, or when they otherwise imply some degree of chemical or morphologic disequilibrium, is an important component in the evaluation of potential biogenicity.

SHERLOC will ascertain if there are potential biosignatures preserved in Martian rocks and outcrops. Potential biosignatures that can be identified and spatially resolved are key organics such as hopanes, steranes, organic macromolecules, etc. This especially strong interrogative power will help identify samples that will facilitate making the case for returning them to Earth. SHERLOC's macro/micro-mapping modes can determine the organic and hydrated minerals present over scales that match the mineralogy and morphology of most biosignatures resulting from microorganisms. It is capable of correlating detected classes of organics with morphology (widths and shapes) to determine whether morphological candidates for microfossils, filaments, or stromatolitic layering are potentially biogenic [2]. SHERLOC is a robotic arm-mounted, Deep UV (DUV) native fluorescence and resonance Raman spectrometer. It utilizes a DUV laser to generate characteristic Raman and fluorescence photons from a targeted spot. The DUV laser is co-boresighted to a context imager and integrated into an autofocusing/scanning optical system that allows us to correlate spectral signatures to surface textures, morphology and visible features. The context imager has a spatial resolution of 30 μm and currently is designed to operate in the 400-500 nm wavelength range.

Through the use of an internal scanning mirror, autofocusing lens, and a depth of focus of ±250 μm, the 50 μm laser spot can be systematically scanned over a 7x7 mm area with a fine-scale spatial resolution on natural or abraded surfaces and boreholes to a depth of ~25 mm, without further arm movement. Through the use of the context imager, SHERLOC's data products can be combined with observations made by other instruments on the Mars 2020 payload [3]. By bringing to bear multiple scientific instruments on a single sample, our ability to assess the habitability of ancient environments and search for potential biosignatures preserved within the geologic record will be greatly enhanced, making possible the selection of high-priority samples for caching. The SHERLOC investigation combines two spectral phenomena, fluorescence and pre-resonance/resonance DUV Raman scattering. These spectral features are resolvable when a high-radiance, narrow line-width, laser source illuminates a sample. In fluorescence, the incident photons are absorbed and re-emitted at a longer wavelength. The difference between the excitation and emission wavelength is the difference between the excitation frequency and the lowest electronic state frequency that increases with increasing aromatic structure (i.e., number of aromatic rings). Typical fluorescence cross-sections are 10^7x greater than traditional Raman, enabling the detection of sub-picograms levels of aromatic organic compounds [2].

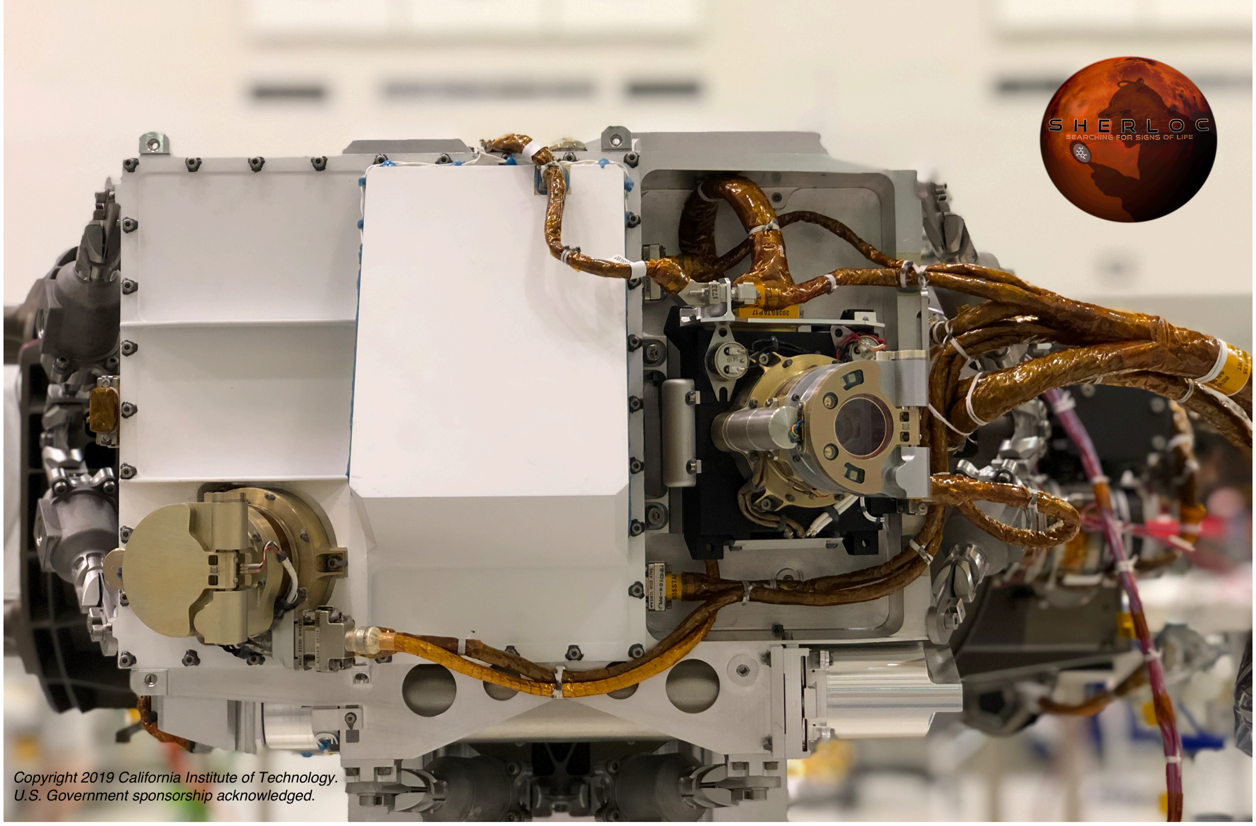
Fluorescence emission of organics extends from ~270 nm into visible wavelengths [3]. On the other hand, mineral fluorescence emission stemming from crystalline defects and impurities is weak in the deep UV, and typically begins longward of 360 nm continuing through the visible and into the NIR [2]. Mineral fluorescence is very unlikely to be seen in samples found on Mars as the only reported fluorescence of naturally occurring *in*organics in the region 250–360 nm is in non-relevant astrophysical conditions [4]. In over 30 years of experiments in our laboratories, the only observed fluorescence at shorter wavelengths (<360 nm) have always been directly attributable to organics trapped inside the mineral matrix of a field sample, not the mineral itself. Thus, the DUV fluorescence technique employed by SHERLOC is well-suited to the detection of organics on mineral surfaces.

SHERLOC's narrow-linewidth (<3 GHz) DUV laser (248.6 nm) also enables fluorescence-free resonance/pre-resonance Raman scattering for additional classification of aromatics and aliphatic organics, and minerals. Raman scattering is inelastic scattering involving loss of photon energy corresponding to vibrational energy. [2]. Raman shifts (cm^{-1}) (i.e., peak position as photon energy loss from the excitation energy) are invariant to excitation wavelength thus peak positions can be compared with values in in Raman databases for all excitation wavelengths (including 229, 248, 488, 532 and 785 nm) (i.e. http://rruff.info/).

As stated, traditional Raman scattering cross section are roughly 10^7 times smaller than the corresponding fluorescence cross-sections. The strength of the induced Raman signal is dependent on incident laser power, laser wavelength and resonance effects. Rayleigh Law states that the intensity of the Raman scattered light has an intensity $\propto \lambda^{-4}$, resulting in 20x greater scattering efficiency at 248.6 nm, than at 532 nm and 100x greater than at 785 nm. Adding to the increases in signal strength, many organics have resonance and pre-resonance signal enhancements of 100 to 10,000 times when excited by 248.6 nm. Finally, many astrobiologically relevant minerals have the same pre-resonance effects at these excitation wavelengths, increasing the Raman signal without high power lasers (Figures 2 and 3).

In order to identify Raman spectral features, it is necessary to block the Rayleigh scattered incident laser light. The laser is injected into the optical path by a Semrock edge-filter that performs within specifications over the range of Martian temperatures. This filter rejects wavelengths <253 nm including the high intensity Rayleigh scattered from the excitation source. This corresponds to a frequency interval between the laser and lowest Raman frequency of 0 to 810 cm^{-1} (248.6 and 253.7 nm). SHERLOC targets organics and mineral Raman spectral features that exist above of 810 cm^{-1} and includes organic functional groups features corresponding to C-H, CN, C=O, and C=C bonds, and carbonates, perchlorates, sulfates, and phyllosilicates (Figures 1 and 2). These functional groups and minerals represent the highest priority astrobiological target species.

Figure 1 The SHERLOC Turret Assembly on the Perseverance robotic arm during the ATLO test with both spectroscopic ACI boresight (left) and WATSON boresight (right) visible .



Copyright 2019 California Institute of Technology.
U.S. Government sponsorship acknowledged.

Figure 1 The SHERLOC Turret Assembly on the Perseverance robotic arm during the ATLO test with both spectroscopic ACI boresight (left) and WATSON boresight (right) visible .

Figure 2 Example Raman spectra of astrobiologically relevant minerals.

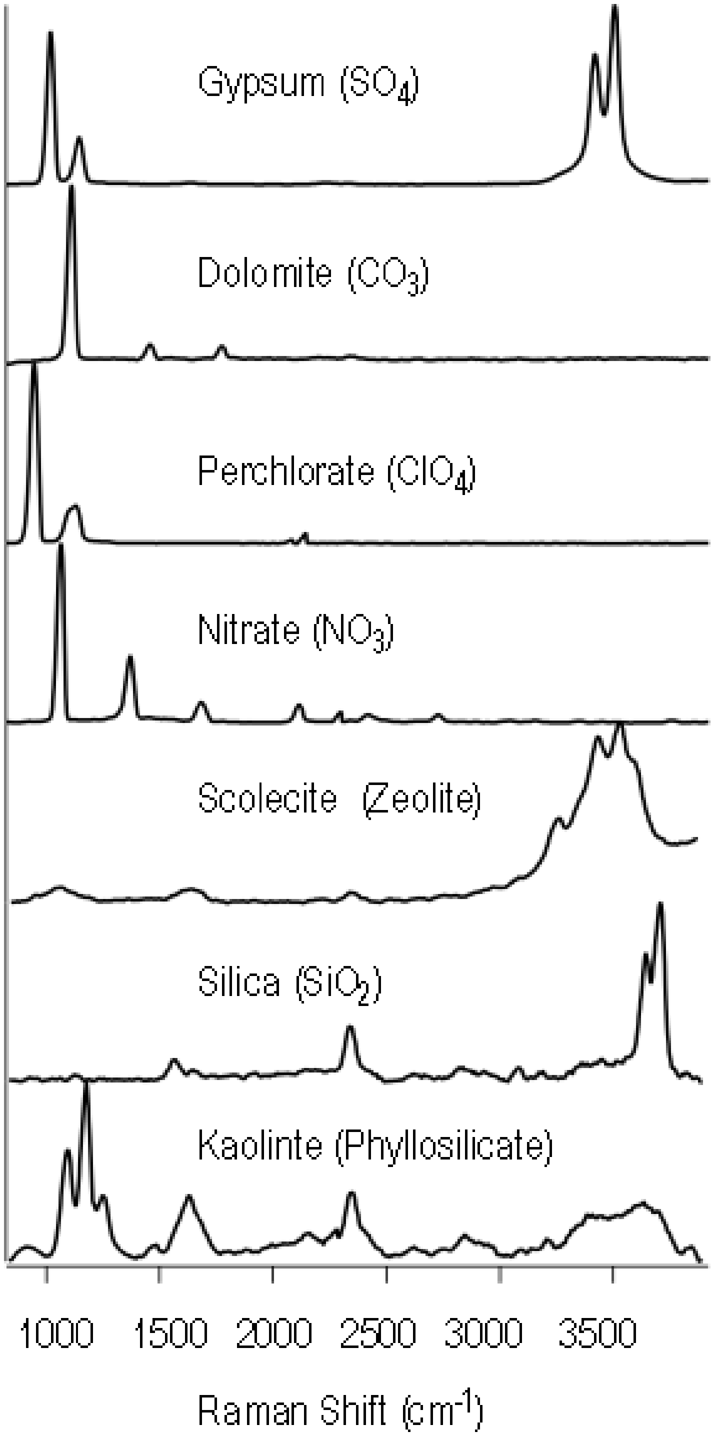


Figure 2 Example Raman spectra of astrobiologically relevant minerals.

Figure 3 Example Raman and Fluorescence spectra of some important organic molecules.

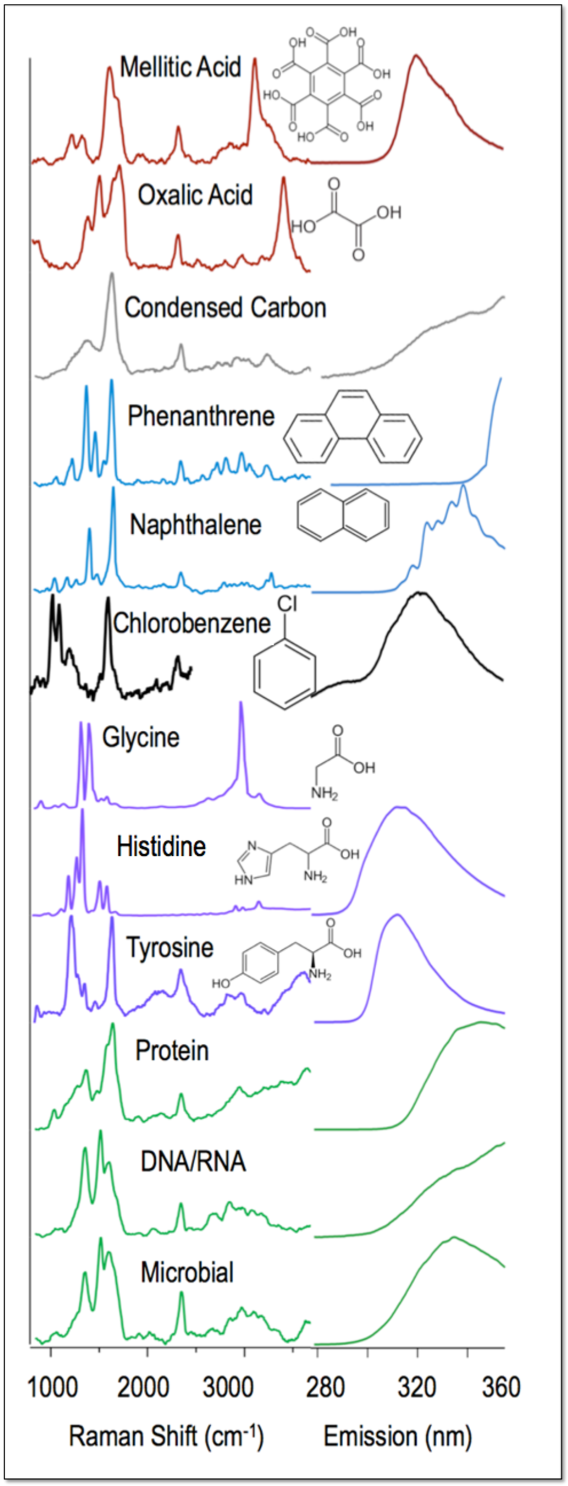


Figure 3 Example Raman and Fluorescence spectra of some important organic molecules.

Excitation at DUV wavelengths (<250 nm) enables resonance and pre-resonance signal enhancements of between 100 and 10,000 times of organic/mineral vibrational bands [2]. As such, SHERLOC combines the detection of both the Raman and fluorescence photons on the same CCD for simultaneous detection (Figure 3). The spectrometer CCD and related electronics have the necessary detector dynamic range to enable detection of both spectral features simultaneously. In addition, the lack of a background fluorescence in DUV Raman spectral region, greatly simplifies the resulting analysis. Figure 4 shows an example observation of a stromatolite. The chert signature observed is highly attenuated by the edge filter but is observable in this sample. Colors blend in the map and organics are green and yellow as they are mixed with the chert signature (sample courtesy of A. Allwood)

Figure 4 Example of SHERLOC science on the Stelley Pool Stromatolite using the lab breadboard MOBIUS instrument [2][5].

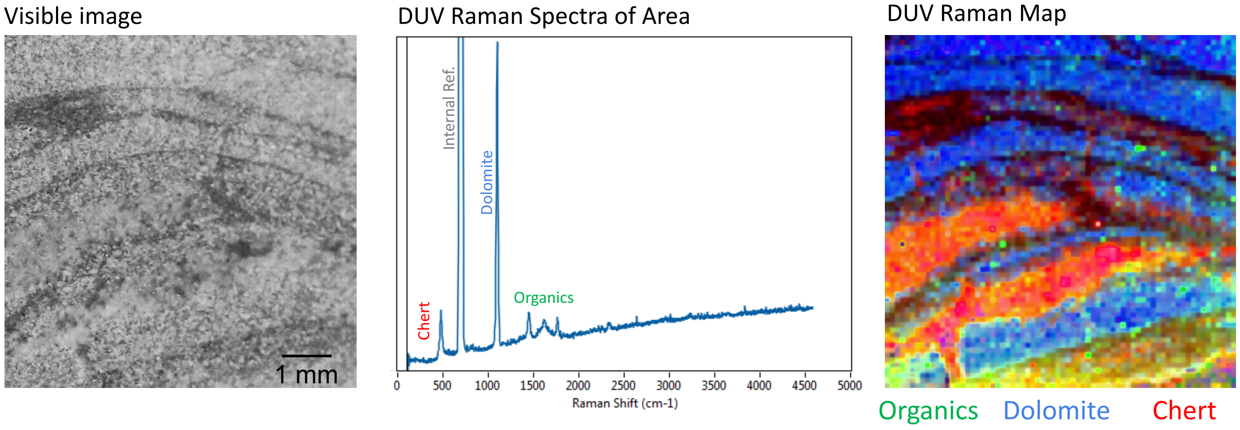


Figure 4 Example of SHERLOC science on the Stelley Pool Stromatolite using the lab breadboard MOBIUS instrument [2][5].

Mars 2020 Obj	**Derived Mission Science Objectives**	**SHERLOC Analysis**	**SHERLOC Data Product ****	**Notes**
A: Decipher geological processes and assess past	Assess how long aqueous conditions existed and identify organic mineral assemblages that constrain chemical and redox environment**)**	Classify mineral assemblages associated with aqueous activity.	DUV Raman spectra of carbonates, sulfates, phyllosilicates, zeolites, etc. with grain sizes >50 µm.	DUV Raman signatures of astrobiologically important organic and mineralogical species describe energy sources, ancient environmental conditions and water availability at a time when the surface of Mars was warmer and wetter.
	Assess availability and distribution of electron donors, key elements and energy sources	Detect and classify CHNOPS elements in minerals and organics. Identify alterations in mineral content due to biologic processes.	DUV Raman spectra of CHNOPS minerals in organics/minerals over an area at 50 µm resolution.	
B: Assess the biosignature potential preservation and search for potential biosignatures	Characterize physiochemical processes and conditions in the paleoenvironment, and identify mechanisms for formation and preservation of biosignatures	Classify organics within mineralogical context and assess the probability of origin by meteoritic infall, native, and/or biologically derived processes.	Textural, fluorescence maps of organics & DUV Raman maps of organics and minerals. Includes grain size analysis (>50 µm) and distribution.	Combining fluorescence and DUV Raman signatures for bulk and fine scale organic and mineral maps of surface/near-surface material describes the potential for organic preservation and potential biosignatures detection. Combining mineral and organic maps enables *in situ* assessment of formation and alteration processes for a given target to assess whether materials are meteoritic, native and/or past life and chemical precursors. Also constrains the potential for biosignature preservation.
	Characterize degree, type, and timing of diagenetic processes that could have degraded biosignatures.	ssess thermal, oxidation, hydroxylation, etc., via organics and mineralogy analysis.	DUV Raman Maps of organics and minerals.	
	Map distributions of potential biosignatures (PBS) relative to geologic features, including characteristics of potentially biogenic structures	Assess organic classes (aromaticity, functional groups, PBS, etc.) and correlating aqueous-related mineralogy and textures on surfaces and boreholes.	DUV Raman and fluorescence maps of organics and minerals co-located with textures and morphology of the target surface over a 5 x 5 mm area with spatial resolution of 100 µm. Borehole mapping of mineral and organic species to 25 mm depth.	
C: Future return of scientifically selected, well documented samples to Earth	Assess evidence for past life, or its chemical precursors, and place constraints on the past habitability and the potential for preservation of the signs of life	Assessment of mineral/ textural characteristics consistent with PBS, energy sources, or preservation. Identification of preserved evidence suggesting biotic or pre-biotic signatures.		Facilitates merger of organic/mineral data with other payload instruments to improve analytical capability of the rover instrument suite. Identification of samples with organic composition is vital to selection of samples for return. The direct analysis of boreholes results in a proxy for core analysis.
	Assess the history and significance of surface modification processes including but not limited to: impact,	Assess morphologic and mineralogical characteristics of Mars' paleoenvironment with co-located organic	Deep UV Raman and fluorescence maps of organic molecules co-located with perchlorates or other	

	photochemical, volcanic, and aeolian. Constrain the magnitude, nature, timing and origin of past planet wide climate change (	molecule mapping, mineral phase mapping, and contextual images. Identify salt, aqueous products, and evaporite concentrations.	oxidizers and textures, (grain size, shape, distribution) co-located with surface features.	SHERLOC's mapping mode inside the borehole can identify organic gradients that indicate degradation of organic material.

Table 2-1 SHERLOC Spectroscopic Investigation Matrix. Mars 2020 Mission Goals and derived Mission Science Objectives are mapped into SHERLOC contributions and Data Products addressed by the SHERLOC investigation

2.1 Instrument Functional Description

The SHERLOC instrument is an arm-mounted, deep ultraviolet (DUV) native fluorescence and resonance Raman spectrometer and imager. SHERLOC uses a DUV laser to illuminate the target and generate the characteristic Raman and fluorescence spectral response. SHERLOC contains two imaging subsystems: Autofocus and Context Imager (ACI) and Wide Angle Topographic Sensor for Operations and eNgineering (WATSON). The DUV laser is co-boresighted with the ACI and an integrated scanning optical system that allows correlation of spectral signatures to surface textures, morphology and visible features. Through the use of an internal scanning mirror, autofocusing lens, and a depth of focus, the SHERLOC laser spot can be systematically scanned over the spectroscopy map area with a fine-scale spatial sampling on natural or abraded surfaces and borehole interior walls, without further arm movement. Through the use of the context imager, SHERLOC's data products will be combined with the other instruments on the Mars 2020 payload. This allows greatly increased scientific analysis by bearing down the entire scientific measurements on a single sample to assess the habitability of ancient environments and search for potential biosignatures preserved within the geologic record to select high-priority samples for caching.

2.1.1 General Science

The SHERLOC investigation will enable spatially resolved, high-sensitivity detection and characterization of organics and minerals in the Martian surface and near subsurface. SHERLOC's goals are to assess past aqueous history, detect the presence and preservation of potential biosignatures, and to support selection of return samples. To do this SHERLOC will detect CHNOPS-containing minerals, detect the distribution and type of organics preserved at the surface, and correlate them to textural features.

2.1.2 Measurement Descriptions

SHERLOC's investigation combines two spectral phenomena, native fluorescence and pre-resonance/resonance DUV Raman scattering. These events are resolvable when a high-radiance, narrow line-width, laser source illuminates a sample. In fluorescence the incident photon is absorbed and re-emitted at a higher wavelength. The difference between the excitation wavelength and the emission wavelength is correlated with the number of electronic transitions between excitation and emission which increases with increasing aromatic structure (i.e., number of aromatic rings). Typical cross-sections are 10^5x greater than Raman, enabling the detection of sub-picograms of carbon.
Native fluorescence emission of organics extends from ~270 nm into the visible. Conversely mineral fluorescence emission stemming from crystalline defects and impurities does not have strong absorption features in the deep UV resulting in mineral fluorescence that typically begins longward of 360 nm and continues through the visible into the NIR. The only reported fluorescence of naturally occurring inorganics in the region 250–360 nm is in non-relevant astrophysical conditions [9]. In over 30 years of experiments in our laboratories, the only observed fluorescence at shorter wavelengths (<360 nm) have always been directly attributable to organics trapped inside the mineral matrix of a field sample, not the mineral matrix.

SHERLOC's narrow-linewidth (3 GHz) DUV laser (248.6 nm) also enables fluorescence-free Raman scattering for additional classification of aromatics and aliphatic organics and minerals. Raman scattering is inelastic scattering where the loss of energy from the excitation energy (40225 cm^{-1}) and defines the vibrational energy of a bond with which it interacted. This enables classification of bonds such as C-H, CN, C=O, C=C, NHx, NOx, SOx, POx, ClOx, and OH.

2.2 References

[1] Murchie, S.L *et al.* 2020, Applied Optics*,* 59, 433
[2] Beegle, L. *et al*. 2015, "SHERLOC: Scanning habitable environments with Raman & luminescence for organics & chemicals," *IEEE Aerospace Conference*, Big Sky, MT, 2015, pp. 1-11
[3] Beegle & Bhartia 2016, . EGUGA..1811215B,EGU General Assembly Conference
[4] Ianoul *et al.* 2002, J. Phys. Chem. 106, 3621-3624
[5] Abbey et al. 2017, Icarus, 390, 201

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 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 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 SHERLOC spectroscopy products consist of two files: the instrument data file in CSV format, and a detached PDS4 label file in XML format. The spectrometer labels differ from the SHERLOC image labels in that there is no VICAR label. The instrument data file contains separate files: the data file in CSV format and separate data file in ODL format. The detached ODL label is used during operations, and the detached PDS4 label is used for archiving the data at PDS. Both labels contain the same semantic content and can be used interchangeably. The ODL label is used by many science teams. Both are included for maximum compatibility, so that operations tools can still be used on archive data

The primary label supporting operations is the detached ODL label.

The primary label from the archive perspective is the detached PDS4 label. This is a separate file with the same base name as the EDR file, with a ".XML" extension. The detached label references 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 the spectroscopy CSV data.

3.2.2.1 **PDS 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 removed 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 spectroscopy 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 spectroscopy 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 spectroscopy 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.

3.3 CSV Data Storage Conventions

EDR data products for M2020 SHERLOC spectral data are stored as CSV data. The PDS labels are stored as ASCII text.

3.3.1 Bit and Byte Ordering

For non-byte instrument data, which includes 8-bit unsigned shorts, 16-bit signed shorts, 32-bit signed ints, and 32- and 64-bit IEEE floating-point numbers, the data may be stored in either Most Significant Byte first ("big-endian", as used by e.g. Sun computers and Java), or Least Significant Byte first ("little-endian", as used by e.g. Linux and Windows computers). In an EDR/RDR product, the instrument data can have only one ordering, but it is dependent on the host platform where the data was processed. Binary header data, not applicable to SHERLOC, can have a different ordering than the instrument data. This follows the PDS/ODL file format conventions.

Table 3.3.1 – M2020 Image EDR/RDR and Spectrum EDR Bit Ordering

Address	MSB-first	LSB-first
n	most significant byte	least significant byte
n+1	next	next
n+2	next	next
n+3	least significant byte	most significant byte

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.

The data packaged in the image data products will be decoded, decompressed, and decompanded camera image data in single frame form as an Experiment Data Record (EDR). The EDR structures defined in this document may vary depending on instrument, with all containing attached metadata labels.

For M2020, the EDR are the fundamental instrument data archive product. They will be generated as "raw" uncalibrated data within an automated pipeline process managed by MIPL under IDS at JPL. The size of an EDR data product varies per instrument and is dependent on several factors (sub-framing, downsample, compression, etc.).

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).

Table 4-1 List of Mars 2020 Data Products to be Archived

Product Name	**PDS Processing Level (raw, pp*, calibrated, derived)**	**PDS4 bundle:collection, assuming prefix urn:nasa:pds:**	**Product Description**	**PDS4 Data Type (e.g. Array_2D_Image, Array_3D_Image, Table_Character, Table_Delimited, Table_Binary)**	**Estimated Single Product Size (Data + Label)**	**Product Aggregation (e.g. how many per sol)**	**Data Producer**	**Provider to PDS**	**PDS Curator (GEO, CIS, ATM)**
				SHERLOC					
SHERLOC Spectroscopy EDR	raw	mars2020_sherloc: data_raw_spectroscopy	Raw Deep Ultra-violet (DUV) Resonance Raman and Fluorescence Spectroscopy data	Table_Delimited	5KB - 9MB	240	IDS	SHERLOC	GEO

Product Name	**PDS Processing Level (raw, pp*, calibrated, derived)**	**PDS4 bundle:collection, assuming prefix urn:nasa:pds:**	**Product Description**	**PDS4 Data Type (e.g. Array_2D_Image, Array_3D_Image, Table_Character, Table_Delimited, Table_Binary)**	**Estimated Single Product Size (Data + Label)**	**Product Aggregation (e.g. how many per sol)**	**Data Producer**	**Provider to PDS**	**PDS Curator (GEO, CIS, ATM)**
SHERLOC ACI EDR	raw	mars2020_imgops: data_aci_imgops mars2020_sherloc: data_aci (secondary members**)	Raw Autofocus Context Imager (ACI) Images	Array_2D_Image / Array_3D_Image	2.0MB	110	IDS	SHERLOC	GEO
SHERLOC WATSON EDR	raw	mars2020_imgops: data_watson_imgops mars2020_sherloc: data_watson (secondary members**)	Raw Wide Angle Topographic Sensor for Operations and eNgineering (WATSON) Images	Array_2D_Image / Array_3D_Image	2.0MB	25	IDS	SHERLOC	GEO
SHERLOC ACI RDR	pp / calibrated / derived	mars2020_imgops: data_aci_imgops mars2020_sherloc: data_aci (secondary members**)	Corrected/Calibrated ACI Images	Array_2D_Image / Array_3D_Image	2.0MB	110	IDS	SHERLOC	GEO
SHERLOC WATSON RDR	pp / calibrated / derived	mars2020_imgops: data_watson_imgops mars2020_sherloc: data_watson (secondary members**)	Corrected/calibrated WATSON Images	Array_2D_Image / Array_3D_Image	2.0MB	25	IDS	SHERLOC	GEO

Product Name	PDS Processing Level (raw, pp*, calibrated, derived)	PDS4 bundle:collection, assuming prefix urn:nasa:pds:	Product Description	PDS4 Data Type (e.g. Array_2D_Image, Array_3D_Image, Table_Character, Table_Delimited, Table_Binary)	Estimated Single Product Size (Data + Label)	Product Aggregation (e.g. how many per sol)	Data Producer	Provider to PDS	PDS Curator (GEO, CIS, ATM)
SHERLOC Spectroscopy RDR	pp / calibrated / derived	mars2020_sherloc: data_spectroscopy	Corrected/calibrated Deep Ultra-violet (DUV) Resonance Raman and Fluorescence Spectroscopy data	Table_Delimited	15KB-18MB	690	SHERLOC	SHERLOC	GEO
SHERLOC EDR SIS	document	mars2020_sherloc: document	Description of EDR contents and format	Document	n/a	n/a	SHERLOC	SHERLOC	GEO
SHERLOC RDR SIS	document	mars2020_sherloc: document	Description of RDR contents and format	Document	n/a	n/a	SHERLOC	SHERLOC	GEO
SHERLOC Bundle SIS	document	mars2020_sherloc: document	Description of mars2020_sherloc bundle organization	Document	n/a	n/a	SHERLOC	SHERLOC	GEO

Notes

* pp = “partially processed”. This processing level is for data that have undergone some processing beyond the raw product, but that are not yet calibrated.

** “Secondary members” indicates that some or all members of the collection are primary members of another collection. Every product is a primary member of exactly one collection, and is physically resident at the location of that collection. A product may be a secondary member of another collection, meaning its Logical Identifier is listed in that collection’s inventory, but it is not physically copied there.

Figure 5 Mars 2020 instruments PIXL, SuperCam, and SHERLOC incoporate cameras although they are not primarily imaging instruments.

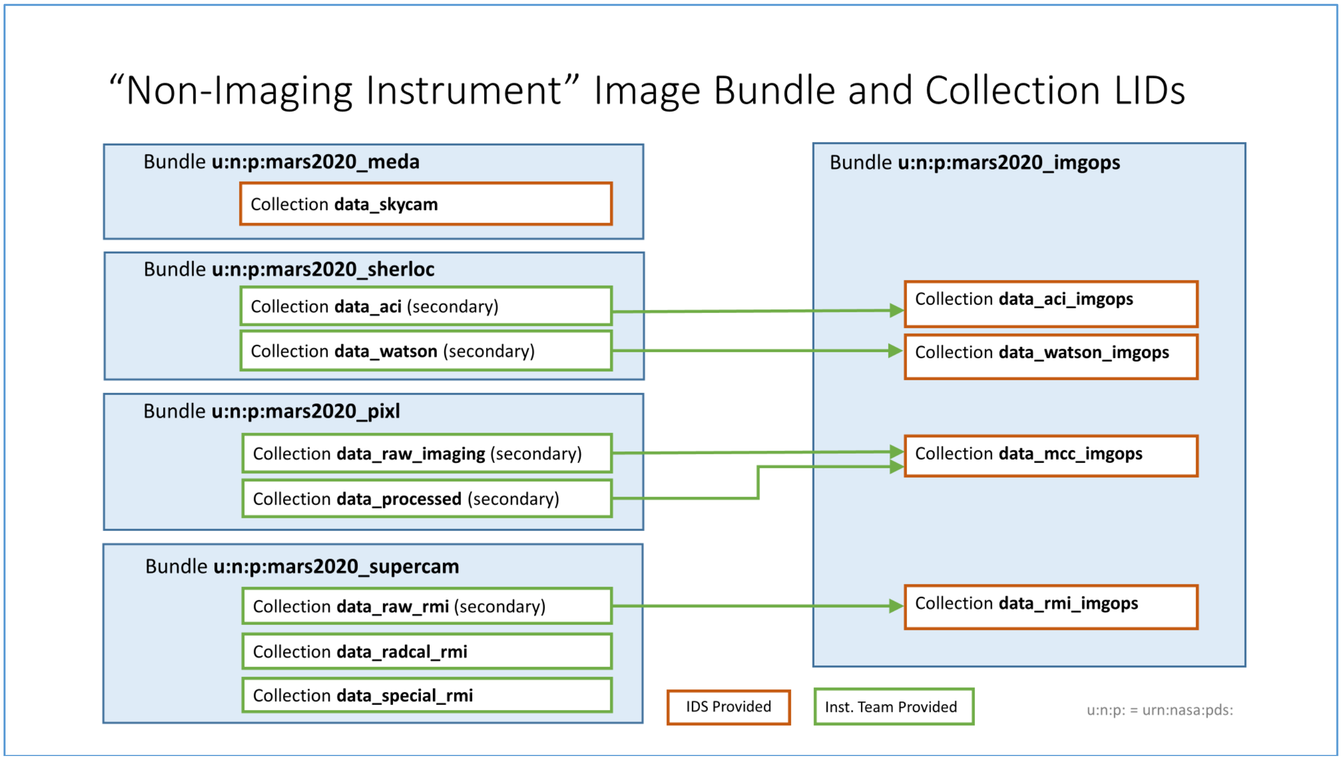


Figure 5 Mars 2020 instruments PIXL, SuperCam, and SHERLOC incoporate cameras although they are not primarily imaging instruments.

*pp = partially processed, for data that have undergone some processing beyond the raw product but are not yet calibrated

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 IDS is illustrated in Figure 6. The data flow within the IDS pipeline to EDR generation is illustrated in Figure 7 and is elaborated subsequently in this section.

Figure 6 Flow of M2020 data from instruments to IDS.

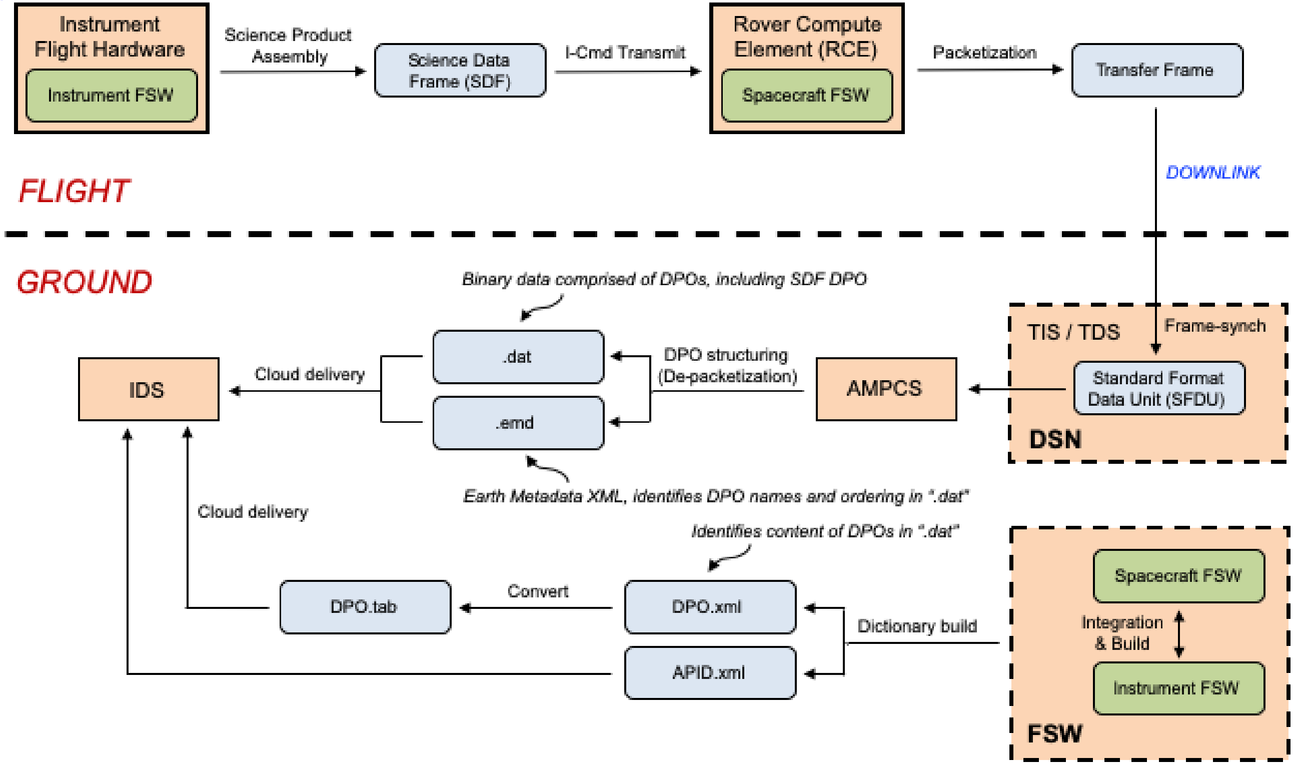


Figure 6 Flow of M2020 data from instruments to IDS.

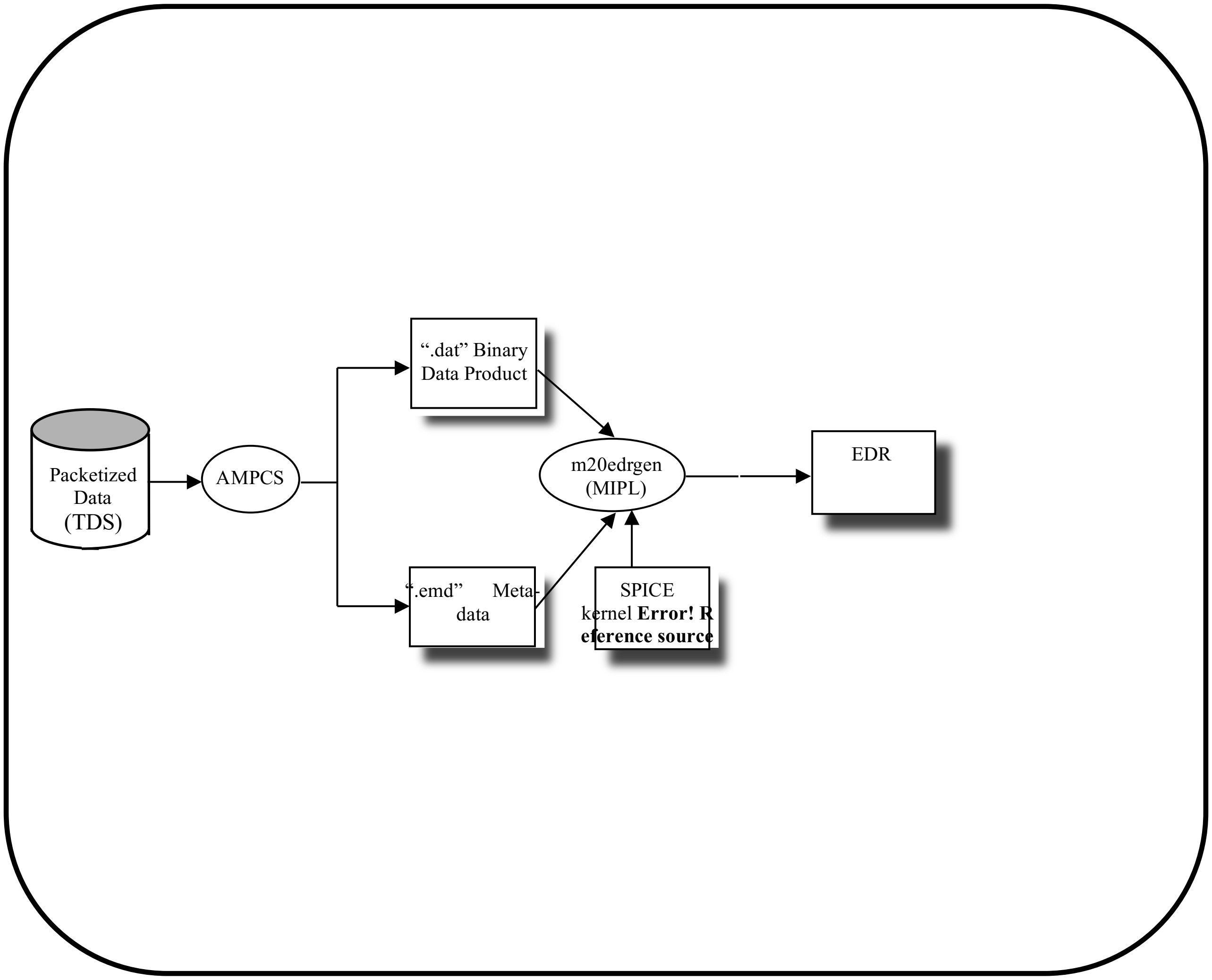


Figure 7 IDS EDR generation data flow

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

Current SHERLOC EDR Types as of G6.6:

Table 4-2 Product IDs for SHERLOC Spectroscopy

Subsystem	Values	Description	Corresponded DP (per IE)
Spectroscopy	**“ProdID” for Cruise Phase:**		
	“EDF”	Engineering data in fault detection	SrlcSpecFault
	“EDR”	Science data frame	SrlcSpecScidata
	“ProdID” for Surface Phase:		
	A . Science Data (raw telemetry in binary format, not archived)		
	“EXS”	Spectroscopy state of health in science mode	SrlcSpecSpecSohOnly
	“ERS”	Full resolution spectra in science mode	SrlcSpecSpecSohRaw
	“ECX”	Spectroscopy state of health in calibration mode	SrlcSpecSpecCalSohOnly
	“ECR”	Full resolution spectra in calibration mode	SrlcSpecSpecCalSohRaw
	“ESS”	Scanner mirror position (in Az/El)	SrlcSpecScan
	“EPD”	Processed data	SrlcSpecProcessData
	A. Science Data (in CSV file format, archived ready)		
	“ESH”	Spectroscopy state of health in science mode	Child of “EXS”
	“ECH”	Spectroscopy state of health in calibration mode	Child of “ECX”
	“EXH”	Scanner position array (in pixel)	Child of “ESS”
	“ERA”	Full resolution active spectra in science mode	Child of “ERS”
	“ERB”	Full resolution background (dark) spectra in science mode	Child of “ERS”
	“ECA”	Full resolution active spectra in calibration mode	Child of “ECR”
	“ECB”	Full resolution background (dark) spectra in calibration mode	Child of “ECR”
	“EPA”	Photodiode array	Child of “ERS” or “ECR” or “ERP”
	“ESP”	Scanner position array (in millimeter unit of measurement)	Child of “ERS” or “ECR” or “ERP”
	“ERP”	Processed data	Child of “EPD”
	B. Engineering Data (raw telemetry in binary format, not archived))		
	“EDF”	Engineering data in fault detection	SrlcSpecFault
	“EUT”	Engineering UTIL test	SrlcSpecUtilTest
	“ED1”	Engineering debug info	SrlcSpecDebugInfo
	“ED2”	Engineering memory [ARGS?] parameter dump	SrlcSpecArgsDump
	“ED3”	Engineering command history parameter dump	SrlcSpecCmdHistoryDump
	“ED4”	Engineering debug parameter dump	SrlcSpecDebugDump
	“ED5”	Engineering error log dump	SrlcSpecErrorLogDump
	“ED6”	Engineering memory parameter dump	SrlcSpecMemoryDump

	"ED7"	Engineering built-in self-test	SrlcSpecDoBist
	"ESR"	Engineering registers readout	SrlcSpecRegisterRead
	"ESE"	Engineering power readout	SrlcSpecPower
	"ESI"	Engineering initial power on readout	SrlcSpecInitSoh
	"ESX"	Engineering spectroscopy SOH readout	SrlcSpecSoh

4.3 EDR Product Format

This section provides the context information into the spectrometer SDF data structure. The same information can also be found in the reference document by Los Alamos National Laboratory (LANL) "Mars 2020 SHERLOC Instrument Software User's Guide". The following section and subsequent sub-sections are replication of LANL Instrument Software User's Guide Section 5.3.1 on Data Markers.

The SHERLOC instrument provided the spec_unpack PGE which incorporated into the IDS EDRgen softwared will read SHERLOC spectroscopy (binary) .dat and .emd file pairs that contain the following DPs: SrlcSpecSpecSohOnly, SrlcSpecSpecSohRaw, SrlcSpecCalSohOnly, SrlcSpecCalSohRaw, SrlcSpecProcessData, and SrlcSpecScan.

For DPs that only contain state-of-health (SOH) data, a single output EDR will be generated with the following product IDs: ESH for SrlcSpecSpecSohOnly, ECH for SrlcSpecCalSohOnly, EXH for SrlcSpecScan.

For DPs that contain SOH and spectral data (SrlcSpecSpecSohRaw and SrlcSpecCalSohRaw), multiple data products will be generated containing active spectra (ERA or ECA product IDs), dark spectra (ERB or ECB), photodiode array values (EPA) and scanner position information (ESP).

Active and dark spectra CSV EDRs will contain all spectral information in data tables of size N x 2148 x R, where N is the number of spectra (represented as a row in each table), 2148 represents the number of wavelength elements (represented by columns in each table), R represents the number of regions (represented by tables in the csv file – usually 3 regions are implemented). If a 2D spectral image is commanded (for diagnostic purposes, the entire spectrometer CCD is read out, rather than a binned spectrum), the active and dark spectra tables are of size 2148 x 515. Photodiode data products will contain laser intensity values for each shot, stored as a single table in the CSV file of size N x S, where N is the number of spectra (represented as a row in the table) and S is the number of shots in each spectrum (represented as columns in the table). The laser scanner position data associated with the spectra is stored in a table of size N x 2, where N is the number of spectra (represented as a row in the table) and 2 is the number of position elements – azimuth and elevation (represented as columns in the table). If the LOAD_TABLE command is issued, a second table containing the commanded azimuth and elevation values will be present as a second table.

The SrlcSpecProcessData DP will produce three EDRs, an EDR containing the photodiode array (EPA), an EDR containing the laser scanner positions (ESP), and an EDR containing the active and dark spectral data (ERP). The tables within these CSV files may vary depending on the algorithms commanded as part of the "Process Data" on-board processing command.

Note that the list of EDRs for IDS production includes both binary and CSV files. The binary science files are the input for the instrument team iSDS and are considered the "parent" files for the archived CSV science EDRs. The binary engineering data products are used for instrument diagnostics by the instrument team and are also not archived by PDS. The spectroscopy EDRs are listed below, with their product IDs (prodid).

4.3.1 **Cruise: Spectrometer Fault (EDF)**

4.3.2 **Cruise: Spectrometer Science Data Frame (EDR)**

4.3.3 **Surface: Spectrometer State of Health in Science Mode (EXS)**

Raw telemetry in binary format. Engineering only, not archived

4.3.4 **Surface: Full Resolution Spectra in Science Mode (ERS)**

Raw telemetry in binary format. Engineering only, not archived

4.3.5 **Surface: Spectrometer State of Health in Calibration Mode (EXC)**

Raw telemetry in binary format. Engineering only, not archived

4.3.6 **Surface: Full Resolution Spectra in Calibration Mode (ECR)**

Raw telemetry in binary format. Engineering only, not archived

4.3.7 **Surface: Scanner Mirror Position in Az/El (ESS)**

Raw telemetry in binary format. Engineering only, not archived

4.3.8 Surface: Processed Data (EPD)

Raw telemetry in binary format. Engineering only, not archived

4.3.9 Surface: Spectrometer State of Health in Science Mode (ESH)

Science Data (in CSV file format, archive ready)

4.3.10 Surface: Spectroscopy State of Health in Calibration Mode (ECH)

Science Data (in CSV file format, archive ready)

4.3.11 Surface: Scanner Position Array (in pixel) (EXH)

Science Data (in CSV file format, archive ready)

4.3.12 Surface: Full Resolution Spectra in Science Mode (ERA)

Science Data (in CSV file format, archive ready)

4.3.13 Surface: Full Resolution Background (Dark) Spectra in Science Mode (ERB)

Science Data (in CSV file format, archive ready)

4.3.14 Surface: Full Resolution Spectra in Calibration Mode (ECA)

Science Data (in CSV file format, archive ready)

4.3.15 Surface: Full Resolution Background (Dark) Spectra in Calibration Mode (ECB)

Science Data (in CSV file format, archive ready)

4.3.16 Surface: Photodiode Array (EPA)

Science Data (in CSV file format, archive ready

4.3.17 Surface: Scanner Position Array (in millimeter units of measurement) (ESP)

Science Data (in CSV file format, archive ready)

4.3.18 Surface: Processed Data (ERP)

Science Data (in CSV file format, archive ready)

4.3.19 Surface: Engineering Data in Fault (EDF)

Raw telemetry in binary format. Engineering only, not archived

4.3.20 Surface: Engineering Utility Test (EUT)

Raw telemetry in binary format. Engineering only, not archived

4.3.21 Surface: Engineering Debug Info (ED1)

Raw telemetry in binary format. Engineering only, not archived

4.3.22 Surface: Engineering Memory Parameter Dump (ED2)

Raw telemetry in binary format. Engineering only, not archived

4.3.23 Surface: Engineering Command History Parameter Dump (ED3)

Raw telemetry in binary format. Engineering only, not archived

4.3.24 Surface: Engineering Debug Parameter Dump (ED4)

Raw telemetry in binary format. Engineering only, not archived

4.3.25 Surface: Engineering Error Log Dump (ED5)

Raw telemetry in binary format. Engineering only, not archived

4.3.26 Surface: Engineering Memory Parameter Dump (ED6)

Raw telemetry in binary format. Engineering only, not archived

4.3.27 Surface: Engineering Built-In Self-Test (ED7)

Raw telemetry in binary format. Engineering only, not archived

4.3.28 Surface: Engineering Registers Readout (ESR)

Raw telemetry in binary format. Engineering only, not archived

4.3.29 Surface: Engineering Power Readout (ESE)

Raw telemetry in binary format. Engineering only, not archived

4.3.30 Surface: Engineering Initial Power On Readout (ESI)

Raw telemetry in binary format. Engineering only, not archived

4.3.31 Surface: Engineering Spectroscopy SOH Readout (ESX)

4.4 EDR Product Structure

The archived EDRs for SHERLOC are ASCII CSV files derived from the binary telemetry data files. The binary telemetry data files are input to the “spec_unpack” algorithm in the IDS and iSDS spectral processing software, which splits the binary data into separate CSV ASCII tables. The science DPO SrlcSpecSpecSohRaw produces the binary EDR with product ID “ERS”. It, in turn, is the source for ERA, ERB, EPA, and ESP CSV EDR types. The calibration DPO SrlcSpecCalSohRaw produces the binary EDR “ECR” and a corresponding set of ASCII spectra (ECA, ECB), as well as EPA and ESP laser photodiode and laser scanner position files. EPA and ESP files may also originate from the SrlcSpecProcess DPO. That mode uses the instrument computer to process data prior to transmission from the rover. The ASCII CSV tables are the products found in the PDS archive, and thus, are the only ones discussed further in this document. The included file M20_SHERLOC_DPO_Structure_V8.xlsx shows the correspondence in tabular form in the worksheet “EDR Structure”.

All “non-processed” SHERLOC spectroscopy EDRs contain the following 5 DPOs at the start of their CSV data files:

SRLCSPECDEFAULT
SRLCSPECARGS1
SRLCSPECPARAM3
SRLCSPECPARAM4
XMIT_DATA_HEADER_AMD_TRAILER
SDF_REPLY

One table should be present for each .CSV (with 1-3 rows each, depending on the number of data product files the observation has been split into). All of the non-processed EDRs except for the Spectral Scan (EXH) type also contain the following tables:

SDF_REPLY
COLLECT_SOH
SE_COLLECT_SOH
SEGMENT_COMMAND
SRLCSPECGENERALSOH_CONFIG_LASER_TIMING
SRLCSPECGENERALSOH_CONFIG_CCD_REGIONS
SRLCSPECGENERALSOH_CONFIG_CCD_HORZ_TIMING
SRLCSPECGENERALSOH_CONFIG_CCD_VERT_TIMING

The ESH and ECH EDRs consists entirely of these tables. The ERA and ECA EDR also have:

ACTIVE_SPECTRA_REGION_1
ACTIVE_SPECTRA_REGION_2
ACTIVE_SPECTRA_REGION_3

The ERB and ECB EDRs instead have:

DARK_SPECTRA_REGION_1
DARK_SPECTRA_REGION_2
DARK_SPECTRA_REGION_3

The EPA EDR has:

LASER_PHOTODIODE_DATA

The ESP EDR file derived from SrlcSpecSpecSohRaw and SrlcSpecCalSohRaw has

RETRIEVED_SCANNER_POSITION_TABLE
COMMANDED_SCANNER_POSITION_TABLE
SCANNER_POSITION_ERROR_TABLE

SCANNER_CURRENT_TABLE

The SHERLOC “processed” EDRs come in many variants, depending on the choice of algorithms to apply to the data before transmission. The included file M20_SHERLOC_DPO_Structure_V8.xslx lists all the possibilities.

4.4.1 Component DPOs

The component DPOs are as follows:

SRLCSPECDEFAULT

Subset	Field	Num Bytes	Data Length
n/a	SBA_PDU_TEMP	8	8
	SBA_DEA_TEMP	8	16
	sta_lps_a_temp	8	24
	sta_lps_b_temp	8	32
	sta_aci_af_temp	8	40
	sta_waf_temp	8	48
	sta_wche_temp	8	56
	sta_sccd_temp	8	64
	sta_se_temp	8	72
	sta_aci_che_temp	8	80
	sta_sde_temp	8	88
	sta_ob_a_temp	8	96
	sta_ob_b_temp	8	104
PwrSwitchState	sba_pdu_switch	4	108
	sba_dea_switch	4	112
	sta_decon_htr_statu	4	116
	sta_survival_htr_status	4	120
	sta_warmup_htr_status	4	124
	sct_decon_htr_status	4	128

SRLCSPECARGS1

Field	**Num Bytes**	**Data Length**
soh_only_priority	4	4
soh_raw_priority	4	8
shots_per_spectra	4	12
scanner_position_type	4	16
SherlocSpecScanModes	4	20
enable_laser	4	24
use_ranked_position	4	28
ranked_process_buffer_id	4	32
offset	4	36
table_location	4	40
table_size	4	44
origin_az	4	48
origin_el	4	52
store_raw_for_downlink	4	56
is_cal	4	60
data_id	4	64

SRLCSPECPARAM3

Field	**Num Bytes**	**Data Length**
el_home_min	4	4
az_home_min	4	8
el_home_max	4	12
az_home_max	4	16
el_home_cal	4	20
az_home_cal	4	24
el_home_origin	4	28
az_home_origin	4	32

SRLCSPECPARAM4

Field	**Num Bytes**	**Data Length**

col_timer_stop	4	4
col_i1_hi	4	8
col_i1_lo	4	12
col_i2_hi	4	16
col_i2_lo	4	20
col_i3_hi	4	24
col_i3_lo	4	28
ro_clock_limit	4	32
r1_clock_hi	4	36
r1_clock_lo	4	40
r2_clock_hi	4	44
r2_clock_lo	4	48
r3_clock_hi	4	52
r3_clock_lo	4	56
orst_clock_hi	4	60
orst_clock_lo	4	64
adc_clock_hi	4	68
adc_clock_lo	4	72
clamp_hi	4	76
clamp_lo	4	80
ccd_gain_2d	4	84
debug	4	88
mode_2d	4	92
region_enable	4	96
horizontal_enable	4	100
gain_enable	4	104
skip_rows_1	4	108
sum_rows_1	4	112
skip_rows_2	4	116
sum_rows_2	4	120
skip_rows_3	4	124
sum_rows_3	4	128
skip_rows_4	4	132
sum_rows_4	4	136
skip_rows_5	4	140
sum_rows_5	4	144

last_skip_rows	4	148
integration_time	4	152
laser_rep_rate	4	156
laser_on_time	4	160
pulse_width	4	164
shots_per_step	4	168
scanner_move_time	4	172
laser_current	4	176
row_step_size_az	4	180
row_step_size_el	4	184
col_step_size_az	4	188
col_step_size_el	4	192
num_cols	4	196

SDF_Reply_SPREADSHEET

The SDF Reply table contains the condition code data, which is converted to one of the following strings, based on the retrieved integer:

1	NOMINAL
2	FRAME_ERR
3	OVERRUN
4	PARITY_ERR
5	TIMEOUT_ERR
6	BAD_OPCODE
7	BAD_ERRCTL_TYPE
8	RESERVED
9	BAD_FLAGS
10	BAD_COND_CODE
11	BAD_DATA_LENGTH
12	BAD_CHECKSUM
13	WRONG_MODE
14	BAD_DATA
15	STOP_ITER
16	NO_DATA
17	BOOT_FAIL
18	SELF_TEST_FAIL
19	SCANNER_STATE_MISCOMPARE
20	SCANNER_ERROR
21	LASER_ARC_DETECTION
22	LASER_MISFIRE
23	ALGORITHM_ERROR

24	REG_WRITE_ERROR
25	BAD_UPLOAD_DATA
26	RESERVED_0
27	RESERVED_1
28	RESERVED_2
29	RESERVED_3
30	RESERVED_4

(ranges from 8 bytes to 24 bytes)

Field	**Num Bytes**	**Data Length**
DPO	18	18
ERRORCONTROL	4	22
ISDATA	4	26
ISREPLY	4	30
SFLAGS_SPARE	4	34
SFLAGS_PROCESS_BUFFER_4_EMPTY	4	38
SFLAGS_PROCESS_BUFFER_3_EMPTY	4	42
SFLAGS_PROCESS_BUFFER_2_EMPTY	4	46
SFLAGS_PROCESS_BUFFER_1_EMPTY	4	50
SFLAGS_ERROR_LOG_EMPTY	4	54
SFLAGS_LASER_BELOW_THRESHOLD	4	58
SFLAGS_LASER_IN_AFT	4	62
SFLAGS_LPS_IN_AFT	4	66
SFLAGS_SCANNER_IN_AFT	4	70
SFLAGS_SCCD_IN_SCI_TEMP	4	74
SFLAGS_SCANNER_STATE	4	78
SFLAGS_STA_COMM_ERROR	4	82
SFLAGS_COMM_SIDE	4	86
SFLAGS_BOOT_SOURCE	4	90
CCODE	4	94

XMIT_data_header_and_trailer_SPREADSHEET

The xmit data header table contains the timing and software/firmware versions information. The total length of the table is determined to be: up to 58 bytes

Field	Num Bytes	Data Length
DPO	18	18
RCE_TIME_SYNC	4	22
MILLISECOND_COUNT	4	26
DATA_DEFINITION_VERSION	4	30
NV_XMIT_BUFFER_COUNT	4	34
CNDH_SOFTWARE_VERSION	4	38
CNDH_FIRMWARE_VERSION	4	42
CNDH_HARDWARE_IDENTIFY	4	46
SE_FIRMWARE_VERSION	4	50
SE_HARDWARE_IDENTIFIER	4	54
XMIT_DATA_ID	4	58
NUMBER_OF_SEGMENTS	4	62
GENERIC_DATA_BUFFER_SIZE	4	66

Segment_Command_SPREADSHEET

This table includes the millisecond counter and the corresponding command. The maximum length of the command name (determined from the CNDH op code) is 30 bytes. The data field does not have a pre-determined width.

Field	Num Bytes	Data Length
DP	18	18
RCE_TIME_SYNC	4	22
MILLISECOND_COUNT	4	26
DATA_LENGTH	4	30
COMMAND_NAME	8	38
SEGMENT_TYPE	7	45

Collect_SOH_SPREADSHEET

Field	Num Bytes	Data Length

RCE_TIME_SYNC	4	4
MILLISECOND_COUNT	4	8
TLM_FORMAT_VERSION_(CMD_DICT_VERSION)	4	12
LAST_BIST_RESULT	4	16
CURRENT_STATUS_FLAGS	4	20
BOOT_BANK_SELECTED	4	24
BOOT_BANK_ACTUAL	4	28
COMMANDS_RECEIVED	4	32
COMMANDS_COMPLETED	4	36
COMMANDS_REJECTED	4	40
NUMBER_OF_ERROR_LOG_ENTRIES_SINCE_BOOT	4	44
BANK_A_KERNEL_CALCULATED_CHECKSUM_-_NV	4	48
BANK_A_APPLICATION_CALCULATED_CHECKSUM_-_NV	4	52
BANK_B_KERNEL_CALCULATED_CHECKSUM_-_N	4	56
BANK_B_APPLICATION_CALCULATED_CHECKSUM_-_NV	4	60
RCE_COMM_SIDE	4	64
SPACEWIRE_COMM_ERROR_COUNT_-_NV	4	68
LAST_SPACEWIRE_ERROR_STATUS_REGISTER	4	72
SINGLE_BIT_MRAM_MEMORY_ERRORS_-_NV	4	76
SINGLE_BIT_SDRAM_MEMORY_ERRORS_-_NV	4	80
LAST_SINGLE_BIT_MEMORY_ADDRESS	4	84
SOFTWARE_VERSION	4	88
PULSES_ID_REG	4	92
ROVER_HSS_TX_WD_CNT_REG	4	96
IRQ_CLR_REG	4	100
ROVER_HSS_CNTRL_REG	4	104
ROVER_HSS_TX_REG	4	108
IRQ_EN_REG	4	112
MRAM_CNTRL_REG	4	116
LED_REG	4	120
SCANNER_DAC_REG	4	124
SCANNER_CTL_REG	4	128
RESERVED_1	4	132
RESERVED_2	4	136
COL_STEP_REG	4	140

ROW_STEP_REG	4	144
NSPS_REG	4	148
MODE_REG	4	152
LZR_REP_RATE_REG	4	156
LZR_ON_TIME_REG	4	160
SCN_MOVE_TIME_REG	4	164
NUM_COLS_REG	4	168
SCAN_ORIGIN_REG	4	172
LZR_OFF_TIME_REG	4	176
INTEGRATION_TIME_REG	4	180
SHOTS_PER_SPECTRA_REG	4	184
TEST_CTRL_REG	4	188
RESERVED_3	4	192
RESERVED_4	4	196
RESERVED_5	4	200
RESERVED_6	4	204
RESERVED_7	4	208
RESERVED_8	4	212
NUM_CTRL_REG	4	216
NUM_STATUS_REG	4	220
SCANNER_ADC_REG	4	224
IRQ_STAT_REG	4	228
ROVER_HSS_FRAME_STAT_REG	4	232
TEST_STAT_REG	4	236
IDENTITY_STAT_REG	4	240
TEST2_STAT_REG	4	244
RESERVED_9	4	248
ROVER_HSS_STAT_REG	4	252
RESERVED_10	4	256
CNDH_PCB_TEMP_STAT_REG	4	260
CNDH_1_2_V_STAT_REG	4	264
CNDH_5_V_DAC_STAT_REG	4	268
CNDH_3_3_V_STAT_REG	4	272
CNDH_5_V_ADC_STAT_REG	4	276
CNDH_NEG_15_V_STAT_REG	4	280
CNDH_15_V_STAT_REG	4	284

CNDH_1_5_V_STAT_REG	4	288
TOTAL_NUMBER_SPECTRA_READ_OUT_-_NV	4	292
TOTAL_NUMBER_OF_LASER_SHOTS_COMMANDED_-_NV	4	296
TOTAL_LASER_MISFIRE_COUNT_-_NV	4	300
TOTAL_DISCRETE_ARC_EVENT_COUNT_-_NV	4	304
CURRENT_SPACEWIRE_STATUS_REGISTER	4	308
RESERVED_2 THIS IS REDUNDANT	4	312

SrlcSpecGeneralSOH_CONFIG_LASER_TIMINGSPREADSHEET

The following CONFIG_* tables may be present in some spectroscopy observations. Following a power_on command, the CCD and laser may be configured, in which case, these tables will be included in the DP.
Total bytes: 25 bytes

Field	**Num Bytes**	**Data Length**
RCE_TIME_SYNC	4	4
MILLISECOND_COUNT	4	8
INTEGRATION_TIME	4	12
LASER_REP_RATE	4	16
LASER_ON_TIME	4	20
PULSE_WIDTH	4	24
SHOTS_PER_SPECTRA	4	28
SHOTS_PER_STEP	4	32
SCANNER_MOVE_TIME	4	36
LASER_CURRENT	4	40

SrlcSpecGeneralSOH_CONFIG_CCD_REGIONSSPREADSHEET

Field	**Num Bytes**	**Data Length**
RCE_TIME_SYNC	4	4
MILLISECOND_COUNT	4	8

CCD_GAIN_2D	4	12
DEBUG	4	16
MODE_2D	4	20
REGION_ENABLE	4	24
HORIZONTAL_ENABLE	4	28
GAIN_ENABLE	4	32
SKIP_ROWS_1	4	36
SUM_ROWS_1	4	40
SKIP_ROWS_2	4	44
SUM_ROWS_2	4	48
SKIP_ROWS_3	4	52
SUM_ROWS_3	4	56
SKIP_ROWS_4	4	60
SUM_ROWS_4	4	62
SKIP_ROWS_5	4	66
SUM_ROWS_5	4	72
LAST_SKIP_ROWS	4	76

SrlcSpecGeneralSOH_CONFIG_CCD_HORZ_TIMINGSPREADSHEET

Field	**Num Bytes**	**Data Length**
RCE_TIME_SYNC	4	4
MILLISECOND_COUNT	4	8
RO_CLOCK_LIMIT	4	12
R1_CLOCK_HI	4	16
R1_CLOCK_LO	4	20
R2_CLOCK_HI	4	24
R2_CLOCK_LO	4	28
R3_CLOCK_HI	4	32
R3_CLOCK_LO	4	36
ORST_CLOCK_HI	4	40
ORST_CLOCK_LO	4	44
ADC_CLOCK_HI	4	48
ADC_CLOCK_LO	4	52

CLAMP_HI	4	56
CLAMP_LO	4	60

SrlcSpecGeneralSOH_CONFIG_CCD_VERT_TIMINGSPREADSHEET

Field	**Num Bytes**	**Data Length**
RCE_TIME_SYNC	4	4
MILLISECOND_COUNT	4	8
COL_TIMER_STOP	4	12
COLI_1_HI	4	16
COLI_1_LO	4	20
COLI_2_HI -THIS IS MISSING	-	-
COLI_2_LO	4	24
COLI_3_HI	4	28
COLI_3_LO	4	32

SE_Collect_SOH_SPREADSHEET

Total table length: 296 bytes

	Bytes	Length
RCE_TIME_SYNC	4	4
MILLISECOND_COUNT	4	8
SE_PULSES_ID_REG	4	12
SE_SKIP1_REG	4	16
SE_SUM1_REG_ENABLE	4	20
SE_SUM1_REG_GAIN	4	24
SE_SUM1_REG	4	28
SE_SKIP2_REG	4	32
SE_SUM2_REG_ENABLE	4	36
SE_SUM2_REG_GAIN	4	40
SE_SUM2_REG	4	44
SE_SKIP3_REG	4	48

SE_SUM3_REG_ENABLE	4	52
SE_SUM3_REG_GAIN	4	56
SE_SUM3_REG	4	60
SE_SKIP4_REG	4	64
SE_SUM4_REG_ENABLE	4	68
SE_SUM4_REG_GAIN	4	72
SE_SUM4_REG	4	76
SE_SKIP5_REG	4	80
SE_SUM5_REG_ENABLE	4	84
SE_SUM5_REG_GAIN	4	88
SE_SUM5_REG	4	92
SE_SOH_CNTRL_REG	4	96
SE_LAST_SKIP_REG	4	100
SE_TEST_CTRL_REG	4	104
SE_RESERVED_1	4	108
SE_RESERVED_2	4	112
SE_MODE_REG	4	116
SE_RESERVED_3	4	120
SE_RESERVED_4	4	124
SE_RO_CLK_LIM_REG	4	128
SE_R1_CLK_HI_REG	4	132
SE_R1_CLK_LO_REG	4	136
SE_R2_CLK_HI_REG	4	140
SE_R2_CLK_LO_REG	4	144
SE_R3_CLK_HI_REG	4	148
SE_R3_CLK_LO_REG	4	152
SE_ORST_CLK_HI_REG	4	156
SE_ORST_CLK_LO_REG	4	160
SE_ADC_CLK_HI_REG	4	164
SE_ADC_CLK_LO_REG	4	168
SE_CLAMP_HI_REG	4	172
SE_CLAMP_LO_REG	4	176
SE_VO_CLK_LIM_REG	4	180
SE_V1_CLK_HI_REG	4	184
SE_V1_CLK_LO_REG	4	188
SE_V2_CLK_HI_REG	4	192
SE_V2_CLK_LO_REG	4	196

SE_V3_CLK_HI_REG	4	200
SE_V3_CLK_LO_REG	4	204
SE_RESERVED_5	4	208
SE_RESERVED_6	4	212
SE_TEST_STAT_REG	4	216
SE_CCD_ID_STAT_REG	4	220
SE_CCD_TEMP_STAT_REG	4	224
SE_PCB_TEMP_STAT_REG	4	228
SE_V_1_5_STAT_REG	4	232
SE_LASER_PRT2_STAT_REG	4	236
SE_LASER_PRT1_STAT_REG	4	240
SE_LPS_PRT1_STAT_REG	4	244
SE_RESERVED_7	4	248
SE_TPRB_HOUSING_PRT_STAT_REG	4	252
SE_LPS_PRT2_STAT_REG	4	256
SE_SPARE1_PRT_STAT_REG	4	260
SE_NOT_CONNECTED_STAT_REG	4	264
SE_RESERVED_8	4	268
SE_LASER_FIRE_CNT_REG	4	272
SE_SOH_STAT_REG	4	276
SE_IDENTITY_REG	4	280
SE_TEST2_STAT_REG	4	284
SE_LASER_SAFETY_CNT_REG	4	288
SE_RESERVED_9	4	292
SE_RESERVED_10	4	296

laser_photodiode_Data_SPREADSHEET

Field	**Bytes**	**Length**
SHOT_NUMBER_0	4	4
SHOT_NUMBER_1	4	8
SHOT_NUMBER_2	4	12
SHOT_NUMBER_3	4	16
SHOT_NUMBER_4	4	20
SHOT_NUMBER_5	4	24
SHOT_NUMBER_6	4	28
SHOT_NUMBER 7	4	32

SHOT_NUMBER 8	4	36
SHOT_NUMBER_9	4	40
SHOT_NUMBER_10	4	44
SHOT_NUMBER_11	4	48
SHOT_NUMBER_12	4	52
SHOT_NUMBER_13	4	56
SHOT_NUMBER_14	4	60
SHOT_NUMBER_15	4	64
SHOT_NUMBER_16	4	68
SHOT_NUMBER_17	4	72
SHOT_NUMBER_18	4	76
SHOT_NUMBER_19	4	80
SHOT_NUMBER_20	4	84
SHOT_NUMBER_21	4	88
SHOT_NUMBER_22	4	92
SHOT_NUMBER_23	4	96
SHOT_NUMBER_24	4	100
SHOT_NUMBER_25	4	104
SHOT_NUMBER_26	4	108
SHOT_NUMBER_27	4	112
SHOT_NUMBER_28	4	116
SHOT_NUMBER_29	4	120
SHOT_NUMBER_30	4	124
SHOT_NUMBER_31	4	128
SHOT_NUMBER_32	4	132
SHOT_NUMBER_33	4	136
SHOT_NUMBER_34	4	140
SHOT_NUMBER_35	4	144
SHOT_NUMBER_36	4	148
SHOT_NUMBER_37	4	152
SHOT_NUMBER_38	4	156
SHOT_NUMBER_39	4	160
SHOT_NUMBER_40	4	164
SHOT_NUMBER_41	4	168
SHOT_NUMBER_42	4	172
SHOT_NUMBER_43	4	176
SHOT_NUMBER_44	4	180

SHOT_NUMBER_45	4	184
SHOT_NUMBER_46	4	188
SHOT_NUMBER_47	4	192
SHOT_NUMBER_48	4	196
SHOT_NUMBER_49	4	200

PROCESS_DATA

This table is expected anytime a “process data” data product is returned (and an ERP EDR is generated). The table contains metadata for the observation. The Spatial location field is the index of the spatial binning table, if one is selected.
Table size: 13 bytes

Field	**Bytes**	**Length**
RCE_TIME_SYNC	4	4
MILLISECOND_COUNT	4	8
SCANNER_TABLE_LOCATION	4	12
SCANNER_TABLE_SIZE	4	16
AZIMUTH_ORIGIN	4	20
ELEVATION_ORIGIN	4	24
NUMBER_OF_DATA_ITEMS	4	28
SPATIAL_LOCATION	4	32
NUMBER_OF_REGIONS	4	36
PROCESSED_DATA_TYPE_SUBMARKER:_CLASSIFICATION_ID	4	40
PROCESSED_DATA_TYPE_SUBMARKER:_LAST_ALGORITHM_ID	4	44

SRLCSPECPROCESSDATA_ALGORITHM_ID_LIST

Field	**Bytes**	**Length**
ALGORITHM_IDS	4	4

This table contains a single column with each row defining the algorithm ID for each algorithm applied to the data on-board: 2 bytes (unsigned int)

SRLCSPECPROCESSDATA_SPECTRA_DATA

This table is similar to the nominal spectral data table, but the spectra may be processed, and are therefore stored as 4 byte floats, rather than 2 byte integers. The table may contain a subset of the channels if spectrally binned (using Binned_Spec[1-6] column headers), or may contain the full spectrum (using R[1-3]_Channel_[0-2147]). The table size therefore may have the following column widths:

- 4 bytes (spectral binning, 1 zone specified)
- 8 bytes (spectral binning, 2 zones specified)
- 12 bytes (spectral binning, 3 zones specified)
- 16 bytes (spectral binning, 4 zones specified)
- 20 bytes (spectral binning, 5 zones specified)
- 24 bytes (spectral binning, 6 zones specified)
- 8592 bytes (no spectral binning applied)

SRLCSPECPROCESSDATA_ZONE_SPECIFICATION

This table contains two columns, with each entry consisting of a 2 byte unsigned int representing the start/stop location of a spectral region of interest. Table size: 4 bytes

SRLCSPECPROCESSDATA_RANKED_LIST

This table contains two columns, a 2 byte unsigned int representing the spectrum number, and a 4 byte float representing the ranked score. Table size: 6 bytes

4.4.2 EDR Types (Unprocessed)

SOH Only: (ESH/ECH)

Table Column Length (bytes	Byte Offset	Table Structure
128	0	SRLCSPECDEFAULT
64	128	SRLCSPECARGS1
32	192	SRLCSPECPARAM3
196	224	SRLCSPECPARAM4
66	420	XMIT_DATA_HEADER_AMD_TRAILER
94	486	SDF_REPLY
312	580	COLLECT_SOH
296	892	SE_COLLECT_SOH
45	1188	SEGMENT_COMMAND
40	1233	SRLCSPECGENERALSOH_CONFIG_LASER_TIMING
76	1273	SRLCSPECGENERALSOH_CONFIG_CCD_REGIONS
60	1349	SRLCSPECGENERALSOH_CONFIG_CCD_HORZ_TIMING
32	1409	SRLCSPECGENERALSOH_CONFIG_CCD_VERT_TIMING

Raw Spectra: (ERA/ERB) or (ECA/ECB for calibration)

There are typically three detector regions commanded, resulting in three tables, each with 2148 columns (column names: R[1-3]_Channel_[0-2147]). Each value is an U16, resulting in a column length of (2148 * (2 bytes)) = 4296 bytes

Table Column Length (bytes	Byte Offset	Table Structure
128	0	SRLCSPECDEFAULT
64	128	SRLCSPECARGS1
32	192	SRLCSPECPARAM3
196	224	SRLCSPECPARAM4
66	420	XMIT_DATA_HEADER_AMD_TRAILER
94	486	SDF_REPLY
312	580	COLLECT_SOH
296	892	SE_COLLECT_SOH
45	1188	SEGMENT_COMMAND
40	1233	SRLCSPECGENERALSOH: CONFIG_LASER_TIMING
76	1273	SRLCSPECGENERALSOH: CONFIG_CCD_REGIONS
60	1349	SRLCSPECGENERALSOH: CONFIG_CCD_HORZ_TIMING
32	1409	SRLCSPECGENERALSOH: CONFIG_CCD_VERT_TIMING
	1441	ACTIVE_SPECTRA_REGION_1
		ACTIVE_SPECTRA_REGION_2
		ACTIVE_SPECTRA_REGION_3

For the “B” versions, ACTIVE_SPECTRA_REGION_1-3 is replaced by DARK_SPECTRA_REGION_1-3._

Photodiode: (EPA)

The photodiode table contains a single reading (U16) for each shot. The table size ([rows] x [columns]) is: [number of spectra] x [number of shots]. This results in a variable column width, depending on the number of shots fired (up to 900). The number of shots per spectrum is not fixed. The table length is ([number of shots] x 2 bytes)

For process_data products, the photodiode table may contain raw data or summary (averaged) data. In the former case, the column name is shot_number_[1-900]. In the latter case, the column name is summary_photodiode_value_0 and the table has a length of 2 bytes.

Table Column	Byte Offset	Table Structure

Length (bytes		
128	0	SRLCSPECDEFAULT
64	128	SRLCSPECARGS1
32	192	SRLCSPECPARAM3
196	224	SRLCSPECPARAM4
66	420	XMIT_DATA_HEADER_AMD_TRAILER
94	486	SDF_REPLY
312	580	COLLECT_SOH
296	892	SE_COLLECT_SOH
45	1188	SEGMENT_COMMAND
40	1233	SRLCSPECGENERALSOH: CONFIG_LASER_TIMING
76	1273	SRLCSPECGENERALSOH: CONFIG_CCD_REGIONS
60	1349	SRLCSPECGENERALSOH: CONFIG_CCD_HORZ_TIMING
32	1409	SRLCSPECGENERALSOH: CONFIG_CCD_VERT_TIMING
200	1441	LASER_PHOTODIODE_DATA

Scanner: (ESP):
The scanner EDR contains several tables:
(az,el): 4 bytes (signed ints)
(az_commanded, el_commanded): 4 bytes (signed ints) <this table may not be present if the commanded table data is not returned>
(az_err, el_err): 4 bytes (signed ints)
(sum_current, diff_current): 4 bytes (signed ints)

Table Column Length (bytes	**Byte Offset**	**Table Structure**
128	0	SRLCSPECDEFAULT
64	128	SRLCSPECARGS1
32	192	SRLCSPECPARAM3
196	224	SRLCSPECPARAM4
66	420	XMIT_DATA_HEADER_AMD_TRAILER
94	486	SDF_REPLY
312	580	COLLECT_SOH
296	892	SE_COLLECT_SOH
45	1188	SEGMENT_COMMAND
40	1233	SRLCSPECGENERALSOH: CONFIG_LASER_TIMING
76	1273	SRLCSPECGENERALSOH: CONFIG_CCD_REGIONS

60	1349	SRLCSPECGENERALSOH: CONFIG_CCD_HORZ_TIMING
32	1409	SRLCSPECGENERALSOH: CONFIG_CCD_VERT_TIMING
8	1441	RETRIEVED_SCANNER_POSITION_TABLE
8	1449	COMMANDED_SCANNER_POSITION_TABLE
8	1457	SCANNER_POSITION_ERROR_TABLE
8	1465	SCANNER_CURRENT_TABLE

The SHERLOC “family tree” table provides this information in tabular form. It is an attached spreadsheet in Appendix C.M20_SHERLOC_DPO_Structure_V9.xslx

4.5 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

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 below.

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" 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 ptimize differentiation of field boundaries for the human user.

5.1.1 EDR Filename

Error! Reference source not found.

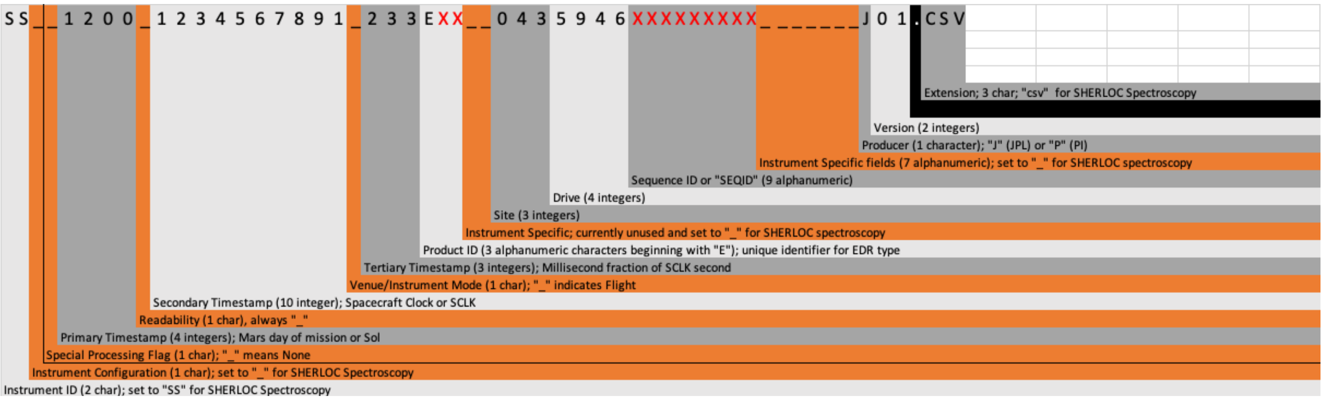
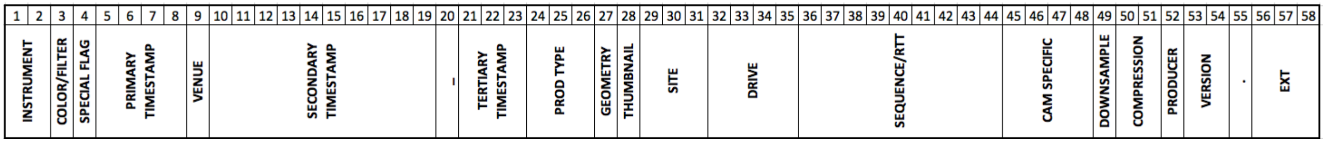


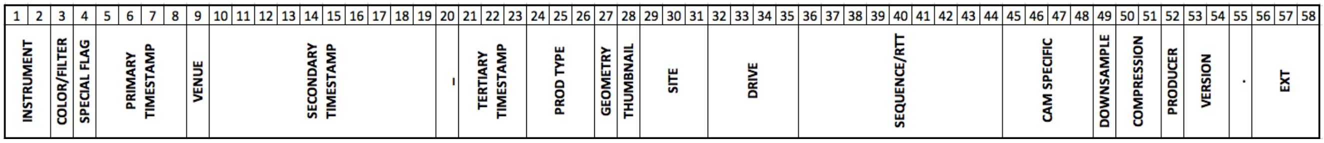
Figure 8 SHERLOC Spectroscopy EDR naming convention

Table 5-1 M2020 EDR filename fields. Several fields are camera specific and only populated for imaging files.

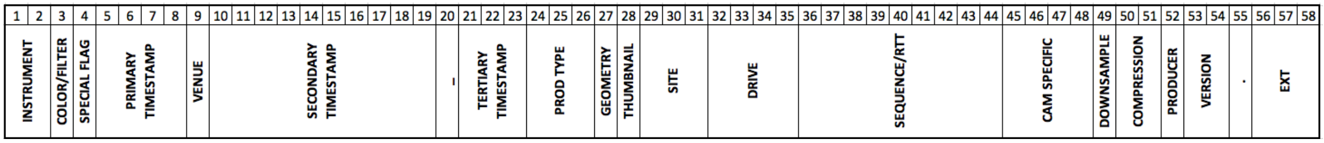


1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
INSTRUMENT		COLOR/FILTER	SPECIAL FLAG	PRIMARY TIMESTAMP				VENUE	SECONDARY TIMESTAMP										_	TERTIARY TIMESTAMP			PROD TYPE			GEOMETRY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

Field	Position (size, type)	Description
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



Field	Position (size, type)	Description
		• 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) • 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+) • 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+)



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

SR: SuperCam RMI (<G6.3)
LR : Supercam RMI (G6.3+)

Non-imaging instrument identifiers:

SA : SuperCam All Spectrometers (<G6.3)
SD : SuperCam Diagnostic (<G6.3)
SG : SuperCam Generic (<G6.3)
SL : SuperCam Libs (<G6.3)
SM : SuperCam Mineral Data (<G6.3)
SP : SuperCam Passive (<G6.3)
LS : SuperCam Spectrometers/Diagnostic/Generic/LIBS/Mineral/Passive (G6.3+)
ME : MEDA Environment
OX : MOXIE
PE : PIXL Engineering
PS : PIXL Spectrometer
SS : SHERLOC Spectrometer
XM : RIMFAX Mobile
XS : RIMFAX Stationary

</td></tr>
<tr><td>Color/Filter</td><td>03 (1, i/a)</td><td>
Color flag (see Section X.X):

E : Raw Bayer pattern
M : Grayscale image (Monochrome/Panchromatic)
A : Upper green bayer cells (G1 see Section X.X)
D : Lower green bayer cells (G2 see Section X.X)
O : Other
_ : N/A

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.
<table>
<tr><th>Color Type</th><th>3-Band</th><th>Band 1</th><th>Band 2</th><th>Band 3</th></tr>
<tr><td>RGB</td><td>F</td><td>R</td><td>G</td><td>B</td></tr>
<tr><td>XYZ</td><td>T</td><td>X</td><td>Y</td><td>Z</td></tr>
</table>
</td></tr>
</table>

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

<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>xyY</td><td>C</td><td>J</td><td>K</td><td>L</td></tr>
<tr><td>HSI</td><td>P</td><td>H</td><td>S</td><td>I</td></tr>
</table>
<p>For certain instruments, this flag may take on additional values indicating illumination or filter:</p>
<p>For PIXL, the flag can be set based on the LEDs used to illuminate the target.</p>
<table>
<tr><th>LED Color</th><th>Flag</th></tr>
<tr><td>Red</td><td>R</td></tr>
<tr><td>Green</td><td>G</td></tr>
<tr><td>Blue</td><td>B</td></tr>
<tr><td>Multiple</td><td>W</td></tr>
<tr><td>UV</td><td>U</td></tr>
<tr><td>Off</td><td>_</td></tr>
</table>
<p>For MCZ and SHERLOC Imaging the flag can be filter or cover state.</p>
<table>
<tr><th>Instrument</th><th>Filters</th><th>Description</th></tr>
<tr><td>Mastcam-Z</td><td>0 – 7</td><td>See section X on MCZ filters</td></tr>
<tr><td>Sherloc</td><td>None</td><td>See section X on SHERLOC filters of the Camera SIS. For spectroscopy SHERLOC, this field is “_”</td></tr>
</table>
<p>Other color flags may be defined in the future.</p>
<p>Only “E”, “F”, or “M” or Filter/LED can appear in EDRs.</p>
</td></tr>
<tr><td>Special flag</td><td>04 (1, a)</td><td><p>Special Processing flag, applicable to RDRs only. EDRs always have "_".</p>
<p>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</p></td></tr>
</table>

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

Field	Position (size, type)	Description
		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.
Primary timestamp	05 (4, i/a)	Primary timestamp that is of coarser granularity than the Secondary timestamp (documented later). 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 – b) Sol (4 integer) - This field stores the 4-integer Sol (Mars solar day) of the <u>first</u> (i.e.,

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
		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	Year-DOY	(same as Flight Cruise)	(same as Flight Cruise)	(same as Flight Cruise)

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>
<table>
<tr><td>is NOT reset</td><td>Sol</td><td><nnnn></td><td>“0000”, “0001”, … “9999”</td><td>0 thru 9999</td></tr>
<tr><td></td><td></td><td><aaaa></td><td>“_ _ _ _” (4 underscores)</td><td>Value is out of range</td></tr>
<tr><td>Ground Test where SCLK is reset</td><td>DOY-Year</td><td><ddd>[A-Z]</td><td>“001A”, “002A”, …,“365A”, “001B”, “002B”,…, “365B”,
•
•
•
“001Z”, “002Z”, … “365Z”</td><td>2017 - Days 1-365 2018 - Days 1-365
•
•
•
2042 - Days 1-365</td></tr>
<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:

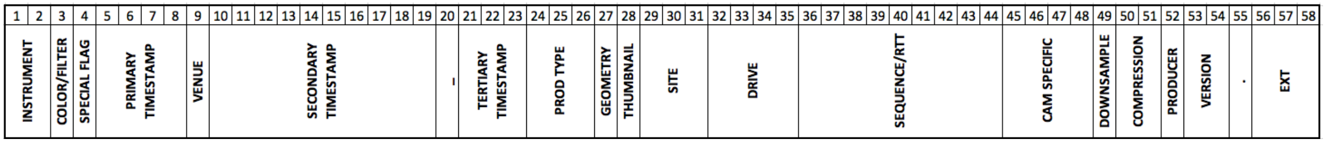
<u>Flight Cruise</u>
SCLK – This field stores the 10-integer SCLK (seconds). Which specific SCLK count (Start or End) is used depends on the instrument, but nominally it is the starting count of the <u>first</u> (i.e., lowest Clock time) acquired instrument data.

<u>Flight Surface</u>
SCLK – Same as for “Flight Cruise”</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
		<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:

Scenario	Time Type	Value Format	Valid Values	Time Range
Flight Cruise	SCLK	<ssssssssss> (Seconds)	**"0000000000"**, **"0000000001"**, • • • **"9999999999"**	0 thru 9999999999
		<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	ERT	<MMDDHHmmss> (Month, Day-of-month, Hour, Minute, Second)	**"0101010000"**, **"0101010001"**, • •	January 1, 01:00:00 thru



<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td><table>
<tr><td rowspan="2">is reset</td><td rowspan="2"></td><td></td><td>• “1231235959”</td><td>December 31, 23:59:59</td></tr>
<tr><td><aaaaaaaaaa> (Alphabetic)</td><td>“__________” (10 underscores)</td><td>Value is out of range</td></tr>
</table></td></tr>
<tr><td>_</td><td>20 (1, a)</td><td>The valid value formats are as follows:</td></tr>
<tr><td>Milliseconds</td><td>21 (3, i)</td><td>Milliseconds of either the SCLK or UTC.</td></tr>
<tr><td>Product type</td><td>24 (3, a)</td><td>Product identifier. See Table 4-2 for details. This field may be extended to 5 characters in non-imaging EDRs (geometry and thumbnails fields are N/A in these cases).</td></tr>
<tr><td>Geometry</td><td>27 (1, a)</td><td>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.

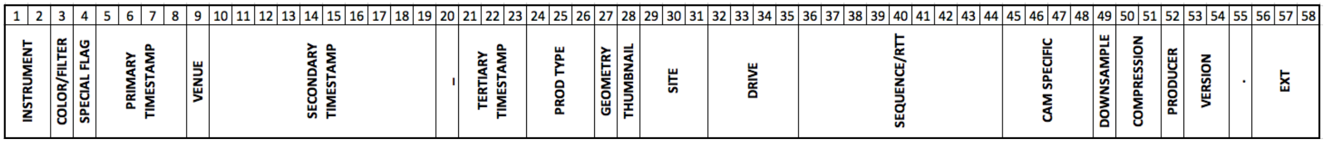
Note that for the “A” case, an image can have multiple stereo partners and the linearized images will be different for each partner. A user will need to look in the ODL/VICAR label to determine which partner was used for linearization.

Note: This field may be subsumed into the product ID field in certain non-imaging EDRs.

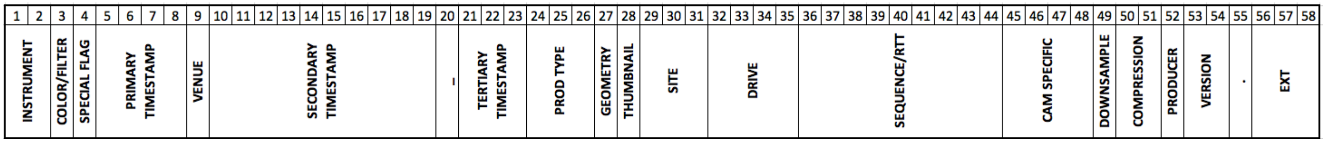
All EDRs are Raw geometry (“_”).</td></tr>
<tr><td>Thumbnail</td><td>28 (1, a)</td><td>Thumbnail flag:
• T : Product is a thumbnail

Note: This field may be subsumed into the product ID field in certain non-imaging EDRs

N : Product is a non-thumbnail (full-frame, sub-frame, downsample)</td></tr>
</table>



<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td>Site</td><td>29 (3, i/a)</td><td>Site identifier (see section X.X on Site frames):
Site location count from the RMC where the data was acquired.
<table>
<tr><th>Values</th><th>Range</th></tr>
<tr><td>000, 001, …, 999</td><td>0 thru 999</td></tr>
<tr><td>A00, A01, …, A99</td><td>1000 thru 1099</td></tr>
<tr><td>B00, B01, …, B99</td><td>1100 thru 1199</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>Z00, Z01, … Z99</td><td>3500 thru 3599</td></tr>
<tr><td>AA0, AA1, …, AA9</td><td>3600 thru 3609</td></tr>
<tr><td>AB0, AB1, …, AB9</td><td>3610 thru 3619</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>ZZ0, ZZ1, …, ZZ9</td><td>10350 thru 10359</td></tr>
<tr><td>AAA, AAB, …, AAZ</td><td>10360 thru 10385</td></tr>
<tr><td>ABA, ABB, …, ABZ</td><td>10386 thru 10411</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>ZZA, ZZB, …, ZZZ</td><td>27910 thru 27935</td></tr>
<tr><td>0AA, 0AB, …, 0AZ</td><td>27936 thru 27961</td></tr>
<tr><td>0BA, 0BB, …, 0BZ</td><td>27962 thru 27987</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>7CA, 7CB, …, 7CZ</td><td>32720 thru 32745</td></tr>
<tr><td>7DA, 7DB, …, 7DV</td><td>32746 thru 32767</td></tr>
<tr><td>_ _ _</td><td>Value out of range</td></tr>
</table></td></tr>
<tr><td>Drive</td><td>32 (4, i/a)</td><td>Drive identifier:
Drive count (position within a Site location) from the RMC where the data was acquired.
<table>
<tr><th>Values</th><th>Range</th></tr>
<tr><td>0000, 0001, …, 9999</td><td>0 thru 9999</td></tr>
</table></td></tr>
</table>

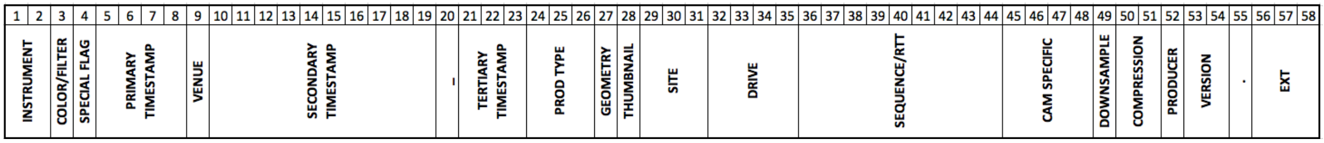


<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>A000, A001, …, A999</td><td>10000 thru 10999</td></tr>
<tr><td>B000, B001, …, B999</td><td>11000 thru 11999</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>Z000, Z001, … Z999</td><td>35000 thru 35999</td></tr>
<tr><td>AA00, AA01, …, AA99</td><td>36000 thru 36099</td></tr>
<tr><td>AB00, AB01, …, AB99</td><td>36100 thru 36199</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>AZ00, AZ01, …, AZ99</td><td>38500 thru 38599</td></tr>
<tr><td>BA00, BA01, …, BA99</td><td>38600 thru 38699</td></tr>
<tr><td>BB00, BB01, …, BB99</td><td>38700 thru 38799</td></tr>
<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 “____” 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>
</table>
</td></tr>
</table>



<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td>
<table>
<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>
<tr><td>L</td><td>Multi-resolution 4x4 (Low-res)</td></tr>
<tr><td>M</td><td>Multi-resolution 2x2 (Med-res)</td></tr>
<tr><td>N</td><td>Multi-resolution 1x1 (No downsample)</td></tr>
</table>

- 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.
- For SHERLOC spectroscopy, fields are "____"

All EDRs are "_".

<table>
<tr><th>Valid values</th><th>Description</th></tr>
<tr><td>_</td><td>Nominal (synchronized) stereo</td></tr>
</table>
</td></tr>
</table>

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

<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>or
No nominal stereo partner</td></tr>
<tr><td>A-Z then 0-9</td><td></td></tr>
</table>

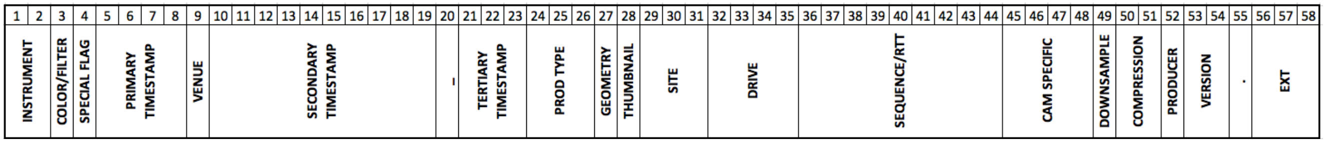
TT: Tile counter (ECAM Tile only). Identifies a unique tile within a reconstructed image. Valid values are 00-99.
ZZZ : Focus value in millimeters (MCZ only). Valid values are 000-999.
_ : Literal underscore. As last character of camera specific field, identifies an ECAM Tile.
0 : Literal zero. Undefined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

Instrument teams with undefined (“0”) fields may define values at a later date.</td></tr>
<tr><td>Downsample</td><td>49 (1, i/a)</td><td>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 x 2^n
<table>
<tr><th>Valid values</th><th>Resolution</th></tr>
<tr><td>0</td><td>1x1</td></tr>
<tr><td>1</td><td>2x2</td></tr>
<tr><td>2</td><td>4x4</td></tr>
<tr><td>3</td><td>8x8</td></tr>
<tr><td>…</td><td>...</td></tr>
</table>
For the case of reconstructed ECAM images, this value represents the highest resolution tile(s) in the reconstructed image (least amount of downsampling).

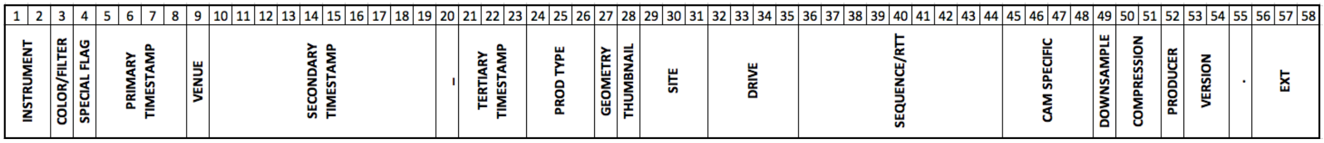
For SHERLOC spectroscopy, field is “_”</td></tr>
</table>



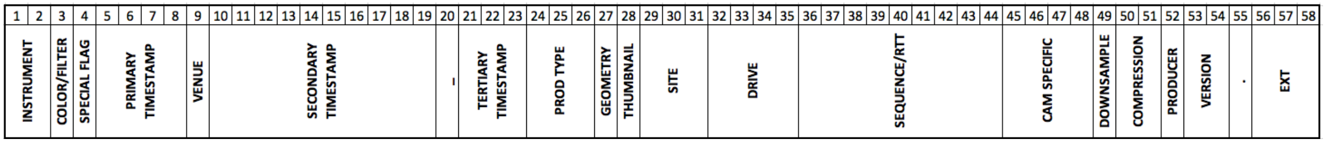
<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td>Compression</td><td>50 (2, i/a)</td><td>
<p>Compression type identifier. This will be “__” in non-imaging modes.</p>
<p>There are several modes of compression available, varying per instrument. The uplink team will 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.</p>
<table>
<tr><th>Type</th><th>Valid values</th><th>Description</th></tr>
<tr><td>JPEG (lossy)</td><td>00
01-99
A0</td><td>Thumbnail
Jpeg quality level
Jpeg quality level 100</td></tr>
<tr><td>ICER (lossy)</td><td>I1, I2, …, I8
I9</td><td>1 bpp, 2 bpp, …, 8 bpp
Anything higher than 8 bpp</td></tr>
<tr><td>Lossless</td><td>LI
LL
LM
LU</td><td>ICER
LOCO
Malin
Uncompressed</td></tr>
</table>
</td></tr>
<tr><td>Producer</td><td>52 (1, a)</td><td>
<p>Identifier for the institution/team that created this product:</p>

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

<table>
<tr><th>Instrument</th><th>PI</th></tr>
<tr><td>ECAM</td><td>JPL</td></tr>
<tr><td>MCZ</td><td>ASU (Tempe, AZ)</td></tr>
<tr><td>SCAM RMI</td><td>IRAP (France)</td></tr>
<tr><td>PIXL MCC</td><td>JPL</td></tr>
<tr><td>SHERLOC</td><td>JPL</td></tr>
<tr><td>MEDA Skycam</td><td>Ministry of Education and Science (Spain)</td></tr>
<tr><td>EDL Cameras</td><td>JPL</td></tr>
</table>
</td></tr>
</table>



<table>
<tr><th>Field</th><th>Position (size, type)</th><th>Description</th></tr>
<tr><td></td><td></td><td><table><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.
TIF : TIFF formatted image file. (no label)
JPG : JPEG formatted image file. (no label)
PNG : PNG formatted image file. (no label)</td></tr>
</table>



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
		• 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 • FITS: SuperCam non-imaging FITS file • CSV: SHERLOC spectroscopic data 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 [Section **Error! Reference source not found.**]. 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 instrument EDR data product complies with Planetary Data System standards for file formats and labels, as specified in the PDS Standards Reference [Section **Error! Reference source not found.**]. 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
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.

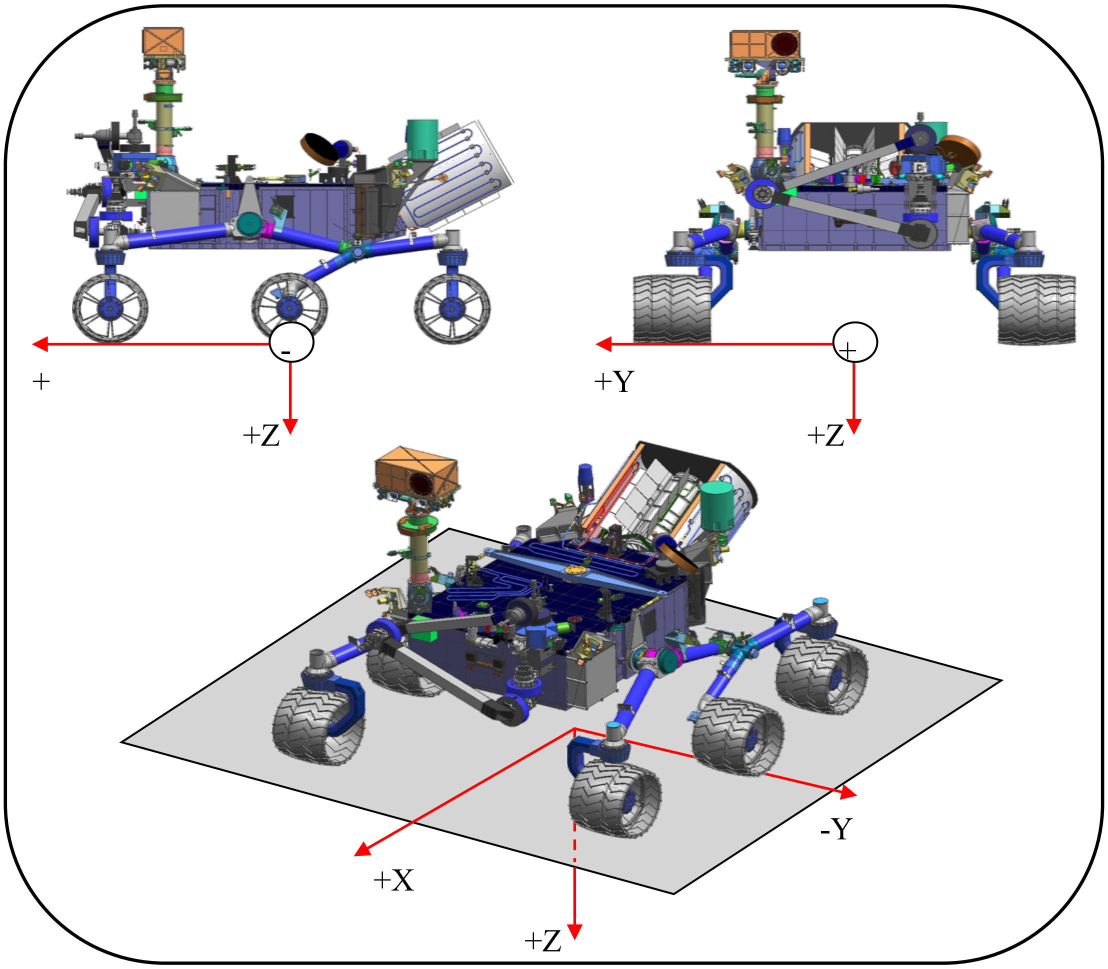
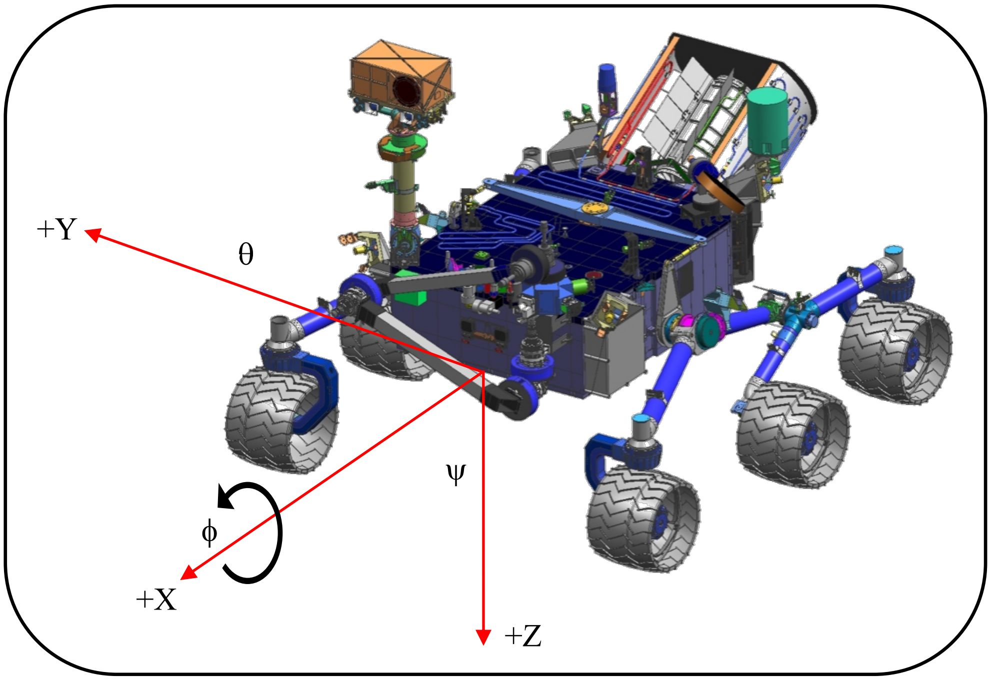


Figure 9 Definition of Rover Nav coordinate frame

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 6.4.1.2, where ψ is heading, θ is attitude or pitch, and ϕ is bank or roll.



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 11.

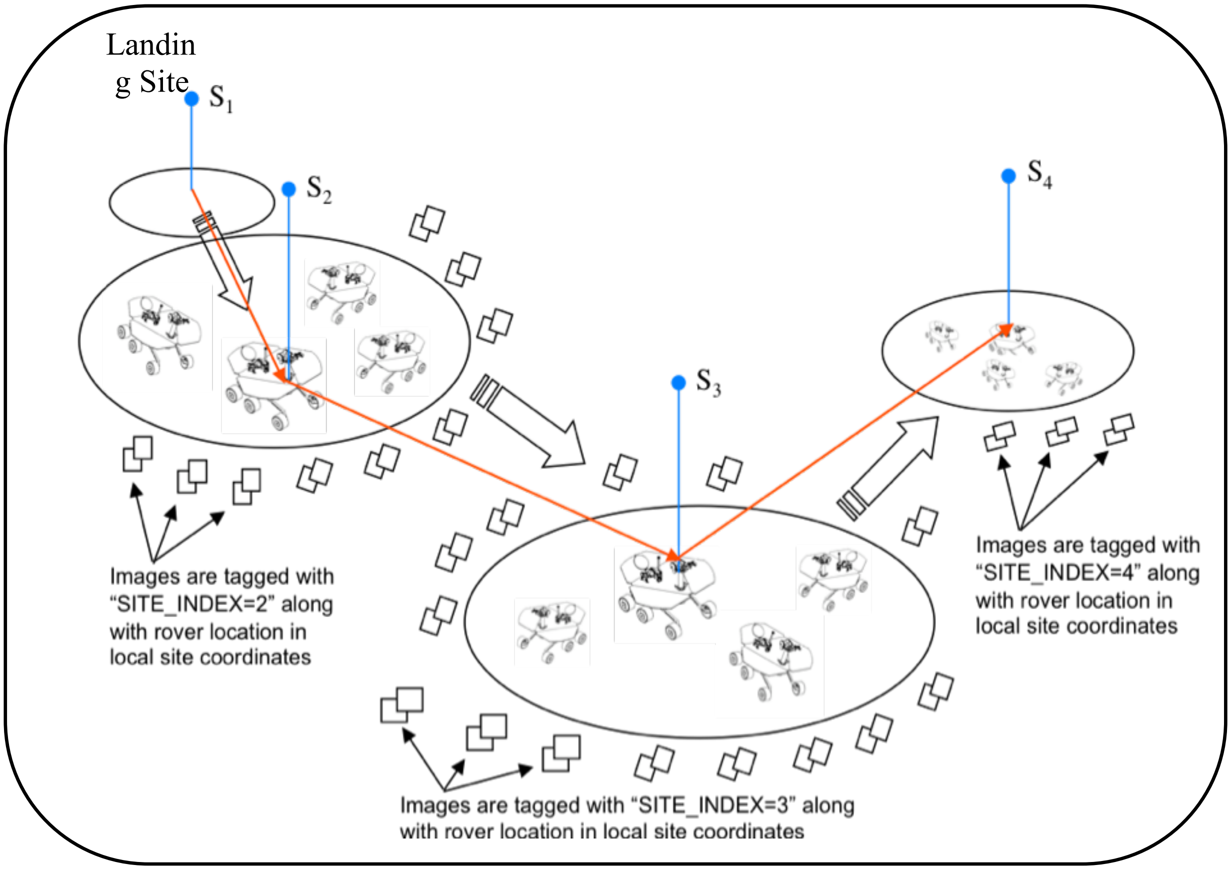


Figure 10 Site Frame definition

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 JPL by the SHERLOC 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 subsytems 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
SHERLOC Ops Software	Specunpack software development is primarily performed at JPL.	Kyle Uckert (JPL)
		Luca Cinquini (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.	Alice Stanboli (JPL / IDS)
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).	Bob Deen (JPL / IDS)

Name	Description	Primary Development Responsibility
	• 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. • 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 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

7 APPENDIX A – Data Product Names for SHERLOC

There are two Cruise and eighteen DPs for Surface Operations identified and these are listed in the table below, see Table Column 2. Table Column 3, to the right of the 'Data Product' column, lists the one level down data structure Part Name or Data Product objectives (DPOs) that constitute within the data product.

Inst. Subsystem	**Phase**	**Data Product**	**Part Name (DPO)**	**Part Name (DPO Structure)**	**Part Type (Byte)**	**Description**
Spectrometer	Cruise	SRLC_SPEC_FAULT	SrlcSpecScidataFrame	header	1-byte unsigned integer	Cruise DP definition
				data		
				checksum		
		SRCL_SPEC_SCIDATA	SrlcSpecScidataFrame	header	1-byte unsigned integer	Cruise DP definition
				data		
				checksum		
	Surface	SRLC_SPEC_DO_BIST	idph_dpo_systemRvrArmRsm			Data product from Instrument DO_BIST I-command, which instructs the C&DH to carry out a built-in self-test (BIST) and transmit all status information, from which the RCE creates a BIST DP.
			srlc_spec_default_ancillary_data			
			do_bist_dpo			
		SRLC_SPEC_DEBUG_INFO	idph_dpo_systemRvrArmRsm			Data product created by the DEBUG_INFO I-command, which allows querying diagnostic state information about the instrument, or current DEA parameter states. This command generates a DEBUG_DIAGNOSTICS data product.
			srlc_spec_default_ancillary_data			
			debug_info_dpo			
		SRLC_SPEC_POWER	idph_dpo_all			Data product created by the same command to manually turns the SHERLOC Spectrometer ON or OFF. When executed, this command creates a SRLC_SOH data products.
			srlc_spec_default_ancillary_data			
			collect_soh_dpo			
			se_collect_soh_dpo			
			scanner_collect_soh_dpo			
		SRLC_SPEC_INIT_SOH	idph_dpl_all			
			srlc_spec_default_ancillary_data			
			collect_soh_dpo			
			se_collect_soh_dpo			
			scanner_collect_soh_dpo			
		SRLC_SPEC_CMD_HISTORY_DUMP	idph_dpo_system			
			srlc_spec_default_ancillary_data			
			cmd_history_dpo			
		SRLC_SPEC_ERROR_LOG_DUMP	idph_dpo_system			
			srlc_spec_default_ancillary_data			
			error_log_dpo			
		SRLC_SPEC_ARGS_DUMP	idph_dpo_system			
			srlc_spec_default_ancillary_data			
			dump_current_args_dpo			
			idph_dpo_system			

		SRLC_SPEC_MEMORY_DUMP	srlc_spec_default_ancillary_data		
			memory_dump_dpo		
		SRLC_SPEC_REGISTER_READ	idph_dpo_system		
			srlc_spec_default_ancillary_data		
			read_registers_dpo		
		SRLC_SPEC_SOH	idph_dpo_all		
			srlc_spec_default_ancillary_data		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
		SRLC_SPEC_DEBUG_DUMP	idph_dpo_all		
			srlc_spec_default_ancillary_data		
			do_bist_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
			debug_info_dpo		
		SRLC_SPEC_SPECTROSCOPY_SOH_ONLY	idph_dpo_all		
			srlc_spec_default_ancillary_data		
			srlc_spec_arguments_dpo_1		
			srlc_spec_parameters_dpo_3		
			srlc_spec_parameters_dpo_4		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
		SRLC_SPEC_SPECTROSCOPY_SOH_RAW	idph_dpo_all		
			srlc_spec_default_ancillary_data		
			srlc_spec_arguments_dpo_1		
			srlc_spec_parameters_dpo_3		
			srlc_spec_parameters_dpo_4		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
			do_point_dpo (multiple?)		
			do_area_dpo (multiple?)		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
		SRLC_SPEC_CAL_SOH_ONLY	idph_dpo_all		
			srlc_spec_default_ancillary_data		
			srlc_spec_arguments_dpo_1		
			srlc_spec_parameters_dpo_3		
			srlc_spec_parameters_dpo_4		
			collect_soh_dpo		

			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
		SRLC_SPEC_CAL_SOH_RAW	idph_dpo_all		
			srlc_spec_default_ancillary_data		
			srlc_spec_arguments_dpo_1		
			srlc_spec_parameters_dpo_3		
			srlc_spec_parameters_dpo_4		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
			do_point_dpo (multiple?)		
			do_area_dpo (multiple?)		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
		SRLC_SPEC_SCAN	idph_dpo_all		
			srlc_spec_default_ancillary_data		
			srlc_spec_arguments_dpo_1		
			srlc_spec_parameters_dpo_3		
			scanner_collect_soh_dpo (multiple entries, up to 3?)		
		SRLC_SPEC_PROCESS_DATA	idph_dpo_system		
			srlc_spec_default_ancillary_data		
			srlc_spec_arguments_dpo_2		
			collect_soh_dpo		
			se_collect_soh_dpo		
			scanner_collect_soh_dpo		
			process_data_dpo (multiple entries?)		
		SRLC_SPEC_UTIL_TEST	idph_dpo_system		
			srlc_spec_default_ancillary_data		
			cmd_frame (multiple)		
			cmdreply_frame (multiple entries?)		
			scidata_frame		

Defined below is SHERLOC spectrometer instrument ancillary data DPOs. These are included for reference purpose only.

Part Name (DPO)	**Part Name (structure of the DPO)**	**Part Name (further structure)**	**Part Type (Byte)**	**Description**
srlc_spec_default_ancillary_data	Instrument_temps	TLM_SBA_DEA_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_SBA_PDU_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_STA_LPS_A_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_STA_LPS_B_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_STA_ACI_AF_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_STA_WAF_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_STA_WCHE_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (Celsius)
		TLM_STA_SCCD_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_STA_SE_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_STA_ACI_CHE_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_STA_SDE_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-40 to +50 Celsius)
		TLM_STA_OB_A_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-80 to +50 Celsius)
		TLM_STA_OB_B_Temp	4-type unsigned integer	Temperature from Thermal module, at time icmd was sent Valid range: (-80 to +50 Celsius)
	Instrument_power	RM_SHERLOC_BA_PDU	Boolean (True or False)	Heater status from power module

		RM_SHERLOC_BA_DEA	Boolean (True or False)	Heater status from power module
		RM_SHERLOC_TA_DECON_HTR	Boolean (True or False)	Heater status from power module
		RM_SHERLOC_TA_SURV_TSTAT	Boolean (True or False)	Heater status from power module
		RM_SHERLOC_TA_SHLC_HTR	Boolean (True or False)	DEA switch status from power module
		RM_SHERLOC_CT_DECON_HTR	Boolean (True or False)	PDU switch status from power module
srlc_spec_arguments_dpo_1	soh_only_priority			
	soh_raw_priority			
	shotsPerSpectra			
	ScannerPosition Type			
	scanMode			
	enableLaser			
	useRankedPosition			
	rankedProcessBufferID			
	offset			
	tableLocation			
	tableSize			
	originAz			
	originEl			
	storeRawForDownlink			
	isCal			
	dataID			
srlc_spec_arguments_dpo_2	priority			
	algorithmID			
	srcProcessBuffer ID			
	destProcessBufferID			
	storeProcForDownlink			
	argument1			
	argument2			
	argument3			
	argument4			
	argument5			
	argument6			
	argument7			
	argument8			
	argument9			
	argument10			
	argument11			
	argument12			
	DataID			
srlc_spec_arguments_dpo_3	El_Home_Min			
	Az_Home_Min			
	El_Home_Max			
	Az_Home_Max			
	El_Home_Cal			
	Az_Home_Cal			

	El_Home_Origin Az_Home_Origin			

8 APPENDIX B – PRODUCT LABEL KEYWORD DEFINITIONS, VALUES, 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_SHERLOC_Labels_sort_pds.pdf
Mars2020_SHERLOC_Labels_sort_pds.html
Mars2020_SHERLOC_Labels_sort_vicar.pdf
Mars2020_SHERLOC_Labels_sort_vicar.html
```

9 APPENDIX C : SHERLOC SDF FORMAT

Field	Num Bytes	Description
Packet header marker	2	0xEBAA – Start of packet header marker.
RCE time sync	4	Last time sync value received from RCE
Data definition version	2	Version of the instrument command dictionary. Defines specifics of the structure of this packet, each command parameter, and the structure of individual data products like SOH.
NV xmit buffer count	4	Non-volatile count of the number of times the generic buffer has been transmitted to the RCE. Acts as a unique identifier for the buffer.
CNDH software version	4	Unique identifier for the software version, is a unix timestamp of when the software was built.
CNDH firmware version	4	Unique identifier for the CNDH firmware version, is a unix timestamp of when the firmware was built.
CNDH hardware identifier	4	Hardware identifier for a specific CNDH board. Used to know which SOH engineering unit conversion factors to apply to the data.
SE firmware version	4	Unique identifier for the SE firmware version, is a unix timestamp of when the firmware was built.
SE hardware identifier	4	Hardware identifier for a specific SE board. Used to know which SOH engineering unit conversion factors to apply to the data.
Reserved 1	4	Not used in the current version. Filled with 0xAAAAAAAA.
Reserved 2	4	Not used in the current version. Filled with 0xBBBBBBBB.
Xmit data ID	4	The data id parameter sent with the XMIT_DATA command
Reserved 3	4	Not used in the current version. Filled with 0's.
Number of segments	4	Number of command or data segments contained in this buffer. Does not include the header section or the trailer section.
Generic data buffer size	4	The number of bytes of the entire generic buffer. Includes commands, data, header, and trailer. Every byte from the packet header marker through the Fletcher checksum.
Data or Command segment marker 1	2	Marker indicating the type of data or command parameters to follow. Valid segment marker values: • DEBUG_INFO 0xEDF7 • DO_BIST 0xEDF4 • DUMP_MEMORY 0xED50 • COLLECT_SOH 0xED52 • READ_REGISTERS 0xED54 • DUMP_COMMAND_HISTORY 0xED58 • DUMP_ERROR_LOG 0xED59 • DUMP_CURRENT_ARGS 0xED5A • PROCESS_DATA 0xED75 (if store argument set) • DO_AREA 0xED80 (if store argument set)

		• DO_POINT 0xED81 (if store argument set) • DO_SPECTRA 0xED83 • SCANNER_COLLECT_SOH 0xED97 • SE_COLLECT_SOH 0xEDA8 • SE_REGISTER_READ 0xEDA9
Millisecond count	4	Number of milliseconds since last time sync value. Indicates when the command arguments or data was added to buffer.
Data length	4	Length of data or command argument values that follow. May be a value of zero if a command has no arguments.
Data	<as req'd>	The actual data or command arguments. Will not exist if data length is zero.
Data or Command segment marker 2 (as needed)	2	Marker indicating the type of data or command parameters to follow.
Millisecond count	4	Number of milliseconds since last time sync value. Indicates when the command or data was added to buffer.
Data length	4	Length of data or command argument values that follow in bytes. May be a value of zero if a command has no arguments.
Data	<as req'd>	The actual data or command arguments. Will not exist if data length is zero.
Packet trailer marker	2	0xEBFF – Start of packet trailer marker.
Millisecond count	4	Number of milliseconds since last time sync value.
Pad length	4	Number of pad bytes added to the buffer to make it 4 byte word aligned. Valid values are 0, 1, 2, and 3
Pad data	<as req'd>	Fill values of 0x00 as needed to 4 byte align the buffer. Will not exist if pad length is zero.
Fletcher checksum	4	Fletcher checksum across all bytes of the data buffer starting with the packet header marker through the pad data bytes. Uses the same calculation as defined for the RCE transfer frame.

9.1.1 Data or Command Segment Marker in Generic SDS Data Structure

A data type marker will be placed at the beginning of each new segment added to the generic buffer. The marker will indicate the type of data or command arguments that will follow. Every two by marker is tightly coupled to the opcodes defined in the command dictionary. When a received command is added to the generic buffer, a marker of “0xECyy” is used where yy is the one byte opcode. Similarly, when data is produced by a command, a marker of “0xEDyy” is used where yy is the one byte opcode.

Two flight commands, NO_OP (0xFE) and FLOW_IN (0xF1) are exceptions and are not recorded in the instrument’s generic data buffer. Similarly, the data product produced by the FLOW_OUT (0xEF) command is an exception and is not captured in the generic data buffer.

The following SHERLOC spectrometer instrument command will generate science data that will be appended to the instrument’s generic data buffer:

- DEBUG_INFO 0xF7

DO_BIST	0xF4	
DUMP_MEMORY	0x50	
COLLECT_SOH	0x52	
READ_REGISTERS	0x54	
DUMP_COMMAND_HISTORY	0x58	
DUMP_ERROR_LOG	0x59	
DUMP_CURRENT_ARGS	0x5A	
PROCESS_DATA	0x75	(if store argument set)
DO_AREA	0x80	(if store argument set)
DO_POINT	0x81	(if store argument set)
DO_SPECTRA	0x83	
SCANNER_COLLECT_SOH	0x97	
SE_COLLECT_SOH	0xA8	
SE_REGISTER_READ	0xA9	

9.1.1.1 Raw Spectra Data Format

For spectra data, the truly raw spectra data generated by a DO_POINT, DO_AREA, or DO_SPECTRA command is marked using the scheme described above. For example, the raw spectrometer data from a DO_POINT command would be marked as 0xED81. The complete data product from one of these commands consists of additional metadata and four separate data types; dark spectra, active spectra, scanner SOH, and photo-diode data. Each of the data types has a separate sub-marker and data length associated with it. The following table describes the raw spectra data layout. The tabular description of spectra, scanner soh, and photo diode data is considered one 'segment' in the overall instrument generic buffer format.

Instrument Generic Buffer – Raw Spectra Format

Field	Num Bytes	Description
Standard segment data marker	2	0xED<opcode> True Raw Spectra Data Opcode: DO_AREA 0xED80 DO_POINT 0xED81 DO_SPECTRA 0xED83
Millisecond count	4	Number of milliseconds since last time sync value. Indicates when the command or data was added to buffer.
Segment data length	4	Length of data that follow for this command response.
Scanner table location	1	Scanner table was used
Scanner table size	2	Commanded value for number of table points to use
Azimuth origin	2	Commanded value for azimuth origin used during scan
Elevation origin	2	Commanded value for elevation origin used during scan
Shots per spectra	4	Commanded value for the number of laser shots per spectra
Number of regions	1	Commanded value for the number of regions
2D mode flag	1	Commanded value = 1 if spectra is 2D
Dark spectra marker	2	0xEE10
Dark spectra size	4	Number of bytes of following dark spectra data
Dark spectra	<as req'd>	The actual dark spectra data
Active spectra marker	2	0xEE11
Active spectra size	4	Number of bytes of following active spectra data
Active spectra	<as req'd>	The actual active spectra data
Scanner SOH marker	2	0xEE12
Scanner SOH size	4	Number of byte of following scanner SOH data
Scanner SOH data	<as req'd>	The actual scanner SOH

Photo diode data marker	2	0xEE13
Photo diode data size	4	Number of bytes of following photodiode data
Photo diode data	<as req'd>	The actual photodiode data

9.1.1.2 Processed Data Format

The SHERLOC spectrometer instrument flight software may also process raw spectra data and produce modified spectra and related data products. Part of the data product will be an array indicating which algorithms were applied to produce the data product, and sub-markers defining each piece of data.

As with other commands that put data into the generic transmit buffer, the processed data will start with the marker 0xED<opcode>. For the PROCESS_DATA command the marker will be 0xED75 and will be immediately followed by the millisecond timestamp and the length of the entire segment.

Instrument Generic Buffer – Processed Data Format

Field	Num Bytes	Description
Segment Data marker	2	0xED75 Processed Data
Millisecond count	4	Number of milliseconds since last time sync value. Indicates when the data was added to buffer.
Segment data length	4	Total length of data that follow.
Table location	1	Commanded value, identifies which scanner table was used during raw acquisition
Table size	2	Number of scanner table locations used, same as number of spectra. Commanded value from DO_*.
Azimuth origin	2	The commanded value for azimuth origin
Elevation origin	2	The commanded value for elevation origin
Number of data items	2	Number of items in the processed data array below. If the data type is normal spectra, this field is the same as table size except for the case of spatial binning.
Spatial location	1	Commanded value identifies which spatial location array was used for spatial binning
Number of regions	1	Commanded value for the number of regions
Processed data type sub-marker	2	Value indicates class of data along with last algorithm applied.
Algorithms applied marker	2	0xEF00
Length of algorithms applied	1	Number of one byte elements in the following array of algorithm identifiers
Array of algorithm id's applied	<as req'd>	Each byte identifies the algorithm applied, the id's are chronological. (max 64)
Processed data marker	2	0xEF01
Length of processed data	4	Number of bytes following of all the processed data items
Processed data	<as req'd>	Array of all the processed data items, usually the array of spectra
Scanner SOH marker	2	0xEF02
Length of scanner soh data	4	Total length of following scanner soh (could be zero)
Scanner soh data	<as req'd>	Array of 16 bit raw scanner soh values
Zone data marker	2	0xEF03
Zone data size	1	Size of zone data, either 0 or 24 bytes
Zone start	<0 or 12>	Array of six values indicating starting positions used in zone specification algorithm, some values may be zero if zone not used. These are not ordered the same way as the command arguments.
Zone stop	<0 or 12>	Array of six values indicating end positions used in zone specification algorithm, some values may be zero if zone not used. These are not ordered the same way as the command arguments.
Zone weight marker	2	0xEF04
Zone weight array size	1	Size of the following zone weight array either 0 or 24 bytes
Zone weight array	< 0 or 24>	Array of FLOATS used with ranking algorithm, for all six zones, started as command parameters to the ranking algorithm
Cosmic ray metadata marker	2	0xEF05
Cosmic ray metadata size	2	Number of bytes to follow for CR metadata (could be zero)

Cosmic ray metadata	<as req'd>	The actual CR metadata. Each entry consists of 12 bytes: 2 byte channel num. 2 bytes spectra num. 4 byte float original intensity, 4 byte float replacement intensity

A. Processed Data Sub-marker and Data Formats

The processed data type sub-marker field describes the kind of data that was the result of the processing and what algorithm produced it. As with the other buffer markers, a two byte field has been used. The first byte indicates the class of data and the second byte indicates the last algorithm that was applied which produced the data. The table below describes the sub-markers.

Instrument Generic Buffer – Processed Data Sub-Marker Format

Data Classification	Classification ID	Last Algorithm Name	Last Algorithm ID	Sub-Marker Value
Spectra	0x00	Active Copy	0	0x0000
Spectra	0x00	Background Subtraction	1	0x0001
Spectra	0x00	Normalize to Laser Energy	2	0x0002
Spectra	0x00	Bad Pixel Removal	5	0x0005
Spectra	0x00	Cosmic Ray Removal	6	0x0006
Spectra	0x00	Zone Specification	7	0x0007
Spectra	0x00	Spatial Binning	9	0x0009
Binned Spectra Sum	0x01	Spectral Binning	8	0x0108
Ranked List	0x02	Ranking	10	0x020A
Raw Photodiode Data	0x03	Dump Raw PD Data	3	0x0303
Summary Photodiode Data	0x04	Dump Summary PD Data	4	0x0404

B. Data Formats within Processed Data Sub-marker

• Processed Data Array Format

If the data in the 'Processed data' field of the buffer is spectra, each value is a four byte float representing channel intensity.

If the data is the result of spectral binning the values are a summation of the channel intensities that were not truncated. The values are four byte floats and there may be up to seven.

If the data is the result of ranking, two values are entered for each spectrum that was analyzed. The first value is a two byte integer indicating the spectra index for the original collection of spectra, and the second value is a floating point number indicating the overall figure of merit calculated for that spectrum.

If the data is photodiode data, the values are two-byte integers. If it is the raw data there will be one value for every laser shot. If it is summary data, there will be one average value for every spectrum.

- **Command and Data Handling (CNDH) SOH Data Format**

The command and data handling SOH collects the SHERLOC spectrometer CNDH-specific state-of-health information. Data size of this data type is 283 bytes.

Part Name (DPO)	**Part Name (Structure of the DPO; can be an array)**	**Part Type (Byte)**	**Description**
collect_soh_dpo	Tlm format version (cmd dict version)	2	
	last BIST result	4	
	current status flag	2	
	boot bank selected	1	
	boot bank actual	1	
	commands received	2	
	commands completed	2	
	commands rejected	2	
	number of error log entries since boot	4	
	Bank A kernel calculated checksum - NV	4	
	bank A application calculated checksum - NV	4	
	bank B kernel calculated checksum - NV	4	
	bank B application calculated checksum - NV	4	
	rce comm side	1	
	spacewire comm error count – NV	4	
	last spacewire error status register	4	
	single bit MRAM memory errors – NV	4	
	single bit SDRAM memory errors – NV	4	
	last single bit memory address	4	
	software version	4	
	PULSES_ID_REG	4	Start of SHERLOC specific FPGA registers
	ROVER_HSS_TX_WD_CNT_REG	4	
	IRQ_CLR_REG	4	
	ROVER_HSS_CNTRL_REG	4	
	ROVER_HSS_TX_REG	4	
	IRQ_EN_REG	4	
	MRAM_CNTRL_REG	4	
	LED_REG	4	
	SCANNER_DAC_REG	4	
	SCANNER_CTL_REG	4	
	RESERVED_1	4	
	RESERVED_2	4	
	COL_STEP_REG	4	
	ROW_STEP_REG	4	
	NSPS_REG	4	
	MODE_REG	4	
	LZR_REP_RATE_REG	4	
	LZR_ON_TIME_REG	4	

	SCN_MOVE_TIME_REG	4	
	NUM_COLS_REG	4	
	SCAN_ORIGIN_REG	4	
	LZR_OFF_TIME_REG	4	
	INTEGRATION_TIME_REG	4	
	SHOTS_PER_SPECTRA_REG	4	
	TEST_CTRL_REG	4	
	RESERVED_3	4	
	RESERVED_4	4	
	RESERVED_5	4	
	RESERVED_6	4	
	RESERVED_7	4	
	RESERVED_8	4	
	NUM_CTRL_REG	4	
	NUM_STATUS_REG	4	
	SCANNER_ADC_REG	4	
	IRQ_STAT_REG	4	
	ROVER_HSS_FRAME_STAT_REG	4	
	TEST_STAT_REG	4	
	IDENTITY_STAT_REG	4	
	TEST2_STAT_REG	4	
	RESERVED_9	4	
	ROVER_HSS_STAT_REG	4	
	RESERVED_10	4	
	CNDH_PCB_TEMP_STAT_REG	4	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: count_value*(0.0547) - 84.179
	CNDH_1_2_V_STAT_REG	4	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: 5.0*count_value/4096.0
	CNDH_5_V_DAC_STAT_REG	4	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: ((10000.0+10000.0)/10000.0)*5.0*count_value/4096.0
	CNDH_3_3_V_STAT_REG	4	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: ((3300.0+10000.0)/10000.0)*(5.0*count_value/4096.0)
	CNDH_5_V_ADC_STAT_REG	4	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: ((10000.0+10000.0)/10000.0)*5.0*count_value/4096.0
	CNDH_NEG_15_V_STAT_REG	4	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: (-1.0)*((47500.0+10000.0)/10000.0)*5.0*count_value/4096.0
	CNDH_15_V_STAT_REG	4	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: ((47500.0+10000.0)/10000.0)*5.0*count_value/4096.0
	CNDH_1_5_V_STAT_REG	4	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: 5.0*count_value/4096.0
	total number spectra read out – NV	4	
	total number of laser shots commanded - NV	4	
	total laser misfire count – NV	4	
	total discrete arc event count – NV	4	
	reserved 1	4	
	reserved 2	4	

- ## Spectrometer Electronics (SE) SOH Data Format

The Spectrometer Electronics SOH collects the SHERLOC spectrometer electronics-specific state-of-health information. The opcode or data marker for SE SOH data type is always “0xEDA8”. Data size of this data type is 124 bytes.

Part Name (DPO)	**Part Name (Structure of the DPO; can be an array)**	**Part Type (Byte)**	**Description**
se_collect_soh_dpo	SE_PULSES_ID_REG	2	
	SE_SKIP1_REG	2	
	SE_SUM1_REG	2	
	SE_SKIP2_REG	2	
	SE_SUM2_REG	2	
	SE_SKIP3_REG	2	
	SE_SUM3_REG	2	
	SE_SKIP4_REG	2	
	SE_SUM4_REG	2	
	SE_SKIP5_REG	2	
	SE_SUM5_REG	2	
	SE_SOH_CNTRL_REG	2	
	SE_LAST_SKIP_REG	2	
	SE_TEST_CTRL_REG	2	
	SE_RESERVED_1	2	
	SE_RESERVED_2	2	
	SE_MODE_REG	2	
	SE_RESERVED_3	2	
	SE_RESERVED_4	2	
	SE_RO_CLK_LIM_REG	2	
	SE_R1_CLK_HI_REG	2	
	SE_R1_CLK_LO_REG	2	
	SE_R2_CLK_HI_REG	2	
	SE_R2_CLK_LO_REG	2	
	SE_R3_CLK_HI_REG	2	
	SE_R3_CLK_LO_REG	2	
	SE_ORST_CLK_HI_REG	2	
	SE_ORST_CLK_LO_REG	2	
	SE_ADC_CLK_HI_REG	2	
	SE_ADC_CLK_LO_REG	2	
	SE_CLAMP_HI_REG	2	
	SE_CLAMP_LO_REG	2	
	SE_VO_CLK_LIM_REG	2	
	SE_V1_CLK_HI_REG	2	
	SE_V1_CLK_LO_REG	2	
	SE_V2_CLK_HI_REG	2	
	SE_V2_CLK_LO_REG	2	
	SE_V3_CLK_HI_REG	2	
	SE_V3_CLK_LO_REG	2	
	SE_RESERVED_5	2	
	SE_RESERVED_6	2	
	SE_TEST_STAT_REG	2	
	SE_CCD_ID_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: n/a
	SE_CCD_TEMP_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: count_value*(0.0547) - 84.179
	SE_PCB_TEMP_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: count_value*(0.0547) - 84.179
	SE_V_1_5_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: 5.0*count_value/4096.0
	SE_LASER_PRT2_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: (0.8885*((count_value*0.00122)**2.0)) + (44.908*(count_value*0.00122)) - 84.063
	SE_LASER_PRT1_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: (0.8885*((count_value*0.00122)**2.0)) + (44.908*(count_value*0.00122)) - 84.063
	SE_LPS_PRT1_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion:

			(0.8885*((count_value*0.00122)**2.0)) + (44.908*(count_value*0.00122)) - 84.063
	SE_RESERVED_7	2	
	SE_TPRB_HOUSING_PRT_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: (0.8885*((count_value*0.00122)**2.0)) + (44.908*(count_value*0.00122)) - 84.063
	SE_LPS_PRT2_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: (0.8885*((count_value*0.00122)**2.0)) + (44.908*(count_value*0.00122)) - 84.063
	SE_SPARE1_PRT_STAT_REG	2	Voltage conversion: 5.0*count_value/4096.0 Engineering Unit conversion: (0.8885*((count_value*0.00122)**2.0)) + (44.908*(count_value*0.00122)) - 84.063
	SE_NOT_CONNECTED_STAT_REG	2	
	SE_RESERVED_8	2	
	SE_LASER_FIRE_CNT_REG	2	
	SE_SOH_STAT_REG	2	
	SE_IDENTITY_REG	2	
	SE_TEST2_STAT_REG	2	
	SE_LASER_SAFETY_CNT_REG	2	
	SE_RESERVED_9	2	
	SE_RESERVED_10	2	
	SE_RESERVED_10	2	

APPENDIX C EDR STRUCTURE TABLE

See included M20_SHERLOC_DPO_Structure_V9.xslx file