SUPERCAM PDS USER GUIDE

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ACRONYMS AND ABBREVIATIONS

AEGIS	Autonomous Exploration for Gathering Increased Science
ASCII	American Standard Code for Information Interchange
AOTF	Acousto-Optic Tunable Filter
ATLO	Assembly, Test, Launch and Operations
AZ	Azimuth
BU	Body Unit
CCD	Charge Coupled Device
CDR	Calibrated Data Record
C&DH	Command and Data Handling
CESR	Centre d'Etude Spatiale des Rayonnements
CNES	Centre National d'Etudes Spatiales
CWL	Continuous Wave Laser
DN	Digital Number
DP	Data Product
DPO	Data Product Object
EDR	Experiment Data Record
EL	Elevation
EM	Engineering Model
EMD	Earth Metadata
FITS	Flexible Image Transport System
FM	Flight Model
FS	Flight System
FWHM	Full Width Half Maximum
GDS	Ground Data System
GSE	Ground Support Equipment
HDR	High Dynamic Range
HDU	Header Data Unit
HSS	High Speed Serial
HVPS	High Voltage Power Supply
ICD	Interface Control Document
i-cmd	Instrument command (command from RCE to SCBU)
IDS	Instrument Data System
IRAP	Institut de Recherche en Astrophysique et Planétologie
IR	InfraRe
IRF	Instrument Response Function
IRS	InfraRed Spectrometer
JPL	Jet Propulsion Laboratory
LANL	Los Alamos National Laboratory
LIBS	Laser-Induced Breakdown Spectroscopy
MIC	SuperCam Microphone
MIPL	Multimission Image Processing Laboratory
MIUL	Materials Identification and Usage List
M2020	Mars 2020

MU	Mast Unit
NACC	Number of Accumulations
NAIF	Navigation and Ancillary Information Facility (for NASA)
OCS	Operations Cloud Store
ODL	Object Description Language
PDS	Planetary Data System (NASA's Planetary Science Archive)
PID	Product ID (EDR type)
PI	Principal Investigator
RCE	Rover Compute Element (Rover computer)
RDR	Reduced Data Record
RMI	Remote Micro-Imager
ROI	Region of Interest
RSM	Remote Sensing Mast
S-cmd	Spacecraft Command
SCBU	SuperCam Body Unit
SCET	Spacecraft Event Time
SCCT	SuperCam Calibration Target
SCLK	Spacecraft Clock
SCMU	SuperCam Mast Unit
SeqID	Sequence Identification Number
SIS	Software Interface Specification
SOH	State of Health
TBC	To Be Confirmed
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Specified
TBU	To Be Updated
TEC	Thermoelectric Cooler
TRLS	Time-resolved fluorescence spectroscopy
TRT	Temperature Requirements Table
TU	Testbed Unit
UV	Ultraviolet
VIO	Violet
VICAR	Video Image Communication And Retrieval
VIS	Visible and Transmission Spectrometer
VISIR	Visible and Infrared Spectrometer
VNIR	Visible to Near InfraRed
XML	eXtended Markup Language

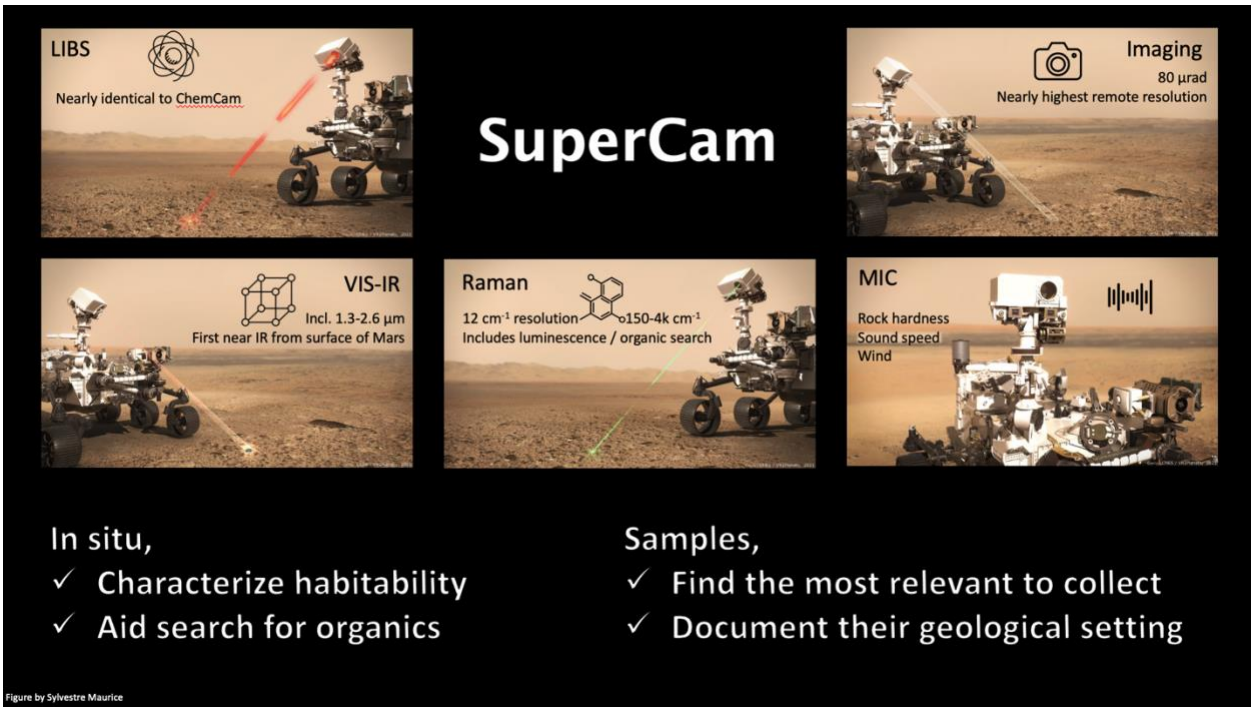
1 Purpose

The purpose of this document is to provide a brief overview of the SuperCam raw data products (Experiment Data Records, or EDRs) and calibrated and derived data products (Reduced Data Records, or RDRs). This document is designed to instruct the user on how to find and access the SuperCam data in order to make basic plots and analyses. It does not explain how to navigate the PDS, nor does it explain how to do high level processing of the data. The detailed data processing for the SuperCam calibrated and derived data products is described in the Wiens, R.C., et al., 2013. [Applicable Document 1].

Several of the derived data products planned for SuperCam have not yet been reviewed and delivered to PDS at the time of the first public release of Mars 2020 data. They will be described in a later version of this document; for the present those sections are marked TBD.

2 Introduction

SuperCam is a remote-sensing instrument that uses remote optical and acoustic measurements, laser spectroscopy, and imaging to determine fine-scale mineralogy, chemistry, and atomic and molecular composition of samples encountered on Mars. SuperCam is, in fact, many instruments in one.



- For measurements of elemental composition, it integrates the remote Laser Induced Breakdown Spectroscopy (LIBS) capabilities of the highly successful ChemCam instrument included in the payload of the Curiosity rover currently exploring Mars. LIBS uses a pulsed laser to investigate targets up to 7 m distance from the rover.

- In addition, SuperCam also performs time-resolved Raman spectroscopy (at 532 nm to investigate targets up to ~7 m distance from the rover), Time-Resolved Luminescence Spectroscopy (TRLS), Visible and InfraRed (VIS, IR) reflectance spectroscopy (400 – 850 nm, 1.3 – 2.6 µm) at a distance in order to provide information about the mineralogy and molecular structure of samples under consideration, as well as being able to search directly for organic materials. SuperCam can also use the VISIR capabilities to study the composition and characteristics of the atmosphere.
- SuperCam also acquires high-resolution images of samples under study using a color remote micro-imager (RMI). The RMI images provide the morphological context for the spectral observations at a scale at which the LIBS, Raman, TRLS, and VISIR footprints can be spatially resolved.
- SuperCam also includes a microphone, which is used primarily to measure the pressure wave produced by the generation of plasma at a LIBS target. The microphone can also be used standalone to study wind or other phenomena.

Each of these SuperCam techniques will produce a different raw data file (EDR) and processed data file (RDR).

2.1 LIBS Data Overview

This technique uses the mast unit LIBS laser beam to generate plasma clouds from target rocks, analyzing the resultant emissions with the body unit spectrometers to provide insight into the chemical makeup of the target rock. Single point observations as well as rasters made up of a collection of points will be achievable in this observation mode. The standard LIBS analysis is 30 laser enabled shots. SuperCam also use the spectrometers to collect background light from the environment without the laser, using the same exposure duration. These "LIBS darks" are subtracted from the active LIBS spectra as part of the data processing. Darks will be taken just before, just after, or before and after the active collection. Typically, 30 darks will be averaged for better statistics; this can be done onboard to save data volume. Dark (i.e. no laser) spectra are subtracted from the laser-active spectra to remove instrument noise or background.

2.2 RAMAN and TRLS Overview

SuperCam Raman spectroscopy uses 532 nm green Raman laser beam to induce inelastic Raman scattering in a material where shifts in the scattered light are related to material properties, such as molecular bonds that can be used to determine mineralogical composition. Single point observations as well as rasters will be achievable in this observation mode. The Raman spectral range is 535-853nm (105-~7070 cm-1 Raman shift) with 12 cm-1 full-width at half-maximum peak resolution. For Raman spectroscopy, with its weak signal, the light from multiple laser pulses can be collected on a single exposure and co-added on board. For example, firing 100 laser pulses and collecting 10 spectra of 10 pulses each (ten one-second exposures at 10 Hz) to avoid saturation. Raman darks will also be taken either just before or just after the active exposures. Dark (i.e. no laser) spectra are subtracted from the laser-active spectra to remove instrument noise or background.

The hardware used for Raman spectroscopy also enables time-resolved luminescence spectroscopy (TRLS). The SuperCam time-resolved luminescence experiment is designed to operate by collecting spectra at variable delay times, where delay refers to the time between firing the green laser and triggering the intensifier. A typical TRLS analysis on Mars will likely consist of either a single time delay to determine if luminescence is present or up to five different time delays if luminescence is expected. No-laser "dark" spectra will also be taken either just before or just after the active exposures. Dark (i.e. no laser) spectra are subtracted from the laser-active spectra to remove instrument noise or background.

2.3 VISIR Data Overview

Using the infrared spectrometer on the Mast Unit, the VIO reflection spectrometer and the transmission spectrometer on the body unit, reflected sunlight from the targets is collected and analyzed. The objective of VISIR is the identification of minerals. The transmission spectrometer is set to low gain and an exposure time in the tens to hundreds of microseconds. The IR spectrometer operates by scanning of an AOTF (Acousto-Optic Tunable Filter) across the wavelengths from 1.3-2.6 microns. The exposure times are estimated based on the time of day and the type of target, either through an autoexposure algorithm or by manually selecting a given exposure time. The exposure time can vary as a function of wavelength. Dark exposures are collected as a separate observation using non-illuminated rows in the VIO spectrometer and low gain and the minimum gate time for the transmission spectrometer regions. Dark measurements are interleaved between each wavelength for the IR spectrometer. Dark (i.e. no laser) spectra are subtracted from the laser-active spectra to remove instrument noise or background. Referring to the circular diagram in Fig. 6, compositions can be determined from mineral characterization techniques. Specifically from the VIS spectral range (400-850 nm), the oxidation state of iron affects the reflectance curve in this spectral range.

2.4 RMI Data Overview

The SuperCam RMI uses the mast unit camera to take high-resolution color images of Mars. In this mode the square FOV of the instrument telescope is used to collect light from the environment and is captured in the mast unit 2048×2048 pixel CMOS device. The RMI data are beyond the scope of this document and are instead discussed in the M2020_EDR_Camera_SIS (D-99960). RMI spatial scale is calculated from pixel scale and distance to the target.

2.5 Microphone Data Overview

Using the mast-unit-mounted microphone (MIC), SuperCam will record the LIBS plasma generation acoustic signatures, to determine quantity of material ablated from Martian rocks. It will also be possible to make Martian and rover sound recordings for maximum recording duration of 167 seconds at 25 kHz and 41 seconds at 100 kHz.

3 Applicable Documents

1. Pre-flight calibration and initial data processing for the ChemCam laser-induced breakdown spectroscopy instrument on the Mars Science Laboratory rover, Spectrochimica Acta Part B: Atomic Spectroscopy, Volume 82, 2013, doi:10.1016/j.sab.2013.02.003.
2. Mars 2020 Rover Mission (M2020) Software Interface Specification: SuperCam Instrument Experiment Data Record (EDR) and Reduced Data Record (CDR, RDR) Data Products for Non-Imaging Components, JPL D-99966, January 19, 2021.
3. Mars 2020 (M2020) Software Interface Specification: Camera Instrument Data Products, JPL D-99960, December 21, 2020.
4. Wiens, R.C., Maurice, S., Robinson, S.H. *et al.* The SuperCam Instrument Suite on the NASA Mars 2020 Rover: Body Unit and Combined System Tests. *Space Sci Rev* **217,** 4 (2021). https://doi.org/10.1007/s11214-020-00777-5
5. Maurice, S., Wiens, R.C., Bernardi, P. *et al.* The SuperCam Instrument Suite on the Mars 2020 Rover: Science Objectives and Mast-Unit Description. *Space Sci Rev* **217,** 47 (2021). https://doi.org/10.1007/s11214-021-00807-w

4 PDS Location

The SuperCam EDRs and RDRs are archived together in one PDS bundle. The bundle's PDS Logical Identifier (LID) is **urn:nasa:pds:mars2020_supercam**.
The EDRs are archived in three collections, data_raw_audio, data_raw_rmi, and data_raw_spectra. Users will most likely be interested in all spectra on a specific target or point no matter what technique has been used to collect the data, so all spectra EDRs are located in the data_raw_spectra collection.
The RDRs are archived in six collections: data_calibrated_audio, data_calibrated_spectra, data_radcal_rmi, data_derived_spectra, data_special_rmi, data_observation_log.

The bundle may be located online using the PDS search tools at https://pds.nasa.gov/datasearch/data-search/, or directly on the PDS Geosciences Node web site at https://pds-geosciences.wustl.edu/missions/mars2020/supercam.htm.

5 Experiment Data Records (EDRs)

The M2020 instrument EDRs will be generated by JPL's Multimission Instrument Processing Laboratory (MIPL) under the IDS subsystem of the M2020 Ground Data System (GDS) element. A formal detailed description of the products and how they are generated is in the SuperCam Experiment Data Record (EDR) and Reduced Data Record (RDR) Software Interface Specification (SIS) Document, in the document collection of the SuperCam archive bundle [Applicable Document 2].
The EDRs consists of unprocessed experiment data stored in FITS binary format. The EDR structures vary depending on the technique being used: LIBS, RAMAN, TRLS, VIS, IR,

Microphone, RMI. Each EDR product is described by a PDS label in a separate file with the same name but with the extension "xml", and also contains embedded metadata. Engineering-only activities (such as Autofocus, Mast-Unit-Power-On, etc., as listed in Table 1 and Table 2) also have associated EDRs. The XML keywords are described in Appendix D.

SuperCam collects LIBS spectra across 5 spectral ranges: Ultraviolet (UV; 245- 340 nm), Violet (VIO; 385-465 nm), Green (534-625 nm), Orange (613-722 nm), and Red (718-853 nm). The Green, Orange, and Red spectra are concatenated into a continuous VNIR spectrum (536-853 nm) which is characterized by a transmission spectrometer. The amount of data generated is:

2148 x 5 = 10740 channels, spectral range 243.5 – 853nm

The RAMAN and TRLS techniques use the transmission spectrometer and generate three sets of spectral data. The amount of data generated is:

2148 x 3 = 6444 channels, spectral range 535 – 853nm (105-~7070 cm-1 Raman shift)

The VIS technique uses the VIO spectrometer and the transmission spectrometer and generates four sets of spectral data. The amount of data generated is:

2148 x 4 = 8592 channels, spectral range 382.1 – 853nm

The IR spectrometer has 256 channels or 256 wavelength steps.

The RMI images are 2048 x 2048 pixels, 16 bits.

The microphone is capable of recording an audio signal for up to 3.5 minutes at 20 kHz.

5.1 EDR Filename Convention

The SuperCam EDR filename follows the naming convention used for all Mars 2020 data products. The filename consists of 59 characters, including the extension, grouped into fields that help identify and classify the data product. Table 1 shows the file name components specific to SuperCam. A more general description of all the fields in the filename is in the EDR/RDR SIS [Applicable Document 2].

Table 1. SuperCam EDR File Naming Scheme

Field	Contents	Description
1-2	LS	Instrument
3	_	Color Filter - Not used for SuperCam non-imaging EDR so default is underscore '_'
4	_	Special Processing flag, applicable to RDRs only. EDRs always have "_".

5-8	Sol number	Primary timestamp
9	_	Venue "_" : Flight (surface or cruise)
10-19	SCLK	Secondary time stamp: Spacecraft clock count, whole number of seconds
20	_	Underscore for readability. Always set to "_"
21-23	SCLK fraction	Spacecraft clock count, fractional seconds
24-26	Product type	SuperCam EDR product type.
27	_	Geometry "_" : raw geometry
28	_	Thumbnail. Not used for non-imaging so default is "_"
29-31	Site	Site location count from the RMC where the data was acquired.
32-35	Drive	Drive count (position within a Site location) from the RMC where the data was acquired.
36-44	Sequence	Sequence-ID : Identifier indicating the command sequenced the image was acquired from. Specific values will be assigned by the uplink team
45	_	Camera specific identifier. Not used for non-imaging so default is "_"
46-48	Point number	Point number in raster, or 001 for single point
49	_	Downsample resolution. This will be "_" in non-imaging ED
50-51	__	Compression. This will be "__" in non-imaging modes
52	P	Producer – Principal investigator of instrument
53-54	Version	Version number
55	.	Separator for filename and extension. Always set to "."
56-59	fits	Extension

Example SuperCam EDR filename:
`ls__0088_0674752882_228el1__0040048scam01088_001_luj01.fits`

The EDR filename has a three-character field (characters 24-26) that is provided to identify the technique and product type of the data. The following sections list the three-character identifications for each SuperCam measurement technique. In these lists, "Actives" refers to active laser shots. "Darks" refers to measurements of background light without laser activation. "All actives/darks" means all shots are collected. "Stats" means that, out of a series of collects, only statistics are collected (pixel-by-pixel mean, median and standard deviation). The non-nominal product type is a place holder for data that cannot be formatted as expected.

5.1.1 LIBS Product Types

- EL0: LIBS all actives / all darks
- EL1: LIBS all actives / dark stats
- EL2: LIBS active stats / dark stats

- EL3: LIBS all actives / no darks
- EL4: LIBS active stats / no darks
- EL5: LIBS no actives / all darks
- EL6: LIBS no actives / dark stats
- EL9: LIBS 2D
- ELS: Non-nominal

5.1.2 RAMAN Product Types

- ER0: RAMAN all actives / all darks
- ER1: RAMAN all actives / dark stats
- ER2: RAMAN active stats / dark stats
- ER3: RAMAN all actives / no darks
- ER4: RAMAN active stats / no darks
- ER5: RAMAN no actives / all darks
- ER6: RAMAN no actives / dark stats
- ER9: RAMAN 2D
- ERS: Non-nominal

5.1.3 TRLS Product Types

- ET0: TRLS all actives / all darks
- ET1: TRLS all actives / dark stats
- ET2: TRLS active stats / dark stats
- ET3: TRLS all actives / no darks
- ET4: TRLS active stats / no darks
- ET5: TRLS no actives / all darks
- ET6: TRLS no actives / dark stats
- ET9: TRLS 2D
- ETS: Non-nominal

5.1.4 PASSIVE (VIS and IR) Product Types

- EP0: VIS All shots
- EP1: VIS Stats
- EP2: IRSpec
- EP3: Double VIS (Dark and Active Spectra)
- EP4: IRScan
- EP9: VIS 2D
- EPS: Non-nominal

5.1.5 Audio (microphone) Product Types

- EA0: LIBS-sync
- EA1: LIBS-Continuous
- EA2: Standalone

5.1.6 Autofocus Product Types

- EF0: RMI-AutoFocus
- EF1: CWL-AutoFocus

5.1.7 State of Health (SOH) Product Types

- ESF: SuperCam Fault (ScamFault)

- EBMD: SuperCam Body Unit Memory Dump (ScamBuMemDump)
- EMMD: SuperCam Mast Unit Memory Dump (ScamMuMemDump)
- EDD: SuperCam Debug Dump (ScamDebugDump)
- ESH: SuperCam State of Health (ScamSoh)
- ESU: SuperCam Util Test (ScamUtilTest)
- EBP1: SuperCam Body Unit Power On (ScamBuSohPowerOn)
- EBP0: SuperCam Body Unit Power Off (ScamBuSohPowerOff)
- EMP1: SuperCam Mast Unit Power On (ScamMuSohPowerOn)
- EMP0: SuperCam Mast Unit Power Off (ScamMuSohPowerOff)
- EBT1: SuperCam Body Unit Thermal On (ScamBuSohThermalOn)
- EBT0: SuperCam Body Unit Thermal Off (ScamBuSohThermalOff)
- EMT1: SuperCam Mast Unit Thermal On (ScamMuSohThermalOn)
- EMT0: SuperCam Mast Unit Thermal Off (ScamMuSohThermalOff)
- ESS: SuperCam Sun Safe (ScamSohSunSafe)
- ESP: SuperCam Point (ScamPoint)

5.2 FITS Format

The file format for SuperCam EDRs and RDRs is FITS (Flexible Image Transport System). FITS is a flexible portable file standard that allows data to be structured in an efficient way. It is widely used in astronomy and there exist a number of tools that allow their contents to be read. A FITS file can contain a number of partitions (called HDU for Header & Data Unit), each one divided into a "header" and a "data" section. The header is made of several ASCII "cards" (records) that contain a key (8-digit, alphanumeric), a value (numeric, literal or Boolean) and a comment section. These header objects contain information about the format of the data object, such as the number of records (rows) and number of fields (columns) as well as the data type of the field. The data section is very flexible: it can contain ASCII tables, binary tables, and images. For a thorough description of the FITS format, see https://fits.gsfc.nasa.gov.

FITS file may be read with any of several free, publicly available software packages. Some are listed at https://fits.gsfc.nasa.gov. However, It is not necessary to use FITS software to read SuperCam data products. The PDS label that accompanies each product includes all the relevant metadata for the product, and also describes each component of the FITS data file in terms of byte offset, length in bytes, data type, and structure of the table or image. PDS labels are text files written XML which can be viewed in a text editor or web browser, and read by software. Software to read PDS-labeled data is available from the PDS Tools web page (https://pds.nasa.gov/tools/about/) and the Tool Registry (https://pds.nasa.gov/tools/tool-registry/). The PDS4 Viewer is a standalone program that can display PDS-labeled images and tables (https://sbnwiki.astro.umd.edu/wiki/PDS4_Viewer).

5.3 EDR Structure

The EDR FITS structure varies depending on which kind of data it contains. The following table lists the content of the HDUs for each product type. More details are found in the EDR/RDR SIS [Applicable Document 2].

Table 2. SuperCam EDR FITS Header & Data Unit (HDU) contents for each type of activity

		Science product (Clean Data Record – EDR)							
	Activity	LIBS	RAMAN	TRLS	VIS	IRSpec	Micro	RMI	RMI JPG
	Activity tag	EL[0-6,S]	ER[0-6,S]	ET[0-6,S]	EP[0,1,S]	EP2	EA[0-2]	LRE*EC*	LRF*EJP
HDU #	HDU section	Content							
0	Header	Generic Header, Status Flags, Activity keywords, Data Processing Keywords							
1	Data	ODL Label							
2	Data	Timeline (I-cmds and arguments)							
3	Data	MU SOH							
4	Data	BU SOH							
5	Data	Laser Data	Laser Data	Laser Data	Empty	IRS Spectel SOH	Empty HDU	Red	Red
6	Data	Darks Before	Darks Before	Darks Before	VIS spectra	Spectra	Time series	Green 1	Green
7	Data	Actives	Actives	Actives		Empty HDU		Green 2	Blue
8	Data	Darks After	Darks After	Darks After		Scan SOH		Blue	

5.3.1 HDUs Common To All SuperCam EDR FITS files

HDUs 0 through 4 are present in all SuperCam FITS files. They are described in the following sections. See Appendix A for examples of all HDUs.

HDU 0 (Primary HDU)

Historically, the primary HDU of a FITS file is reserved for an image and for the primary header. This primary header contains a list of key cards (name-value-description). Because of the specificity of the SuperCam data files, the data section of this HDU is kept empty.

HDU 1 ODL Label

The data section of HDU 1 contains an exact copy of the ODL (Object Description Language) label produced by IDS for each EDR and used during mission operations. It is stored as a stream of ASCII text. The metadata encoded in the ODL label is also present in the detached PDS label.

HDU 2 Timeline

The data in HDU 2 contains the timeline of the filling of the generic buffer with commands and command replies. This data is stored in the form of a FITS binary table that contains the following columns.

- ms_since_last_sync (double) : this specifies the offset in milliseconds at which the command was sent (or command reply received) since the last RSYNC, specified in the primary header in the keyword RCE_SYNC (in epoch).

- cmd_name (string): the command name according to the SuperCam command dictionary.
- opcode (string): the command opcode
- type (string): can be *cmd* (command)*, data, spectra*.
- data_length (double): specifies the length of the data (or command arguments, or spectra array) that followed the opcode in the generic buffer.
- args (string): contains a string representation of the Python dictionary containing the command arguments to that command. Dictionary is empty in case type = data or type = spectra .
- data (string): contains a string representation of the hex values of the command replies. In case the data is reported elsewhere (spectra, replies of MU_SEND_HOUSEKEEPINGS, MU_RECORD_SOUND, COLLECT_SOH, MU_TAKE_IR_SPECTRUM, MU_SEND_LASER_DATA), this field points to the corresponding HDU.

HDU 3 Mast Unit SOH

HDU 3 contains the command reply to MU_SEND_HOUSEKEEPINGS command. Each SOH (according to the command dictionary) is reported in one separate column.
The column order is the following:

- 27 numeric SOH in their raw integer values
- 24 digital SOH in their Boolean values
- Millisecond offset sync the last sync of the command reply.
- 27 numeric SOH converted to physical units using the appropriate transfer functions.

HDU 4 Body Unit SOH

HDU 4 contains the command reply to COLLECT_SOH command. Each SOH (according to the command dictionary) is reported in one separate column.
The column order is the following:

- 83 numeric SOH in their raw integer values
- Millisecond offset sync the last sync of the command reply.
- 29 numeric SOH converted to physical units using the appropriate transfer functions.

5.3.2 Technique-Specific HDUs

HDUs 5 to 10 are specific to the SuperCam science module or technique that has been used to obtain the data. See Table 2 for the contents of each type. For example, a LIBS EDR file contains Laser Data, Darks Before, Actives, and Darks After HDUs. The non-image HDUs are described in the following sections, and the HDUs for image products are described in the Camera SIS [Applicable Document 3]. See Appendix A for examples.

HDU 5 Laser Data

A table of the laser data. One row for each laser shot. The columns are Shot Number, Stack voltage Raw, Pumping Current Raw, Optical Power Raw, Stack voltage (Volts), Pumping Current (Amps), Optical Power (mJ). The laser data is used to monitor the SOH of the laser.

HDU 5 IRS Spectel SOH (IRSpec only)

A table of the IR House keeping values. One row for each spectel (256). The columns are Detector Temperature, RF Power and Status. If spectel not used then value in column is 0.

HDU 5 Red (RMI and RMI JPG)

Raw red pixels 1024 x 1024.

HDU 6 Darks Before

A table of the dark spectra data (non laser) collected. One row for each pixel (6444). The columns are either one column for the DN value for each shot if all shots recorded or statistics values, mean, median and standard deviation of all shots, if statistics recorded. This table may be empty depending on if darks were collected before the actives.

HDU 6 VIS Spectra (VIS only)

A table of the VIS spectra data collected. One row for each pixel. The columns are either one column for the DN value for each shot if all shots recorded or statistics values, mean, median and standard deviation of all shots, if statistics recorded.

HDU 6 Spectra (IRSpec only)

A table of the raw IR spectra data. One row for each spectel. There are six columns: DN (Raw digitized detector signal), Radiance (signal converted in radiance using the surface ITF), I_F (TBD),I_F_Atm (TBD), F_sky (TBD), AtmTrans (TBD). If spectel not used then value in column is 0. I_F, I_F_Atm, F_sky and AtmTrans are currently set to NaN and may be subject to change in future releases.

HDU 6 Time Series (Microphone only)

A table specific to the microphone data. A measurement of frequency vs time. The "SOUND" HDU of a microphone recording hosts each sample of the microphone acquisition, calibrated into Pa. The sound is sampled at the frequency specified in the primary header key MIC_SAMP (25000 or 100000 Hz), and its duration is in the key MIC_DURA (in seconds). CA2 files correspond to passive continuous recordings, intended to listen a sound source indicated in the key TargetName. In the case of CA1 files, the recording covers a LIBS burst of n shots (n being the number of shots indicated in the key XXX), continuously from the first to the last shot. The target name is indicated by the key XXX. For the pulsed mic (CA0) the microphone records the LIBS-induced acoustic signal of a LIBS burst over 60ms long time widows thanks to a synchronization between the microphone and the laser ignition (see instrument papers). The time series corresponds to the concatenation of n-1 windows, n being the number of shots indicated in the key XXX. The last shot of the burst is not recorded.

HDU 6 Green 1 (RMI only)

Raw green pixels 1024 x 1024.

HDU 6 Green (RMI JPG only)

Raw green pixels 1024 x 1024.

HDU 7 Actives

A table of the active spectra data (with laser) collected. One row for each pixel. The columns are either one column for the DN value for each shot if all shots recorded or statistics values, mean median and standard deviation of all shots, if statistics recorded.

HDU 7 Green 2 (RMI only)

Raw green pixels 1024 x 1024.

HDU 7 Blue (RMI JPG only)

Raw blue pixels 1024 x 1024.

HDU 8 Darks After

A table of the dark data (non laser) collected. One row for each pixel. The columns are either one column for the DN value for each shot if all shots recorded or statistics values, mean, median and standard deviation of all shots, if statistics recorded. This table may be empty depending on if darks were collected after the actives.

HDU 8 Scan SOH (IRSpec only)

(Currently not implemented.)

HDU 8 Blue (RMI only)

Raw blue pixels 1024 x 1024.

5.4 Target Name

The filename for the SuperCam EDRs does not contain the target name, and the target name is not in the meta data. To assist the user in identifying the target for a particular file, there is a M2020_SCAM_masterlist.csv file in the data_observation_log collection, that will contain the EDR filename as well as several other fields of information related to contents of the EDR data file, including the target name.

5.5 Software and Tools

FITS is a standard library used in astronomy allowing to structure complex data in an efficient way in multiple header-and-data units (HDUs). In origin, it was meant to store only one image and metadata, but its use has been extended and now it is used for all sorts of data. FITS can be read by many viewers, and most high-level programming language have ready-to-use libraries (astrolib for IDL, astropy for python, ...). A suggested fits file viewers is QFitsView (https://www.mpe.mpg.de/~ott/QFitsView/) which allows to browse each HDU and each entry of the FITS. Another tool is fv (https://heasarc.gsfc.nasa.gov/docs/software/ftools/fv/). The

NASA page https://fits.gsfc.nasa.gov/fits_viewer.html shows a number of other tools although some of them deal with the original scope of FITS (one image and header in the first header).

PDS also provides several tools for viewing.
PDS4 Viewer: A general read-in and visualization GUI tool for PDS4 data, runs on multiple platforms. (http://sbndev.astro.umd.edu/wiki/PDS4_Viewer). Note: The .xml file rather than the .fits file is what should be opened and that they both need to be in the same directory.

6 Reduced Data Records (RDRs)

Reduced Data Record (RDR) is a catchall term that refers to any data product to which higher level processing has been applied; that is, all products except EDRs. SuperCam RDRs include Calibrated Data Records (CDRs) and Derived Data Records (DDRs).

6.1 CDR (Calibrated Data Record)

The file format for CDRs is FITS. In fact, the CDR FITS structure is very similar to that of the EDRs. The data section in HDUs 0-4 of a CDR is an exact copy of the EDR and is reported for consistency. The Primary header also contains a copy of all the key words of the EDR primary header, but adds some keywords specific to the data processing that was performed on the science data. Finally, HDU 5 and above contain the processed data, and (as for the EDRs) are specific to each technique. Each RDR data file is described in a separate file with the same base name but with the extension “xml”.

6.1.1 CDR Filename Convention

The SuperCam CDR filename will capture many elements of the EDR filename. An important addition to the CDR filename will be the target name (name of the target of observation). This will be a maximum 20 character entry with ‘_’ (underscore) to pad the filename if the target is less than 20 characters. If the target name is longer than 20 characters it is truncated in the filename.

Table 3a. SuperCam CDR File Naming Scheme (except microphone)

Field	Contents	Description
1-4	SCAM	Instrument
5	_	Underscore for readability
6-9	Sol number	Sol (Martian day)
10	_	Underscore for readability
11-20	SCLK	Spacecraft clock count, whole number of seconds

21	_	Underscore for readability
22-24	SCLK fraction	Spacecraft clock count, fractional seconds
25	_	Underscore for readability
26-28	Product type	SuperCam CDR product type.
29	_	Underscore for readability
30-38	Sequence	Sequence number
39	_	Underscore for readability
40-59	Target name	Name of target of observation, padded with underscores if needed
60	_	Underscore for readability
61-62	Point number	Point number in raster, or 01 for single point
63	P	Producer: "P" for Principal Investigator
64-65	Version	Version number
66-70	.fits	Extension

Example CDR Filename:
SCAM_0298_0625300815_526_CR0_SCAM15219_TargetName20charslen_01P01.fits

As with the EDR filename, the SuperCam CDR filename has a three-character field (characters 26-28) that identifies the technique and product type of the data. The following sections list the three-character identifications for each SuperCam measurement technique (product type).

6.1.1.1 LIBS Product Types

- CL0: LIBS all actives / all darks
- CL1: LIBS all actives / dark stats
- CL2: LIBS active stats / dark stats
- CL3: LIBS all actives / no darks
- CL4: LIBS active stats / no darks
- CL5: LIBS no actives / all darks
- CL6: LIBS no actives / dark stats

6.1.1.2 RAMAN Product Types

- CR0: RAMAN all actives / all darks
- CR1: RAMAN all actives / dark stats
- CR2: RAMAN active stats / dark stats
- CR3: RAMAN all actives / no darks
- CR4: RAMAN active stats / no darks
- CR5: RAMAN no actives / all darks
- CR6: RAMAN no actives / dark stats

6.1.1.3 TRLS Product Types

- CT0: TRLS all actives / all darks
- CT1: TRLS all actives / dark stats
- CT2: TRLS active stats / dark stats
- CT3: TRLS all actives / no darks
- CT4: TRLS active stats / no darks
- CT5: TRLS no actives / all darks
- CT6: TRLS no actives / dark stats

6.1.1.4 PASSIVE (VIS and IR) Product Types

- CP0: VIS multiple spectra (but no dark subtraction)
- CP1: VIS Statistics only (but no dark subtraction)
- CP2: IRSpec: single spectrum
- CP3: VIS multiple or statistics (including dark subtraction)
- CP4: IRScan: multiple IR spectra acquisition in the same product.

6.1.1.5 Audio (microphone) Product Types

- CA0: LIBS-sync
- CA1: LIBS-Continuous
- CA2: Standalone

6.1.1.6 Autofocus Product Types

- CF0: RMI-AutoFocus
- CF1: CWL-AutoFocus

6.1.1.7 RMI Product Types

- CI_: RMI Color Image
- CZ_: RMI Z-Stack
- CH_: RMI HDR

The SuperCam Microphone wav file will have a different filename format. (Table 3b)

Table 3b. SuperCam Microphone CDR File Naming Scheme

Field	Contents	Description
1-5	ASCAM	Instrument
6	_	Underscore for readability
7-13	Sol number	Sol (Martian day) preceded by “SOL”
14	_	Underscore for readability
15-24	SCLK	Spacecraft clock count, whole number of seconds
25	_	Underscore for readability

26-28	SCLK fraction	Spacecraft clock count, fractional seconds
29	_	Underscore for readability
30-32	Product type	SuperCam CDR product type.
33	_	Underscore for readability
34-42	Sequence	Sequence number
43	_	Underscore for readability
44-63	Target name	Name of target of observation, padded with underscores if needed
64	_	Underscore for readability
65-66	Point number	Point number in raster, or 01 for single point
67	P	Producer: "P" for Principal Investigator
68-69	Version	Version number
70-73	.wav	Extension

Example Microphone wav Filename:
ASCAM_SOL0092_0675108131_916_CA0_scam03092_Neeznaa_scam_____10P01.wav

6.1.2 CDR Processing

Processing is different for each SuperCam technique, as described in this section. More detail on each processing step that is common to several techniques can be found in Appendix E.

6.1.2.1 LIBS Processing (CDR)

The data processing for LIBS benefits from the experience on ChemCam. In many aspects, the ChemCam data reduction and calibration pipeline can be adapted to SuperCam's LIBS spectra. The main steps of data processing and calibration that have been defined by the team are the following:

- **Saturation Check**. If the raw DN for the channel exceeds 64500 counts
- **Dark subtraction**. The mean of the dark spectra in the EDR are subtracted from each active spectrum in the EDR.
- **Computation of Statistics. (if shot to shot)** Calculate mean, median and standard deviation of all spectra.
- **Stitching of the spectral bands in the VNIR range.** The three parts of the VNIR spectrometer (a.k.a. green, orange and red) will be merged, selecting the best signal-to-noise vs resolution compromise.
- **Denoise.** A wavelet transform algorithm developed by Olivier Forni is applied to each spectrum.
- **Wavelength calibration**. A pattern-recognition algorithm developed by team members has been tested on ChemCam data. A similar algorithm will be used to SuperCam data.

Currently the wavelength calibration is preliminary, and based on Ti data collected during ATLO.

- **Correction for the Instrument Response function**. Conversion from counts to photons.
- **Continuum removal.** Wavelet transform algorithm developed by the team.
- **Convert Photons-to-radiance**.

Final data range after processing for LIBS data is 7933 x number of shots.

6.1.2.2 Raman Processing (CDRs)

The data processing for RAMAN that have been defined by the team are the following:

- **Saturation Check**. If the raw DN for the channel exceeds 64500 counts
- **Dark subtraction**. The mean of the dark spectra in the EDR are subtracted from each active spectrum in the EDR.
- **Computation of Statistics. (if shot to shot)** Calculate mean, median and standard deviation of all spectra.
- **Stitching of the spectral bands in the VNIR range.** The three parts of the VNIR spectrometer (a.k.a. green, orange and red) will be merged, selecting the best signal-to-noise vs resolution compromise.
- **Denoise.** A wavelet transform algorithm developed by Olivier Forni is applied to each spectrum.
- **Wavelength calibration**. Wavelength calibration for Raman will be done using LIBS on the calibration targets. For Raman, this will be converted to Raman shift in wavenumbers. (1/wavelength in cm e.g. cm^-1 or 1/cm). Currently the wavelength calibration is preliminary and based on Ti data collected during ATLO. The calibration targets (e.g. diamond) will eventually be used to ensure that the calibration is accurate.
- **Correction for the Instrument Response function**. Conversion from counts to photons.
- **Despiking of data.** The Raman spectra from SuperCam present a relatively high number of spikes and peaks that are not related to Raman emissions of the analyzed samples, but to detector effects and/or cosmic rays impacting the detector or the camera intensifier, including negative peaks, which occur when dark spectra that contain intensity spikes from cosmic rays or hot pixels are subtracted from the active spectra. The SuperCam team has implemented a despiking algorithm for the detection, identification and removal of these spikes. These consist in the statistical removal of spikes from the individual actives and darks by comparing pixel intensities with respect to the median of all the spectra, removing spikes appearing randomly on the data (cosmic ray removal). Additionally, the dark-subtracted spectrum is despiked by performing a sigma-clipping algorithm in the mean and median spectra (stats).

Final data range after processing for RAMAN data is 3888 x number of spectra.

The reported positions for the Raman data are indicated based on the maximum peak position in the region, without making any curve fitting to provide a more accurate peak center, so these should be considered as approximated positions. As such, it is advisable to use these assignments cautiously. For example, the olivine doublet reported positions in some cases might not be directly applicable to existing models to calculate the Fo/Fa ratio (these are indicated with an * in the Raman data table annex).

Many of the Raman spectra obtained by SuperCam show a bump in low wavenumbers that is not listed as a Raman feature. This bump is due to the Raman emission caused by the laser on the SuperCam optical fiber, which is a well-known issue that will be corrected in future releases to the PDS. The Raman features related to the fiber bump consist on a large asymmetric band between ~200 and ~530 cm^{-1} with a relatively narrow feature at ~490 cm^{-1}, followed by wide lower-intensity bands at ~605, ~825 and ~1050 cm^{-1}. Other issues to note are, typical coadd-to-coadd spectra (ten shots per coadd) on diamond shows that SCAM Raman data has a maximum shift between coadds of 1 pixel, i.e. <2.2 cm-1 at 1330 cm-1, which could be considered as a first approximation of the typical uncertainty of the peak positions. This inaccuracy can be due to several factors, of which the laser wavelength stability with temperature could be one; another factor is the intensity noise of the instrument -related to the shot-to-shot variability expected from a pulsed excitation Raman instrument, with very low Raman intensity per shot, and there might be others. Furthermore, in low-SNR spectra, the spectral noise could increase this uncertainty to higher values in several cm-1.

6.1.2.3 TRLS Processing (CDRs)

The data processing for TRLS that have been defined by the team are the following:

- **Saturation Check**. If the raw DN for the channel exceeds 64500 counts
- **Dark subtraction**. The mean of the dark spectra in the EDR are subtracted from each active spectrum in the EDR.
- **Computation of Statistics. (if shot to shot)** Calculate mean, median and standard deviation of all spectra.
- **Stitching of the spectral bands in the VNIR range.** The three parts of the VNIR spectrometer (a.k.a. green, orange and red) will be merged, selecting the best signal-to-noise vs resolution compromise.
- **Denoise.** A wavelet transform algorithm developed by Olivier Forni is applied to each spectrum.
- **Wavelength calibration**. Wavelength calibration for TRLS will be done using LIBS on the calibration targets. TRLS data will be provided in wavelength (nm) and will use the LIBS wavelength calibration.
- **Correction for the Instrument Response function**. Conversion from counts to photons.

Final data range after processing for TRLS data is 3888 x number of sweeps or iterations.

6.1.2.4 VIS Processing (CDRs)

The data processing for VIS that have been defined by the team are the following:

- **Saturation Check**. If the raw DN for the channel exceeds 64500 counts
- **Dark Subtraction (in DN)**
- **Conversion to Radiance**
- **Conversion to reflectance** by division by a reference (Sol 20 or Sol 184 depending on the instrument's settings) and by scaling the geometry of the illumination: multiplication by the ratio of the cosines of the solar incidence and by the ratio of the squares of the Mars-to-Sun distance. The sol 20 collect used 70 rows of the detector to integrate the "red" part of the spectra, while the sol-184 used 200 rows. They have been chosen because of their good signal-to-noise ratio. The calibration pipeline for a VIS dataset use the reference spectrum that uses the same number of rows.

Final data range after processing for VIS data is 5925 x number of shots but are usually collected as statistics so data range will be 5925 x 3 (mean, median, standard deviation)

6.1.2.5 IRS Processing (CDRs)

The flight calibration pipeline follows several steps to remove every instrumental contributions from science data. The data processing for IRS that have been defined by the team are the following:

- **Saturation check.** Check If the raw DN for the channel exceeds 60000 counts
- **Dark smoothing** to only keep the low frequency trend (Savitzky-Golay algorithm), assuming that high frequencies consist of noise and readout spikes;
- **Dark subtraction**
- **Radiometric calibration** using ITF_{20} (Sol 20 White SCCT measurement as reference) data is converted into radiance - this is in a column in HDU 6 of the CDR;
- **Thermal calibration.** A correction vector to the ITF is derived from a model and the actual temperature of the IR electronic board and applied to reflectance data. It corrects the dependence of the instrument's response to the RF power shift due to IR board temperature variations.
- **Glitch removal.** Glitches are EMI/EMC artifacts from an unknown origin, randomly occurring as signal decrease on individual spectral channels. They are related to RF power perturbations which affect the AOTF diffraction efficiency. Glitches are removed by detection on RF power measurements and interpolation to undisturbed neighboring spectral channels;
- **Spikes removal.** Spikes occur on both Signal and Dark measurements, as random negative or positive peaks several times above the noise level. They are statistically detected, using a 3 σ filter and removed like the glitches.

- **Conversion to reflectance.** Radiance data is divided by a solar spectrum calculated through an illumination model, taking into account the geometry and time of the observation. Corrected reflectance is given as a column (I_F) in HDU 6 of the CDR;
- **Atmospheric correction.** Reflectance data is corrected from the atmospheric (mainly CO2) absorption features by maximizing the correlation with a reference spectrum fitted to the actual column density. Atmospheric correction spectrum is given as a column (I_F_Atm) in HDU 6 of the CDR.

6.1.2.6 Microphone Processing (CDRs)

The Microphone CDRs are located in the data_calibrated_audio collection. The data processing for the Microphone have been defined by the team are the following:

- **Conversion DN to volt**
- **Conversion Volt to pascal**
- **Mean signal subtraction**

6.1.2.7 RMI Processing (CDRs)

The RMI CDRs are located in the data_radcal_rmi collection. The RMI CDRs are Partially radiometrically corrected. The data processing steps for RMI that have been defined by the team are the following:

- **Demosaicing (if input is Bayer filter).** Convert Bayer's input (2048x2048 RGGB channel) to a 2048x2048 image for each of the RGB channel. This is done using the Malvar algorithm.
- **Crop out-of-field pixels.** MA mask with a radius of 468 pixels and centered in x=512, y=520 is applied, so that any pixel outside this mask is set to 0.
- **White Balance.** The RGB channels are corrected using this scaling factors: [1, 0.781, 0.797] to achieve a good white balance, based on the first white paint observations performed on Mars.
- **Flatfield correction.** Each plane is corrected by "vignetting effect" using a preliminary flat field image observed during the ground testing. This is being improved as we obtained more Mars data.

NOTE: For dark subtraction for all spectra products, the mean dark spectrum is computed by averaging all darks (this is done either on board, or during the data processing pipeline), then this dark is then subtracted by each "active" spectrum.

6.1.3 CDR Structure

The main file format for CDRs is FITS. Some additional information about the data processing parameters, the pipeline and some quality checks will be added to each section. Successive HDUs will contain data specific for each analysis. The following table lists the content of each HDU.

Table 4. SuperCam CDR FITS Header & Data Unit (HDU) contents for each type of activity

		Science product (Clean Data Record – CDR)						
	Activity	LIBS	RAMAN	TRLS	VIS	IRSpec	Micro	RMI
	Activity tag	CL[0-6,S]	CR[0-6,S]	CT[0-6,S]	CP[0,1,S]	CP2	CA[0-2]	CI
HDU #	HDU section	Content						
0	Header	Generic Header, Status Flags, Activity keywords, Data Processing Keywords						
1	Data	ODL Label						
2	Data	Timeline (I-cmds and arguments)						
3	Data	MU SOH						
4	Data	BU SOH						
5	Data	Laser Data	Laser Data	Laser Data	Empty	IRS Spectel SOH	Laser Data/Empty HDU	Red
6	Data	Shot-to-shot spectra	Shot-to-shot spectra	Delay Spectra	Shot-to-shot spectra	Spectra	Time series	Green
7	Data	Statistics spectra	Statistics spectra	Statistics spectra	Statistics spectra	Wavelength	Saturation Mask	Blue
8	Data	Wavelength	Wavelength	Wavelength	Wavelength	IRS Acquisition SOH		
9	Data	Saturation Mask	Saturation Mask	Saturation Mask	Saturation Mask	Data Quality		
10					Shot-to-shot reflectance spectra			
11					Stastistics reflectance spectra			

NOTE: Delay spectra means multiple spectra each taken at a different delay relative to the laser, for the purpose of time resolution of luminescence data. Shot-to-shot means multiple spectra per laser burst.HDUs Common To All SuperCam CDR FITS Files

HDU 0 or primary header contains a list of key cards (name-value-description), mainly, activity keywords and Data Processing Keywords. HDUs 1 through 4 in a SuperCam CDR are copied from the EDR product used to generate the CDR. They are as described above in section 5.3.1.

6.1.3.1 Technique-Specific HDUs

HDUs 5 to 9 are specific to the SuperCam science module that has been used to obtain the data. See Table 4 for the contents of each type. For example, a Raman RDR file contains Laser Data, Shot-to-shot Spectra, Statistics Spectra, Wavelength, and Saturation HDUs. The non-image

HDUs are described in the following sections, and the HDUs for image products are described in the Camera SIS [Applicable Document 3]. See Appendix B for examples.

HDU 5 - Laser Data

A table of the laser data. One row for each laser shot. The columns are Shot Number, Stack voltage Raw, Pumping Current Raw, Optical Power Raw, Stack voltage (Volts), Pumping Current (Amps), Optical Power (mJ).

HDU 5 - IRS Acquisition SOH

A table of IRS state of health values. The columns are table acquisition number, Analog integration time value, power offset of the AOTF driver, nacc offset, AOTF initial temperature, configuration of the measurement (DET_SEL, MEAS_MODE), measurement initial temperature, IRS TEC setpoint, AOTF final temperature, TEC hot side temperature, IR board temperature, Detector selected, IRS mode (SPECTRUM or SCAN).

HDU 5 – Red

A table of the partially radiometrically corrected images red pixels 2048 x 2048.

HDU 6 – Shot-to-shot Spectra / Spectra

A table of the processed calibrated spectra data. The columns are either one column for radiance value for each shot if all shots recorded. One row for each pixel.

HDU 6 – Delay Spectra

A table specific to TRLS. One row for each pixel. The columns are for each spectra taken or sweep.

HDU 6 – Spectra

A table specific to the IRS spectrometer. One row for each spectel. The columns are DN, Radiance, Reflectance, I_F Atm Reflectance, Reference Spectra used to compute reflectance, and Atmosphere corrected radiance (Rad_Atm_corr).

HDU 6 – Time Series

A table specific to the microphone data. A measurement of frequency vs time. The "SOUND" HDU of a microphone recording hosts each sample of the microphone acquisition. In the case of a continuous recording (CA1 and CA2 files), the sound is sampled at the frequency specified in the primary header key MIC_SAMP (25000 or 100000 Hz), and its duration is in the key MIC_DURA (in seconds). For the pulsed mic (CA0) it is the concatenation of each of the 60-msec recordings at a frequency of MIC_SAMP around each laser pulse. The pulsed microphone synchronization is described in the instrument papers.

HDU 6 – Green

A table of the partially radiometrically corrected image green pixels 2048 x 2048.

HDU 7 – Statistics Spectra

A table of the mean, median and standard deviation of all shots in the shot-to-shot spectra table.

HDU 7 – Wavelength (IRSpec only)

A table specific to IRSpec data one row for each spectel and two columns, one for the wavelength at the center of each spectel, corrected for AOTF temperature dependence, and one for Full width half maximum of the AOTF line spread function.

HDU 7 – Saturation Mask (Microphone only)

A table of logical expressions, TRUE or FALSE, to indicate if data has reached saturation level (>64500 DN). One row for each wavelength. The columns are either one column for each shot if all shots recorded or statistics values, mean, median and standard deviation of all shots, if statistics recorded.

HDU 7 – Blue

A table of the partially radiometrically corrected image blue pixels 2048 x 2048.

HDU 8 – Wavelength (LIBS,TRLS,VIS)

A table to indicate the wavelength and instrument response function(IRF) for each pixel. The wavelength is a mapping of CCD pixels to the expected wavelength of light incident on that pixel. Stored as a 16 bit signed floating point number. The IRF maps the number of photons incident on the telescope aperture to an expected signal recorded by the CCD. It is in units of "photons/DN" where DN is Digital Number, which is just another name for "CCD counts."

HDU 8 – Wavelength (RAMAN)

A table to indicate the wavenumber and the instrument response function (IRF) for each pixel. The Wavenumber is Raman Shift (cm^-1), which represent the difference between the incident laser frequency and the scattered frequency. The IRF maps the number of photons incident on the telescope aperture to an expected signal recorded by the CCD. It is in units of "photons/DN" where DN is Digital Number, which is just another name for "CCD counts."

HDU 8 – IRS Acquisition SOH

A table of IRS state of health values. The columns are table acquisition number, Analog integration time value, power offset of the AOTF driver, nacc offset, AOTF initial temperature, configuration of the measurement (DET_SEL, MEAS_MODE), measurement initial temperature, IRS TEC setpoint, AOTF final temperature, TEC hot side temperature, IR board temperature, Detector selected, IRS mode (SPECTRUM or SCAN).

HDU 9 – Saturation(LIBS,RAMAN,TRLS,VIS)

A table of logical expressions, TRUE or FALSE, to indicate if data has reached saturation level (>64500 DN). One row for each wavelength. The columns are either one column for each shot if all shots recorded or statistics values, mean, median and standard deviation of all shots, if statistics recorded.

HDU 9 – Data Quality (IRSpec)

For the IRSpec data this table indicates data quality. One row for each spectel. There are four columns: Saturation, Glitch, Spike and StDev. The values for Saturation, Glitch and Spike are set to 1 for True, 0 for False, NaN if a particular spectel was not used in that particular observation. The StDev is the Standard Deviation of the I_F spectrum.
Glitches are identified where there is an RF Power Offset. IRSpec that have glitches may be reprocessed at a later date.

HDU 10 – Shot-to-shot Reflectance Spectra (VIS)

A table of the processed calibrated spectra data for VIS. The columns represent the reflectance value for all the spectra recorded (HDU6). One row for each pixel.

HDU 11 – Statistics Reflectance Spectra (VIS)

A table of the mean, median and standard deviation of all shots in the shot-to-shot spectra table (as HDU7) but in units of reflectance.

6.2 DDR (Derived Data Record)

The file format for DDRs varies depending on the technique. Not all techniques will have a derived data record. Each DDR will have a different filename convention.

6.2.1 LIBS DDR

LIBS Elemental Abundances

SuperCam uses laser-induced breakdown spectroscopy (LIBS) to obtain semi-quantitative elemental abundances from rasters of small (300–600 µm in diameter) observation points at distances of 2-7 m. Results are currently obtained for oxides of the major elements: SiO_2, TiO_2, Al_2O_3, FeO_T (total iron content assessed as FeO), MgO, CaO, Na_2O, K_2O, and the totals of these elements, all given as weight percent (wt%). Quantitative chemistry is based on multivariate statistical models trained on laboratory spectra of a suite of diverse, well-characterized reference samples, collected on the flight body unit coupled to the engineering qualification model of the SuperCam mast unit. This suite of spectra and corresponding known compositions are available in the file libs_spectral_library_reference.csv in the calibration_supercam collection (https://pds-geosciences.wustl.edu/m2020/urn-nasa-pds-mars2020_supercam/calibration_supercam/libs_spectral_library_reference.csv). The file also includes metadata indicating which samples were used as training and test sets for each of the major elements, which were excluded as outliers, and information about the geologic type and origin of the samples. For details about data preprocessing and multivariate model selection, as well as known limitations of the current calibration, please refer to Anderson et al., 2021 (https://doi.org/10.1016/j.sab.2021.106347).

A brief description of the data processing is as follows:

Laboratory data are masked to remove noisy portions of the spectra, and then the values from each spectrometer are normalized to the total signal from the spectrometer, so that the full spectrum sums to 5. In some cases, "peak binning" is applied prior to normalization. This binning uses the average training set spectrum to define local minima and maxima, and then each individual spectrum is summed between local minima, with the resulting values assigned the wavelength of the corresponding local maximum. This reduces the size of the spectra, consolidates signal from weak/broad lines, and increases robustness to wavelength shifts. In some cases, the spectra are also standardized: each spectral channel is mean-centered and scaled by the standard deviation. This reduces the influence of the strongest lines and amplifies the influence of weaker lines, resulting in improved results in some cases.

For each major element, the laboratory data were subdivided into five folds, with similar distribution of compositions ensured by sorting on the composition of interest prior to fold assignment. All spectra of the same target were included in the same fold. One fold was held out as an independent test set, the remaining four folds were used for model cross validation and optimization. A variety of multivariate regression models were evaluated, including Ordinary Least Squares (OLS), Partial Least Squares (PLS), Least Absolute Shrinkage and Selection Operator (LASSO), Orthogonal Matching Pursuit (OMP), Least Angle Regression (LARS), Support Vector Regression (SVR), Elastic Net, Gradient Boosting Regression (GBR), Random Forest Regression (RF). All of these methods were implemented using the scikit-learn library. In addition, Local Elastic Net and blended submodel regression were used. These methods were implemented via the Python Hyperspectral Analysis Tool (PyHAT). Each model was optimized by selecting the parameters that minimized the Root Mean Squared Error of Cross Validation (RMSECV). Final models were then chosen based on the accuracy when predicting the independent test set (Root Mean Squared Error of Prediction; RMSEP), as well as performance when obtaining the derived abundances of the SuperCam calibration targets, and through assessment of initial abundances of Mars targets.

For SiO2, the derived abundances are an average of the results of GBR and PLS models. For TiO2, RF was the most accurate model. For Al2O3, the reported compositions are an average of the abundances derived from RF, two different implementations of PLS, and Local Elastic Net. For FeOT and CaO, RF was the most accurate model. For MgO and Na2O, GBR was the most accurate model. For K2O, the reported compositions are an average of Elastic Net, SVR, Local Elastic Net, LASSO, and PLS results.

The table of results is organized with each average spectrum as a row, and abundances of each major element oxide as columns. An additional column for each major element contains the standard deviation of the derived abundances of that element for each of the individual laser shots on that location. This standard deviation helps to identify points with increased variation between shots, which may indicate changes in composition with laser ablation depth. Above the results, the Minimum, First quartile, Median, Third quartile, and Maximum value of the training set for each major element oxide are listed. These are useful for evaluating whether a derived composition exceeds the range over which the multivariate model is expected to be reliable. It is the nature of many multivariate models that they do not extrapolate beyond the training set range very well, so an abundance approaching or exceeding the training set maximum value may indicate a higher true composition. The best estimate of the accuracy is the RMSEP; this is listed

above the abundances of each major element oxide. At the right-hand side of the table, the "Total" column lists the sum of major element oxides. The abundances are not normalized to 100 wt.%, so this value can vary. Low totals can indicate that a target contains significant amounts of un-quantified elements (e.g. sulfur, hydrogen, etc.) A final column lists the total emission of the spectrum prior to normalization. This can be used to assess the quality of the spectrum: low signal may indicate a poor-quality spectrum (though users should visually inspect spectra as well).

6.2.2 RAMAN DDR

Raman Features:
The Raman Derived Data file is a table of features with columns for summary of findings, number of features identified and then a column for raman shift(s) of that feature, id of feature, potential minerals observed and confidence of the identification. This list only shows the data that has identifiable features. By identifiable features, we mean all those Raman features that are related to the sample itself. These are identified by the SuperCam Raman experts by evaluating the relative intensity of the features with respect to the noise and spectrum background, by checking that the width corresponds to values as expected from Raman features from SuperCam and by evaluating the presence of the feature in the multiple shots that are acquired per point. The Raman derived data product is a csv file in the data_derived_spectra collection of the SuperCam bundle with the name supercam_raman.csv. Also included is an xml PDS4 label with the same base name and an extension of ".xml".

The CSV file contains the following fields: (all fields are ASCII string except Number of Features).

File: PDS Logical Identifier for CDR referenced
Target: Martian target name
Summary: summary of detections on the sample, and any other comments. Motivation of feature identification for low confidence features.
Number_of_features: number of Raman features detected on the spectra.
Then, for each feature there are the following fields, repeated Number_of_features times:
Feature1_RamanShift: Raman shift in which Feature 1 is found in wavenumbers (cm-1)
Feature1_ID: Assignment and or identification of the feature
Feature1_PotentialMinerals: Potential minerals related to the feature
Feature1_Confidence: confidence of the identification. It can be low, medium or high.

The Feature Confidence Level is a qualitative parameter obtained as a combined assessment made by the SuperCam team. This assessment is based upon the experience gained by the analysis and study of SCAM representative spectra both on Mars and on laboratory setups, relying also on the analysis of factors such as signal to noise ratios and peak position. Additionally, it also takes into account information from other techniques, e.g. LIBS and VISIR, and imagery (these other data are not necessarily from the exact same position the Raman spectrum of interest were taken and is instead made on a higher level).

6.2.3 TRLS DDR

(TBD) for part 2 of review

6.2.4 VIS DDR

The VIS CDR now are both in units of Radiance and Reflectance (cf. section 6.1.2.4, VIS processing). Further processing of the VIS and by-products of the VIS CDRs are under investigation by the team.

6.2.5 IRS DDR

(TBD) for part 2 of review

6.2.6 RMI Mosaic DDR (data_special_rmi)

The RMI Mosaic derived RDR or DRD, is file composed of one or more RMI images of the same target region or sequence. SuperCam also provides a fused mosaic without shot annotation. The format of the RMI mosaic DDRs is a png file. If the mosaic is documentation of a SuperCam science observation it may contain markers indicating location of science observation points, as well as a key to indicate the SuperCam technique used. The RMI mosaic may also be just image of land scape or region. The product and RMI records contained in the png are described in a separate PDS4 xml label with the same base name and an extension of ".xml". The filename convention is described in the following table:

Table 5. SuperCam RMI Mosaic File Naming Scheme

Field	Contents	Description
1-5	ASCAM	Instrument
6	_	Underscore for readability
7-13	Sol number	Sol (Martian day) preceded by "SOL"
14	_	Underscore for readability
15-23	Sequence	Sequence number
24	_	Underscore for readability
25-27	MOS	Mosaic tag
28	_	Underscore for readability
29-32	FR08	Resolution and bit scale (Full resolution 8 bit)
33	_	Underscore for readability
34-36	Image order	AFT = Last image on top or FUS = Fused.
37	_	Underscore for readability
38-40	RGB	RGB color model Image enhancement
41	_	Underscore for readability
42	L	Indicated LIBS science product

43	R or V	R = Raman V= VIO+TRANS
44	I	Indicates IR spectrometer science product
45	_	Underscore for readability
46-65	Target name	Name of target of observation, padded with underscores if needed (20 characters) or truncated if filename longer than 20 characters
66	_	Underscore for readability
67	P	Producer : "P" for Principal Investigator
68-69	Version	Version number
70-73	.png	Extension

Example RMI Mosaic Filename:

```
ASCAM_SOL0092_scam02092_MOS_FR08_AFT_RGB_L___Naadiin_scam_________P01.png
ASCAM_SOL0092_scam02092_MOS_FR08_FUS_RGB_L___Naadiin_scam_________P01.png
```

Fused Mosaic processing steps:

1. Place the image centres
2. Each image is associated with a 2D apodized (~gaussian) weight function, in which the weight is 0 at the edge of the RMI and maximum in the center.
3. The intensity of each pixel (x,y,color) in the final mosaic is calculated as [I1(x,y,color) * w1(x,y,color) + I2(x,y,color)* w2(x,y,color) + …] / [w1+w2+w3]

6.2.7 RMI with Mastcam Mosaic DDR

(TBD) for part 2 of review

6.2.8 Master Target DDR

The master target DDR is an observation log of the SuperCam science data product targets. It includes information like sol, sequence number, EDR filename, CDR filename, target name, distance to the target, etc. This file is contained in the data_observation_log collection. The file is a comma-separated values file. The file name is M2020_SCAM_MASTERLIST.CSV. The product and fields are described in a separate PDS4 xml label with the same base name and an extension of ".xml".

6.3 Calibration Data

The SuperCam Calibration data used for generating the SuperCam LIBS derived data is contained in the calibration_supercam collection. The format of the data file is the same as the surface libs spectra. The files are fits format and are accompanied by a PDS4 xml label. The quantitative chemistry reported in the LIBS derived spectra, is based on multivariate statistical models trained on laboratory spectra of a suite of diverse, well-characterized reference samples,

collected on the flight body unit coupled to the engineering qualification model of the SuperCam mast unit. The suite of spectra and corresponding known compositions are also available in the file libs_spectral_library_reference.csv in the calibration_supercam collection.

7 Appendix A: Examples of FITS Header & Data Unit Structures

HDU 0-4 are common to all EDR and CDR fits files.
HDU 0 only has a header object. The contents are keyword = values with a brief comment/description of the keyword.
An example of the contents of HDU 0 header:

```
SIMPLE  =                    T / conforms to FITS standard
BITPIX  =                    8 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T

      / S-CMD parameters

SCMDTYPE=                    9 / S-CMD type
SCMDTWOD=                    0 / S-CMD TwoD spectrum
SCMDLDRK=                    1 / S-CMD LIBS Dark Type
SCMDRDRK=                    0 / S-CMD RAMAN Dark Type
SCMDRDST=                    0 / S-CMD RAMAN Dark Stats
SCMDRAST=                    0 / S-CMD RAMAN Active Stats
SCMDLDST=                    1 / S-CMD LIBS Dark Stats
SCMDLAST=                    0 / S-CMD LIBS Active Stats
SCMDPNTN=                    1 / S-CMD Point Number

      / Autoexposure

AE_00_SD=                   30 / Autoexposure Seed
AE_00_DT=                   90 / Autoexposure Data

      / Activity-specific header

ACTIVES =                   30 / Number of Active spectra for a DO_SPECTRA
ASTATS  =                    0 / Active Stats ON/OFF
ACOADDS =                    1 / Number of coadds per active spectra
DARKS   =                   30 / Number of Dark for a DO_SPECTRA
DSTATS  =                    1 / Dark Stats ON/OFF
DCOADDS =                    1 / Number of coadds per dark spectra
UVROWS  =                  200 / Number of Rows used in the UV spectrometer
VIOROWS =                  200 / Number of Rows used in the VIO spectrometer
ORANROWS=                  128 / Number of Rows used in the ORANGE spectrometer
GREEROWS=                  120 / Number of Rows used in the GREEN spectrometer
REDROWS =                   70 / Number of Rows used in the RED spectrometer
INTT_TS =             4982.98 / Integration Time of TS spectro in microsec
INTT_VIO=               34.13 / Integration Time of VIO spectro in microsec
INTT_UV =               34.13 / Integration Time of UV spectro in microsec
DELAY   =                  650 / Last Delay set (in ns)
GATE    =                10000 / Last Gate set (in ns)
LASPOWER=                  155 / Laser Power (Amp) commanded
LASSELEC= '0xe2   '            / Laser Selection
HVPSGAIN=                 2500 / Gain of the transmission spectrometer
LAS_PMPD=                  200 / Laser Pumping Duration Commanded
LAS_PMPC=                  155 / Laser Pumping Current Commanded
LAS_PKDC=                    4 / Laser Pockels Delay Commanded
MIC_GAIN=                    2 / Microphone Gain
MIC_SAMC=                   21 / Microphone Sample Code
MIC_SAMP=               100000 / Data Sampling (Hz)
MIC_DOWN=                    F / Data downsampled from 100 Khz
MIC_DURA=                    1 / Mic Duration (from MU_CONFIGURE_MIC)
HSS_MEMB=                    0 /  Memory Bank for MU_SEND_HSS_DATA
HSS_NUMW=               174000 /  NumWords sent by MU_SEND_HSS_DATA
ACT_DELS= '[650]  '            / Do Spectra Active Sweep delay list
ACTVNREP=                    1 / Number of Active DO_SPECTRA commands
DARKNREP=                    1 / Number of Dark DO_SPECTRA commands
DARKTYPE=                    1 / Darks After
AF_PAIR =                    T / An associated AF product should exist
```

```
LIBS_MIC=                   T / LIBS+MIC activity

       / FITS producer and date

BINFILE = 'ScamScidata_0674771977-10592-1.dat' / Original DP
BINPATH = '.       '          / Path of the original file
SEQID   = '' / SeqID
FITSGENV= '1.9.21  '          / Script generating the product
SOH_CONV= 'FM2     '          / SOH conversion law
FITSGENA= 'P. Pilleri'        / Developer of the FITS_GEN script
FITSGENE= 'paolo.pilleri_at_irap.omp.eu' / Email of the FITS_GEN developer
DATE    = '2021-06-28T20:25:49' / GMT-time of FITS creation

       / Generic buffer header and trailer (from XMIT data)

RCE_TSYN=           674770544 / RCE Time Sync
DATADEFV=                  23 / Data definition version
NVXMITCT=               31645 / NV buffer count
BUSOFTV = '0x5f9afe57'        / BU software version
CNDHFIRM=          1555627866 / CNDH firmware version
BUHARDID= '0x64    '          / BU hardware ID
SEFIRMV =               37176 / SE firmware version
SEHARDID=                 784 / SE hardware ID
MUVERSID= '0x0     '          / MU version ID
MUHARDID= '0x0     '          / MU hardware ID
XMIT_ID =                   0 / XMIT data ID
NUMSECT =                 241 / Number of sections
GENBUFSZ=             1133552 / Generic data buffer size
BUF_TRMS=             1433175 / Generic buffer trailer sync
PARS_ERR=                   F / Parsing errors

       / ITF status

ITF0OPC1=                 142 / Opcode
ITF0ECTF=                   2 / ECTF
ITF0DATP=                   1 / Data Present
ITF0STFL=               14529 / Status Flags
ITF0DATL=             1133552 / Data length
ITF1OPC1=                 142 / Opcode
ITF1ECTF=                   2 / ECTF
ITF1DATP=                   0 / Data Present
ITF1STFL=               14529 / Status Flags
ITF1DATL=                   0 / Data length
ITF0CMDR=                   F / Command Reply
ITF0SYSE=                   F / System Error
ITF0SNDE=                   F / Send EVR
ITF0SHTD=                   F / ShutDown
ITF0SSAF=                   F / Sun Safe
ITF0BHON=                   F / BU HVPS ON
ITF0MSON=                   F / MU Shutter ON
ITF0MLON=                   T / MU Laser ON
ITF0MDON=                   T / MU DC chain ON
ITF0MUON=                   T / Mast Unit ON
ITF0CCDA=                   F / CCD Almost Ready
ITF0CCDR=                   F / CCD Ready
ITF0IRSR=                   F / IRS Ready
ITF0LDBR=                   T / Laser Doubler Ready
ITF0LSTR=                   T / Laser Stack Ready
ITF0CWLR=                   F / CWL Ready
ITF0COND=                   1 / ConditionCode
ITF1CMDR=                   F / Command Reply
ITF1SYSE=                   F / System Error
ITF1SNDE=                   F / Send EVR
ITF1SHTD=                   F / ShutDown
ITF1SSAF=                   F / Sun Safe
ITF1BHON=                   F / BU HVPS ON
ITF1MSON=                   F / MU Shutter ON
ITF1MLON=                   T / MU Laser ON
ITF1MDON=                   T / MU DC chain ON
```

```
ITF1MUON=                    T / Mast Unit ON
ITF1CCDA=                    F / CCD Almost Ready
ITF1CCDR=                    F / CCD Ready
ITF1IRSR=                    F / IRS Ready
ITF1LDBR=                    T / Laser Doubler Ready
ITF1LSTR=                    T / Laser Stack Ready
ITF1CWLR=                    F / CWL Ready
ITF1COND=                    1 / ConditionCode

      / Dataset Children

NUMDSETS=                    5 / Number of datasets
FITSEXT0= 'Primary Header'     / Only used for the primary label.
FITSEXT1= 'ODL Label'          / Contains the ODL label
FITSEXT2= 'Timeline'           / Content of FITS Extension #2
FITSEXT3= 'MU-SOH  '           / Content of FITS Extension #3
FITSEXT4= 'BU-SOH  '           / Content of FITS Extension #4

      / Information from the EMD file

EMD_SFWV= '411264494'          / FSW version from EMD file
EMD_FSWN= 'm20surf-pkg-S6_4_1_20210111_02' / FSW name from EMD file
EMD_NDPO=                    6 / Number of DPOs found in the DP
EMD_SCLK=      674771977.16162 / Sclock from EMD file
EMD_GCT =      674771977.16162 / Ground Creation time of DP from EMD file
EMD_ERT =      674771977.16162 / ERT from the EMD file
EMD_SEQN= 'scam06088'          / SeqID from the  EMD file
EMD_VEN = 'SURFACE '           / Venue from the  EMD file
EMD_SCET= '2021-140T08:42:09.063377104' / SCET from the  EMD file
EMD_AZ  =           2.6066043 / RSM Az from the EMD file
EMD_EL  =           1.2658073 / RSM El from the EMD file
EMD_PRIO=                52.0 / Product Priority from the EMD file
EMD_ACID=                 0.0 / Activity ID from the EMD file

      / DPO name and size from the EMD file

DPO000NM= 'ImfIdphSubset4'     / Name of DPO0
DPO000SZ= '402     '           / Size of DPO0
DPO001NM= 'ScamAncillaryTemperatures' / Name of DPO1
DPO001SZ= '60      '           / Size of DPO1
DPO002NM= 'ScamAncillarySendDataArgs' / Name of DPO2
DPO002SZ= '9       '           / Size of DPO2
DPO003NM= 'ScamFocalDistance'  / Name of DPO3
DPO003SZ= '4       '           / Size of DPO3
DPO004NM= 'ScamSciDataFrame'   / Name of DPO4
DPO004SZ= '1133568 '           / Size of DPO4
DPO005NM= 'ScamSciDataFrame'   / Name of DPO5
DPO005SZ= '12      '           / Size of DPO5

      / Python libraries used in FITS_GEN

FG_PYVER= '3.6.7  '            / Python Version used in FITS_GEN
FG_ASVER= '4.0    '            / Astropy version used in FITS_GEN
FG_NPVER= '1.18.1 '            / Numpy version used in FITS_GEN
FG_PDVER= '0.25.3 '            / Pandas version used in FITS_GEN
FG_SPVER= '1.3.1  '            / Scipy version used in FITS_GEN
FG_XLVER= '1.2.0    '              / XLRD version used in FITS_GEN
```

HDU 1 - ODL LABEL

An example of the contents of HDU 1 header:

```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                   85 / length of dimension 1
NAXIS2  =                  374 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
```

```
TFIELDS =                    1 / number of table fields
EXTNAME = 'ODL LABEL'          / extension name
TTYPE1  = 'ODLlabel'
TFORM1  = '85A     '
```

An example of the contents of HDU 1 data:

```
FITS_rec([('ODL_VERSION_ID                = ODL3',), ('',),
        ('/* FILE DATA ELEMENTS */',), ('',),
        ('RECORD_TYPE                     = FIXED_LENGTH',),
        ('RECORD_BYTES                    = 2056',),
        ('LABEL_RECORDS                   = 1',),
        ('FILE_RECORDS                    = 1',), ('',),
        ('/* POINTERS TO DATA OBJECTS */',), ('',),
        ('^SCIENCE_TABLE                  = 2',), ('',), ('',),
        ('/* IDENTIFICATION DATA ELEMENTS */',), ('',),
        ('COMMAND_SEQUENCE_NUMBER         = 11',),
        ('GEOMETRY_PROJECTION_TYPE        = RAW',),
        ('INSTRUMENT_HOST_ID              = "M20"',),
        ('INSTRUMENT_HOST_NAME            = "MARS 2020"',),
        ('INSTRUMENT_ID                   = UNK',),
        ('INSTRUMENT_NAME                 = UNK',),
        ('INSTRUMENT_SERIAL_NUMBER        = "UNK"',),
        ('INSTRUMENT_TYPE                 = "SPECTROMETER"',),
        ('INSTRUMENT_VERSION_ID           = "FM"',),
        ('LOCAL_MEAN_SOLAR_TIME           = "Sol-00088M17:44:57.023"',),
        ('LOCAL_TRUE_SOLAR_TIME           = "17:38:14"',),
        ('MISSION_NAME                    = "MARS 2020"',),
        ('MISSION_PHASE_NAME              = "PRIMARY_SURFACE_MISSION"',),
        ('PLANET_DAY_NUMBER               = 88',),
        ('LOCAL_TRUE_SOLAR_TIME_SOL       = "N/A"',),
        ('PRODUCER_INSTITUTION_NAME       = "MULTIMISSION INSTRUMENT PROCESSING LAB,',),
        ('JET PROPULSION LAB"',),
        ('PRODUCT_CREATION_TIME           = 2021-06-28T20:25:37.000',),
        ('PRODUCT_VERSION_ID              = "V2.0 D-22849"',),
        ('RELEASE_ID                      = "0001"',),
        ('REQUEST_ID                      = "0"',),
        ('ROVER_MOTION_COUNTER            = (4,48,220,766,88,0,334,204,8,4)',),
        ('ROVER_MOTION_COUNTER_NAME       = (SITE, DRIVE, POSE, ARM, SHA,',),
        ('DRILL, RSM, HGA, BITCAR, SEAL)',),
        ('SEQUENCE_ID                     = "scam06088"',),
        ('SEQUENCE_VERSION_ID             = "0"',),
        ('SOLAR_LONGITUDE                 = 47.6148',),
        ('SPACECRAFT_CLOCK_CNT_PARTITION  = 1',),
        ('SPACECRAFT_CLOCK_START_COUNT    = "674771977.105"',),
        ('SPACECRAFT_CLOCK_STOP_COUNT     = "UNK"',),
        ('START_TIME                      = 2021-05-20T08:42:10.911',),
        ('STOP_TIME                       = "UNK"',),
        ('TARGET_NAME                     = MARS',),
        ('TARGET_TYPE                     = PLANET',),
        ('MARS_YEAR                       = 36',),
        ('MARS_HELIOCENTRIC_DISTANCE      = 2.47105e+08 <km>',), ('',),
        ('/* TELEMETRY DATA ELEMENTS */',), ('',),
        ('ACTIVE_FLIGHT_STRING_ID         = A',),
        ('ACTIVITY_ID                     = 0',),
        ('APPLICATION_PROCESS_ID          = 426',),
        ('APPLICATION_PROCESS_NAME        = "ScamScidata"',),
        ('AUTO_DELETE_FLAG                = "FALSE"',),
        ('DOWNLOAD_PRIORITY               = 52',),
        ('DP_CMPRS_MODE                   = 0',),
        ('DP_CREATION_TIME                = "674771977.10476"',),
        ('EARTH_RECEIVED_START_TIME       = 2021-05-20T20:15:07.878',),
```

```
('EARTH_RECEIVED_STOP_TIME        = 2021-05-20T20:21:28.211',),
('EXPECTED_PACKETS                = 113',),
('RECEIVED_PACKETS                = 113',),
('SPICE_FILE_NAME                 = "chronos.m2020_ops210303_v1'",),
('TELEMETRY_PROVIDER_ID           = "MPCS_M2020_DP'",),
('TELEMETRY_SOURCE_HOST_NAME      = "m20-sops-control-1'",),
('TELEMETRY_SOURCE_NAME           = "ScamScidata_0674771977-10592-1.dat'",),
('TELEMETRY_SOURCE_TYPE           = "DATA PRODUCT'",),
('COMMUNICATION_SESSION_ID        = "0'",),
('EXPECTED_TRANSMISSION_PATH      = "128'",),
('FLIGHT_SOFTWARE_MODE            = "8'",),
('FLIGHT_SOFTWARE_VERSION_ID      = "411264494'",),
('PRODUCT_COMPLETION_STATUS       = "COMPLETE_CHECKSUM_PASS'",),
('PRODUCT_TAG                     = "0'",),
('SEQUENCE_EXECUTION_COUNT        = 1',),
('TELEMETRY_SOURCE_START_TIME     = 2021-140T08:42:09.063Z',),
('TELEMETRY_SOURCE_SCLK_START     = "674771977.105'",),
('TELEMETRY_SOURCE_CHECKSUM       = 4042',),
('TELEMETRY_SOURCE_SIZE           = 1134055',),
('TRANSMISSION_PATH               = "0'",),
('VIRTUAL_CHANNEL_ID              = "0'",),
('BOOT_COUNT                      = 530',), (",),
('/* HISTORY DATA ELEMENTS */',), (",),
('GROUP                           = M2020EDRGEN_HISTORY_PARMS',),
('SOFTWARE_NAME                   = M2020EDRGEN',),
('SOFTWARE_VERSION_ID             = "V7.0 2-17-2021'",),
('PROCESSING_HISTORY_TEXT         = "CODMAC LEVEL 1 TO LEVEL 2 CONVERSION',),
('VIA JPL/MIPL M2020EDRGEN'",),
('END_GROUP                       = M2020EDRGEN_HISTORY_PARMS',),
(",), ('/* SCAM ANCILLARY HEADER DATA ELEMENTS */',), (",),
('GROUP                           = SCAM_ANCILLARY_HEADER_DATA_ELEMENTS',),
('POINT_NUMBER                    = 1',),
('TYPE                            = 9',),
('TWO_D                           = 0',),
('LDARK                           = 1',),
('RDARK                           = 0',),
('RDSTATS                         = 0',),
('RASTATS                         = 0',),
('LDSTATS                         = 1',),
('LASTATS                         = 0',),
('END_GROUP                       = SCAM_ANCILLARY_HEADER_DATA_ELEMENTS',),
(",), ('/* GENERIC PACKET HEADER DATA ELEMENTS */',), (",),
('GROUP                           = GENERIC_PACKET_HEADER_DATA_ELEMENTS',),
('RCE_TIME_SYNC                   = 674770544',),
('DATA_DEFINITION_VERSION         = 23',),
('NV_XMIT_BUFFER_COUNT            = 31645',),
('BU_SOFTWARE_VERSION             = 1603993175',),
('CNDH_FIRMWARE_VERSION           = 1555627866',),
('BU_HARDWARE_IDENTIFIER          = 100',),
('SE_FIRMWARE_VERSION             = 37176',),
('SE_HARDWARE_IDENTIFIER          = 784',),
('MU_VERSION_IDENTIFIER           = 0',),
('MU_HARDWARE_IDENTIFIER          = 0',),
('XMIT_DATA_ID                    = 674771977',),
('RESERVED                        = 0',),
('NUMBER_OF_SECTIONS              = 241',),
('GENERIC_DATA_BUFFER_SIZE        = 1133552',),
('END_GROUP                       = GENERIC_PACKET_HEADER_DATA_ELEMENTS',),
(",), ('/* COORDINATE SYSTEM STATE: ROVER */',), (",),
('GROUP                           = ROVER_COORDINATE_SYSTEM',),
('COORDINATE_SYSTEM_NAME          = "ROVER_NAV_FRAME'",),
```

```
('ROVER_MOTION_COUNTER          = (4,48,220,766,88,0,334,204,8,4)',),
('COORDINATE_SYSTEM_INDEX_NAME    = (SITE, DRIVE, POSE, ARM, SHA,',),
('DRILL, RSM, HGA, BITCAR, SEAL)',),
('ORIGIN_OFFSET_VECTOR          = (-3.65094,-3.41273,0.0201761)',),
('ORIGIN_ROTATION_QUATERNION      = (0.33237,-0.00591894,0.00225424,-0.943128)',),
('QUATERNION_MEASUREMENT_METHOD    = FINE',),
('POSITIVE_AZIMUTH_DIRECTION      = CLOCKWISE',),
('POSITIVE_ELEVATION_DIRECTION    = UP',),
('REFERENCE_COORD_SYSTEM_NAME     = SITE_FRAME',),
('REFERENCE_COORD_SYSTEM_INDEX    = 4',),
('END_GROUP                       = ROVER_COORDINATE_SYSTEM',),
('',), ('/* COORDINATE SYSTEM STATE: REMOTE SENSING MAST */',),
('',),
('GROUP                           = RSM_COORDINATE_SYSTEM',),
('COORDINATE_SYSTEM_NAME          = "RSM_HEAD_FRAME"',),
('COORDINATE_SYSTEM_INDEX         = (4,48,220,766,88,0,334,204,8,4)',),
('COORDINATE_SYSTEM_INDEX_NAME    = (SITE, DRIVE, POSE, ARM, SHA,',),
('DRILL, RSM, HGA, BITCAR, SEAL)',),
('ORIGIN_OFFSET_VECTOR          = (0.805024,0.559406,-1.91903)',),
('ORIGIN_ROTATION_QUATERNION      = (0.94851,-0.0446928,-0.155112,-0.272529)',),
('POSITIVE_AZIMUTH_DIRECTION      = CLOCKWISE',),
('POSITIVE_ELEVATION_DIRECTION    = UP',),
('REFERENCE_COORD_SYSTEM_NAME     = ROVER_NAV_FRAME',),
('REFERENCE_COORD_SYSTEM_INDEX    = (4,48,220,766,88,0,334,204,8,4)',),
('END_GROUP                       = RSM_COORDINATE_SYSTEM',),
('',), ('/* COORDINATE SYSTEM STATE: ROBOTIC ARM */',), ('',),
('GROUP                           = ARM_COORDINATE_SYSTEM',),
('COORDINATE_SYSTEM_INDEX         = (4,48,220,766,88,0,334,204,8,4)',),
('COORDINATE_SYSTEM_INDEX_NAME    = (SITE, DRIVE, POSE, ARM, SHA,',),
('DRILL, RSM, HGA, BITCAR, SEAL)',),
('COORDINATE_SYSTEM_NAME          = "ARM_WATSON_FRAME"',),
('ORIGIN_OFFSET_VECTOR          = (1.82274,-1.28121,-1.97497)',),
('ORIGIN_ROTATION_QUATERNION      = (0.990347,-0.00459359,-0.00187715,-0.138518)',),
('REFERENCE_COORD_SYSTEM_NAME     = ROVER_NAV_FRAME',),
('REFERENCE_COORD_SYSTEM_INDEX    = (4,48,220,766,88,0,334,204,8,4)',),
('POSITIVE_AZIMUTH_DIRECTION      = CLOCKWISE',),
('POSITIVE_ELEVATION_DIRECTION    = UP',),
('END_GROUP                       = ARM_COORDINATE_SYSTEM',),
('',), ('/* COORDINATE SYSTEM STATE: TURRET */',), ('',),
('GROUP                           = TURRET_COORDINATE_SYSTEM',),
('COORDINATE_SYSTEM_NAME          = "ARM_TURRET_FRAME"',),
('COORDINATE_SYSTEM_INDEX         = (4,48,220,766,88,0,334,204,8,4)',),
('COORDINATE_SYSTEM_INDEX_NAME    = (SITE, DRIVE, POSE, ARM, SHA,',),
('DRILL, RSM, HGA, BITCAR, SEAL)',),
('ORIGIN_OFFSET_VECTOR          = (1.49785,-1.18839,-1.96237)',),
('ORIGIN_ROTATION_QUATERNION      = (0.681507,-0.00417245,0.00268617,0.731795)',),
('REFERENCE_COORD_SYSTEM_NAME     = ROVER_NAV_FRAME',),
('REFERENCE_COORD_SYSTEM_INDEX    = (4,48,220,766,88,0,334,204,8,4)',),
('POSITIVE_AZIMUTH_DIRECTION      = CLOCKWISE',),
('POSITIVE_ELEVATION_DIRECTION    = UP',),
('END_GROUP                       = TURRET_COORDINATE_SYSTEM',),
('',), ('/* COORDINATE SYSTEM STATE: TOOL */',), ('',),
('GROUP                           = TOOL_COORDINATE_SYSTEM',),
('COORDINATE_SYSTEM_NAME          = "TOOL_FRAME"',),
('COORDINATE_SYSTEM_INDEX         = (4,48,220,766,88,0,334,204,8,4)',),
('COORDINATE_SYSTEM_INDEX_NAME    = (SITE, DRIVE, POSE, ARM, SHA,',),
('DRILL, RSM, HGA, BITCAR, SEAL)',),
('ORIGIN_OFFSET_VECTOR          = (1.82274,-1.28121,-1.97497)',),
('ORIGIN_ROTATION_QUATERNION      = (0.990347,-0.00459359,-0.00187715,-0.138518)',),
('REFERENCE_COORD_SYSTEM_NAME     = ROVER_NAV_FRAME',),
('REFERENCE_COORD_SYSTEM_INDEX    = (4,48,220,766,88,0,334,204,8,4)',),
```

```
('POSITIVE_AZIMUTH_DIRECTION      = CLOCKWISE',),
('POSITIVE_ELEVATION_DIRECTION    = UP',),
('END_GROUP                       = TOOL_COORDINATE_SYSTEM',),
(',), ('/* ARTICULATION DEVICE STATE: REMOTE SENSING MAST */',),
(',),
('GROUP                           = RSM_ARTICULATION_STATE',),
('ARTICULATION_DEVICE_ID          = RSM',),
('ARTICULATION_DEVICE_NAME        = "REMOTE SENSING MAST"',),
('ARTICULATION_DEVICE_ANGLE       = (2.60182 <rad>, 1.26335 <rad>, 2.6702 <rad>,',),
('1.21323 <rad>, 2.60654 <rad>, 1.26583 <rad>,',),
('2.6066 <rad>, 1.26581 <rad>, 2.6749 <rad>,',),
('1.21574 <rad>)',),
('ARTICULATION_DEVICE_ANGLE_NAME  = ("AZIMUTH FINAL-RESOLVER",',),
('"ELEVATION FINAL-RESOLVER",',),
('"AZIMUTH INITIAL-RESOLVER",',),
('"ELEVATION INITIAL-RESOLVER",',), ('"AZIMUTH REQUESTED",',),
('"ELEVATION REQUESTED",',), ('"AZIMUTH FINAL-ENCODER",',),
('"ELEVATION FINAL-ENCODER",',), ('"AZIMUTH INITIAL-ENCODER",',),
('"ELEVATION INITIAL-ENCODER")',),
('ARTICULATION_DEVICE_MODE        = DEPLOYED',),
('ARTICULATION_DEVICE_TEMP        = (-36.1666<degC>, -35.7631<degC>)',),
('ARTICULATION_DEVICE_TEMP_NAME   = ("NAVCAM LEFT CAMERA PLATE",',),
('"NAVCAM RIGHT CAMERA PLATE")',),
('END_GROUP                       = RSM_ARTICULATION_STATE',),
(',), ('/* ARTICULATION DEVICE STATE: SAMPLE ARM */',), (',),
('GROUP                           = ARM_ARTICULATION_STATE',),
('ARTICULATION_DEVICE_ID          = ARM',),
('ARTICULATION_DEVICE_NAME        = "SAMPLE ARM"',),
('ARTICULATION_DEVICE_ANGLE       = (-1.49999 <rad>, -1.57078 <rad>, 1.57078 <rad>,',),
('-0 <rad>, 3.14156 <rad>, -1.5 <rad>,',),
('-1.57045 <rad>, 1.57201 <rad>, -0.000872503 <rad>,',),
('3.14184 <rad>, 0.0601695 <rad>)',),
('ARTICULATION_DEVICE_ANGLE_NAME  = ("JOINT 1 AZIMUTH-HALL ENCODER",',),
('"JOINT 2 ELEVATION-HALL ENCODER",',),
('"JOINT 3 ELBOW-HALL ENCODER",',),
('"JOINT 4 WRIST-HALL ENCODER",',),
('"JOINT 5 TURRET-HALL ENCODER",',),
('"JOINT 1 AZIMUTH-RESOLVER",',),
('"JOINT 2 ELEVATION-RESOLVER",',),
('"JOINT 3 ELBOW-RESOLVER",',), ('"JOINT 4 WRIST-RESOLVER",',),
('"JOINT 5 TURRET-RESOLVER",',), ('"SCS DOCKING CLOCK ANGLE")',),
('ARTICULATION_DEVICE_TEMP        = (-15.8973<degC>, -23.8472<degC>, -19.3221<degC>,',),
('-30.545<degC>, -20.2263<degC>, 0<degC>,',),
('-51.2024<degC>)',),
('ARTICULATION_DEVICE_TEMP_NAME   = ("AZIMUTH JOINT",',),
('"ELEVATION JOINT",',), ('"ELBOW JOINT",',),
('"WRIST JOINT",',), ('"TURRET JOINT",',),
('"DEFLECTION BODY DELTA TEMPERATURE",',),
('"DEFLECTION ARM DELTA TEMPERATURE")',),
('ARTICULATION_DEV_VECTOR      = (1.82274,-1.28121,-1.97497)',),
('ARTICULATION_DEV_VECTOR_NAME  = "GRAVITY"',),
('ARTICULATION_DEV_INSTRUMENT_ID  = "WATSON"',),
('CONTACT_SENSOR_STATE            = ("NO CONTACT",',),
('"NO CONTACT",',), ('"NO CONTACT",',), ('"NO CONTACT",',),
('"NO CONTACT",',), ('"NO CONTACT",',), ('"NO CONTACT",',),
('"NO CONTACT")',),
('CONTACT_SENSOR_STATE_NAME       = ("FACILITY CONTACT SENSOR A",',),
('"FACILITY CONTACT SENSOR B",',), ('"DRILL STABILIZER 1",',),
('"DRILL STABILIZER 2",',), ('"DOCK 1",',), ('"DOCK 2",',),
('"DOCK 3",',), ('"DOCK 4")',),
('ART_DEV_COMPONENT_STATE = ("6","WATSON")',),
```

```
('ART_DEV_COMPONENT_STATE_NAME = ("PRELOAD_VALUE","PRELOAD_TOOL")',),
('END_GROUP                    = ARM_ARTICULATION_STATE',),
(",), ('/* ARTICULATION DEVICE STATE: MOBILITY CHASSIS */',),
(",),
('GROUP                        = CHASSIS_ARTICULATION_STATE',),
('ARTICULATION_DEVICE_ID       = CHASSIS',),
('ARTICULATION_DEVICE_NAME     = "MOBILITY CHASSIS"',),
('ARTICULATION_DEVICE_ANGLE    = (-0 <rad>, -0.000170442 <rad>,',),
('-0.000937433 <rad>, -0.00102265 <rad>,',),
('0.0287444 <rad>, -0.00576038 <rad>,',),
('-0.000384145 <rad>, 0.0144141 <rad>,',),
('0 <rad>, 0 <rad>,',), ('0 <rad>, 0 <rad>,',),
('0 <rad>, 0 <rad>)',),
('ARTICULATION_DEVICE_ANGLE_NAME  = ("LEFT FRONT WHEEL STEER MOTOR",',),
('"RIGHT FRONT WHEEL STEER MOTOR",',),
('"LEFT REAR WHEEL STEER MOTOR",',),
('"RIGHT REAR WHEEL STEER MOTOR",',), ('"LEFT BOGIE",',),
('"RIGHT BOGIE",',), ('"LEFT DIFFERENTIAL",',),
('"RIGHT DIFFERENTIAL",',), ('"LEFT FRONT WHEEL DRIVE MOTOR",',),
('"RIGHT FRONT WHEEL DRIVE MOTOR",',),
('"LEFT MIDDLE WHEEL DRIVE MOTOR",',),
('"RIGHT MIDDLE WHEEL DRIVE MOTOR",',),
('"LEFT REAR WHEEL DRIVE MOTOR",',),
('"RIGHT REAR WHEEL DRIVE MOTOR")',),
('ARTICULATION_DEVICE_MODE     = DEPLOYED',),
('END_GROUP                    = CHASSIS_ARTICULATION_STATE',),
(",), ('/* ARTICULATION DEVICE STATE: HIGH GAIN ANTENNA */',),
(",),
('GROUP                        = HGA_ARTICULATION_STATE',),
('ARTICULATION_DEVICE_ID       = HGA',),
('ARTICULATION_DEVICE_NAME     = "HIGH GAIN ANTENNA"',),
('ARTICULATION_DEVICE_ANGLE    = (1.13451 <rad>, -0.784975 <rad>)',),
('ARTICULATION_DEVICE_ANGLE_NAME  = ("AZIMUTH", "ELEVATION")',),
('ARTICULATION_DEVICE_MODE     = DEPLOYED',),
('END_GROUP                    = HGA_ARTICULATION_STATE',),
(",), ('/* OBSERVATION REQUEST */',), (",),
('GROUP                        = OBSERVATION_REQUEST_PARMS',),
('SOURCE_ID                    = "GROUND COMMANDED"',),
('INSTRUMENT_COORD_FRAME_INDEX    = 0',),
('INSTRUMENT_COORDINATE_NAME      = "UNK"',),
('INSTRUMENT_COORDINATE           = "UNK"',),
('INSTRUMENT_COORDINATE_TYPE      = "UNK"',),
('GROUP_APPLICABILITY_FLAG        = "TRUE"',),
('INSTRUMENT_MODE_ID              = "UNK"',),
('INSTRUMENT_FOCUS_DISTANCE       = "UNK"',),
('END_GROUP                    = OBSERVATION_REQUEST_PARMS',),
(",), ('/* INSTRUMENT STATE RESULTS */',), (",),
('GROUP                        = INSTRUMENT_STATE_PARMS',),
('INSTRUMENT_TEMPERATURE          = (-25.6712 <degC>, -25.6712 <degC>, -10.2226 <degC>,',),
('-25.4451 <degC>, 24.0664 <degC>)',),
('INSTRUMENT_TEMPERATURE_NAME     = ("MU_OBOX_TEMP", "MU_LASER_IF_TEMP",',),
('"MU_EBOX_TEMP", "MU_SEC_MIRROR_TEMP",',), ('"RAMP_TEMP")',),
('INSTRUMENT_TEMPERATURE_STATUS    = (0, -45, 0, 0, 0)',), (",),
('END_GROUP                    = INSTRUMENT_STATE_PARMS',),
(",), ('/* DERIVED GEOMETRY DATA ELEMENTS: ROVER FRAME */',),
(",),
('GROUP                        = ROVER_DERIVED_GEOMETRY_PARMS',),
('INSTRUMENT_AZIMUTH              = 328.003',),
('INSTRUMENT_ELEVATION            = -19.0093',),
('REFERENCE_COORD_SYSTEM_NAME     = "ROVER_NAV_FRAME"',),
('REFERENCE_COORD_SYSTEM_INDEX    = (4,48,220,766,88,0,334,204,8,4)',),
```

```
('SUN_VIEW_DIRECTION          = (0.383737, 0.902257, -0.196665)',),
('SOLAR_AZIMUTH               = 66.9596 <deg>',),
('SOLAR_ELEVATION             = 11.342 <deg>',),
('END_GROUP                   = ROVER_DERIVED_GEOMETRY_PARMS',),
('',), ('/* DERIVED GEOMETRY DATA ELEMENTS: SITE FRAME */',),
('',),
('GROUP                       = SITE_DERIVED_GEOMETRY_PARMS',),
('INSTRUMENT_AZIMUTH          = 186.866',),
('INSTRUMENT_ELEVATION        = -19.7275',),
('REFERENCE_COORD_SYSTEM_NAME     = "SITE_FRAME"',),
('REFERENCE_COORD_SYSTEM_INDEX    = (4,48,220,766,88,0,334,204,8,4)',),
('SOLAR_AZIMUTH               = 285.897 <deg>',),
('SOLAR_ELEVATION             = 10.7091 <deg>',),
('POSITIVE_AZIMUTH_DIRECTION      = CLOCKWISE',),
('PHASE_ANGLE                 = 77.973 <deg>',),
('SOLAR_INCIDENCE_TARGET_ANG      = 67.004 <deg>',),
('SOLAR_INCIDENCE_TARGET_ANG_NAME = "SuperCam Calibration Target"',),
('END_GROUP                   = SITE_DERIVED_GEOMETRY_PARMS',),
('',)],
dtype=(numpy.record, [('ODLlabel', 'S85')]))
```

HDU 2 - Time Line (commands and arguments or data)

An example of the contents of HDU 2 header:

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                  910 / length of dimension 1
NAXIS2  =                  241 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                    7 / number of table fields
EXTNAME = 'TIMELINE'          / extension name
TTYPE1  = 'ms_since_last_sync'
TFORM1  = 'D      '
TTYPE2  = 'cmd_name'
TFORM2  = '26A    '
TTYPE3  = 'opcode  '
TFORM3  = '2A     '
TTYPE4  = 'type   '
TFORM4  = '7A     '
TTYPE5  = 'data_length'
TFORM5  = 'D      '
TTYPE6  = 'args   '
TFORM6  = '299A   '
TTYPE7  = 'data   '
TFORM7  = '560A   '
```

An example of the contents of HDU 2 data:

```
FITS_rec([ ( 1297985., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd',   4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
       ( 1298105., 'MU_SEND_HOUSEKEEPINGS', '', 'data',   6.80000000e+01, '', 'See HDU 3 MU_SOH'),
       ( 1298115., 'COLLECT_SOH', '', 'cmd',   0.00000000e+00, '{}', ''),
       ( 1298115., 'COLLECT_SOH', '', 'data',   3.64000000e+02, '', 'See HDU 4 BU_SOH'),
       ( 1298125., 'MU_DC_DC_CHAIN_ON_OFF', '', 'cmd',   1.00000000e+00, "{'onOff': 1}", ''),
       ( 1298170., 'MU_CONFIGURE_STEPPER_MOTOR', '', 'cmd',   2.00000000e+00, "{'mode': 0, 'motorSpeed': 3}", ''),
       ( 1298220., 'MU_MOTOR_ON_OFF', '', 'cmd',   1.00000000e+00, "{'onOff': 1}", ''),
       ( 1298280., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd',   4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
       ( 1298400., 'MU_SEND_HOUSEKEEPINGS', '', 'data',   6.80000000e+01, '', 'See HDU 3 MU_SOH'),
       ( 1298410., 'COLLECT_SOH', '', 'cmd',   0.00000000e+00, '{}', ''),
       ( 1298410., 'COLLECT_SOH', '', 'data',   3.64000000e+02, '', 'See HDU 4 BU_SOH'),
       ( 1298415., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd',   4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
```

(1298535., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1298545., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1298545., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1298550., 'DO_FOCUS', '', 'cmd', 4.00000000e+00, "{'focusType': 1, 'seedDistance': 5178, 'autoFocusMethod': 0}", ''),
(1298550., 'MU_STEPPER_MOTOR_MOVE', '', 'cmd', 8.00000000e+00, "{'num_displacements': 1, 'num_steps_per_displacement': 3709, 'direction': 1, 'bypass_on_off': 0, 'sampling_on_off': 0, 'gain': 0}", ''),
(1322920., 'MU_STEPPER_MOTOR_MOVE', '', 'data', 6.00000000e+00, '', '00 00 0E 7D 00 04'),
(1322920., 'MU_STEPPER_MOTOR_MOVE', '', 'cmd', 8.00000000e+00, "{'num_displacements': 1, 'num_steps_per_displacement': 500, 'direction': 0, 'bypass_on_off': 0, 'sampling_on_off': 0, 'gain': 0}", ''),
(1326255., 'MU_STEPPER_MOTOR_MOVE', '', 'data', 6.00000000e+00, '', '00 00 01 F4 00 04'),
(1326280., 'MU_MOTOR_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 0}", ''),
(1326330., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1326450., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1326460., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1326460., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1326470., 'DEBUG_INFO', '', 'cmd', 1.00000000e+00, "{'arg': 14}", ''),
(1326470., 'DEBUG_INFO', '', 'data', 4.00000000e+00, '', '00 00 14 3F'),
(1327985., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1328105., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1328115., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1328115., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1328125., 'MU_DC_DC_CHAIN_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 1}", ''),
(1328170., 'MU_CONFIGURE_STEPPER_MOTOR', '', 'cmd', 2.00000000e+00, "{'mode': 0, 'motorSpeed': 3}", ''),
(1328220., 'MU_MOTOR_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 1}", ''),
(1328280., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1328400., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1328445., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1328445., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1328490., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1328610., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1328620., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1328620., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1328625., 'MU_RMI_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 1}", ''),
(1329235., 'MU_CONFIGURE_RMI_TABLE', '', 'cmd', 1.00000000e+00, "{'table_num': 0}", ''),
(1329290., 'MU_CONFIGURE_AUTOEXPOSURE', '', 'cmd', 1.60000000e+01, "{'lower_threshold': 140, 'upper_threshold': 580, 'max_num_pixels_under_lower_threshold': 31452, 'max_num_pixels_above_upper_threshold': 31452, 'roi_size': 1024, 'roi_y_position': 512}", ''),
(1329350., 'MU_DO_AUTOEXPOSURE', '', 'cmd', 3.00000000e+00, "{'exposure_time': 30, 'memory_bank': 0}", ''),
(1329950., 'MU_DO_AUTOEXPOSURE', '', 'data', 2.00000000e+00, '', '00 5A'),
(1329955., 'MU_CONFIGURE_RMI_AUTOFOCUS', '', 'cmd', 1.10000000e+01, "{'num_displacements': 14, 'num_steps_per_displacement': 11, 'exposure_time': 0, 'roi_size': 140, 'roi_y_position': 953, 'memory_bank': 0, 'backlash': 500}", ''),
(1330025., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1330145., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1330155., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1330155., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1330160., 'DO_FOCUS', '', 'cmd', 4.00000000e+00, "{'focusType': 0, 'seedDistance': 5178, 'autoFocusMethod': 82}", ''),
(1397800., 'MU_DO_AUTOFOCUS', '', 'data', 6.30000000e+01, '', '00 FF F7 00 02 26 75 00 02 49 E4 00 02 72 0F 00 02 B2 46 00 03 0D 0B 00 03 61 36 00 03 FE 1A 00 07 01 10 00 08 A3 8E 00 04 FB C9 00 02 BD D4 00 02 64 72 00 02 37 6B 00 02 2A A0 00 02 1F C9'),
(1397815., 'MU_RMI_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 0}", ''),
(1397860., 'MU_MOTOR_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 0}", ''),
(1397915., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1398035., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1398050., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1398050., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1398055., 'DEBUG_INFO', '', 'cmd', 1.00000000e+00, "{'arg': 14}", ''),
(1398055., 'DEBUG_INFO', '', 'data', 4.00000000e+00, '', '00 00 14 1E'),
(1400990., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1401110., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1401120., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),

(1401120., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1401125., 'MU_DC_DC_CHAIN_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 1}", ''),
(1401175., 'MU_CONFIGURE_STEPPER_MOTOR', '', 'cmd', 2.00000000e+00, "{'mode': 0, 'motorSpeed': 3}", ''),
(1401220., 'MU_MOTOR_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 1}", ''),
(1401285., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1401405., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1401415., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1401415., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1401425., 'DO_FOCUS_OFFSET', '', 'cmd', 1.00000000e+00, "{'focusOffsetType': 1}", ''),
(1401425., 'MU_STEPPER_MOTOR_MOVE', '', 'cmd', 8.00000000e+00, "{'num_displacements': 1, 'num_steps_per_displacement': 23, 'direction': 0, 'bypass_on_off': 0, 'sampling_on_off': 0, 'gain': 0}", ''),
(1401635., 'MU_STEPPER_MOTOR_MOVE', '', 'data', 6.00000000e+00, '', '00 00 00 17 00 04'),
(1401660., 'MU_MOTOR_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 0}", ''),
(1401705., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1401825., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1401835., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1401835., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1401845., 'DEBUG_INFO', '', 'cmd', 1.00000000e+00, "{'arg': 14}", ''),
(1401845., 'DEBUG_INFO', '', 'data', 4.00000000e+00, '', '00 00 13 E5'),
(1401850., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1401970., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1401980., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1401980., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1401985., 'SE_RESET', '', 'cmd', 0.00000000e+00, '{}', ''),
(1402440., 'CONFIGURE_CCD_VERT_TIMING', '', 'cmd', 1.50000000e+01, "{'spectrometerSelect': 7, 'colTimerStop': 536, 'coli1Hi': 179, 'coli1Lo': 447, 'coli2Hi': 358, 'coli2Lo': 90, 'coli3Hi': 1, 'coli3Lo': 269}", ''),
(1402475., 'CONFIGURE_CCD_HORZ_TIMING', '', 'cmd', 3.30000000e+01, "{'spectrometerSelect': 4, 'debug': 0, 'mode2D': 0, 'integrationTime': 146, 'ROclockLimit': 74, 'R1clockHi': 0, 'R1clockLo': 66, 'R2clockHi': 62, 'R2clockLo': 72, 'R3clockHi': 68, 'R3clockLo': 31, 'ORSTclockHi': 62, 'ORSTclockLo': 69, 'ADCclockHi': 19, 'ADCclockLo': 50, 'clampHi': 62, 'clampLo': 14}", ''),
(1402510., 'CONFIGURE_CCD_HORZ_TIMING', '', 'cmd', 3.30000000e+01, "{'spectrometerSelect': 2, 'debug': 0, 'mode2D': 0, 'integrationTime': 1, 'ROclockLimit': 74, 'R1clockHi': 0, 'R1clockLo': 66, 'R2clockHi': 62, 'R2clockLo': 72, 'R3clockHi': 68, 'R3clockLo': 31, 'ORSTclockHi': 62, 'ORSTclockLo': 69, 'ADCclockHi': 19, 'ADCclockLo': 50, 'clampHi': 62, 'clampLo': 14}", ''),
(1402550., 'CONFIGURE_CCD_HORZ_TIMING', '', 'cmd', 3.30000000e+01, "{'spectrometerSelect': 1, 'debug': 0, 'mode2D': 0, 'integrationTime': 1, 'ROclockLimit': 74, 'R1clockHi': 0, 'R1clockLo': 66, 'R2clockHi': 62, 'R2clockLo': 72, 'R3clockHi': 68, 'R3clockLo': 31, 'ORSTclockHi': 62, 'ORSTclockLo': 69, 'ADCclockHi': 19, 'ADCclockLo': 50, 'clampHi': 62, 'clampLo': 14}", ''),
(1402585., 'CONFIGURE_CCD_REGIONS', '', 'cmd', 1.70000000e+01, "{'spectrometerSelect': 4, 'skipRows1': 91, 'sumRows1': 70, 'region2enable': 1, 'skipRows2': 75, 'sumRows2': 120, 'region3enable': 1, 'skipRows3': 22, 'sumRows3': 128, 'lastSkipRows': 9}", ''),
(1402595., 'CONFIGURE_CCD_REGIONS', '', 'cmd', 1.70000000e+01, "{'spectrometerSelect': 2, 'skipRows1': 151, 'sumRows1': 200, 'region2enable': 0, 'skipRows2': 0, 'sumRows2': 0, 'region3enable': 0, 'skipRows3': 0, 'sumRows3': 0, 'lastSkipRows': 164}", ''),
(1402600., 'CONFIGURE_CCD_REGIONS', '', 'cmd', 1.70000000e+01, "{'spectrometerSelect': 1, 'skipRows1': 151, 'sumRows1': 200, 'region2enable': 0, 'skipRows2': 0, 'sumRows2': 0, 'region3enable': 0, 'skipRows3': 0, 'sumRows3': 0, 'lastSkipRows': 164}", ''),
(1402610., 'CONFIGURE_HVPS', '', 'cmd', 3.00000000e+00, "{'enableHvps': 1, 'hvpsGain': 2500}", ''),
(1404115., 'CONFIGURE_INTENSIFIER', '', 'cmd', 8.00000000e+00, "{'openTimeTicks': 65, 'durationTimeTicks': 1000}", ''),
(1404120., 'MU_DC_DC_CHAIN_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 1}", ''),
(1404165., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1404285., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1404300., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1404300., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1404305., 'MU_LASER_CONVERTERS_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 1}", ''),
(1404350., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1404470., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1404480., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1404480., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),

(1405345., 'MU_CONFIGURE_MICROPHONE', '', 'cmd', 3.00000000e+00, "{'gain': 2, 'duration': 1, 'sampleRate': 21}", ''),
(1405410., 'MU_MICROPHONE_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 1}", ''),
(1405455., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1405575., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1405585., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1405585., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1405595., 'MU_CONFIGURE_LASER', '', 'cmd', 7.00000000e+00, "{'pumpingCurrent': 155, 'pumpingDuration': 200, 'pockelsDelay': 4, 'shotFrequency': 3, 'laserSelection': 226, 'numShots': 30}", ''),
(1405655., 'DO_SPECTRA', '', 'cmd', 2.00000000e+01, "{'spectrometerSelect': 7, 'enableLaser': 1, 'collectID': 0, 'laserRepRate': 260416, 'shotsPerSpectra': 1, 'numSpectra': 30, 'performStatistics': 0, 'config': 0, 'doNotStoreSpectra': 0}", ''),
(1406670., '', '', 'spectra', 4.29600000e+03, '', 'See Spectral Data HDUs'),
(1406690., '', '', 'spectra', 1.28880000e+04, '', 'See Spectral Data HDUs'),
(1407005., '', '', 'spectra', 4.29600000e+03, '', 'See Spectral Data HDUs'),
…
…
(1416340., '', '', 'spectra', 4.29600000e+03, '', 'See Spectral Data HDUs'),
(1416355., '', '', 'spectra', 1.28880000e+04, '', 'See Spectral Data HDUs'),
(1416605., 'MU_RECORD_SOUND', '', 'data', 5.00000000e+00, '', '00 02 06 CC 64'),
(1416610., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1416730., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1416740., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1416740., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1416750., 'MU_MICROPHONE_ON_OFF', '', 'cmd', 1.00000000e+00, "{'onOff': 0}", ''),
(1416800., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1416920., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1416930., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1416930., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1416940., 'MU_SEND_HSS_DATA', '', 'cmd', 6.00000000e+00, "{'memory_bank': 0, 'num_words': 21000, 'type': 1}", ''),
(1416940., 'MU_SEND_HSS_DATA', '', 'cmd', 6.00000000e+00, "{'memory_bank': 0, 'num_words': 174000, 'type': 1}", ''),
(1417265., 'MU_SEND_HSS_DATA', '', 'data', 3.48000000e+05, '', 'See Image/Audio data HDUs'),
(1417290., 'MU_SEND_LASER_DATA', '', 'cmd', 0.00000000e+00, '{}', ''),
(1417535., 'MU_SEND_LASER_DATA', '', 'data', 1.87000000e+02, '', '9B C8 04 03 E2 00 1E 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 06 B7 04 0F 0A 0B'),
(1417540., 'MU_CONFIGURE_LASER', '', 'cmd', 7.00000000e+00, "{'pumpingCurrent': 0, 'pumpingDuration': 200, 'pockelsDelay': 4, 'shotFrequency': 3, 'laserSelection': 82, 'numShots': 30}", ''),
(1417595., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1417715., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1417725., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1417725., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1417735., 'MU_CONFIGURE_LASER', '', 'cmd', 7.00000000e+00, "{'pumpingCurrent': 0, 'pumpingDuration': 200, 'pockelsDelay': 4, 'shotFrequency': 3, 'laserSelection': 82, 'numShots': 30}", ''),
(1417785., 'DO_SPECTRA', '', 'cmd', 2.00000000e+01, "{'spectrometerSelect': 7, 'enableLaser': 0, 'collectID': 0, 'laserRepRate': 260416, 'shotsPerSpectra': 1, 'numSpectra': 30, 'performStatistics': 1, 'config': 0, 'doNotStoreSpectra': 0}", ''),
(1429110., '', '', 'spectra', 2.57760000e+04, '', 'See Spectral Data HDUs'),
(1429745., '', '', 'spectra', 2.57760000e+04, '', 'See Spectral Data HDUs'),
(1431610., '', '', 'spectra', 7.73280000e+04, '', 'See Spectral Data HDUs'),
(1431660., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1431780., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),
(1431790., 'COLLECT_SOH', '', 'cmd', 0.00000000e+00, '{}', ''),
(1431790., 'COLLECT_SOH', '', 'data', 3.64000000e+02, '', 'See HDU 4 BU_SOH'),
(1431800., 'SE_RESET', '', 'cmd', 0.00000000e+00, '{}', ''),
(1432255., 'CONFIGURE_HVPS', '', 'cmd', 3.00000000e+00, "{'enableHvps': 0, 'hvpsGain': 0}", ''),
(1432760., 'MU_SEND_HOUSEKEEPINGS', '', 'cmd', 4.00000000e+00, "{'HKmask': 'FFFFFFFF'}", ''),
(1432880., 'MU_SEND_HOUSEKEEPINGS', '', 'data', 6.80000000e+01, '', 'See HDU 3 MU_SOH'),

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( 1432910., 'COLLECT_SOH', '', 'cmd',   0.00000000e+00, '{}', ''),
( 1432910., 'COLLECT_SOH', '', 'data',   3.64000000e+02, '', 'See HDU 4 BU_SOH'),
( 1433175., 'XMIT_DATA', '', 'cmd',   4.00000000e+00, "{'dataID': 674771977}", '')],
dtype=(numpy.record, [('ms_since_last_sync', '>f8'), ('cmd_name', 'S26'), ('opcode', 'S2'), ('type', 'S7'), ('data_length', '>f8'),
('args', 'S299'), ('data', 'S560')]))
```

HDU 3 – MU State of Health (SOH)

An example of the contents of HDU 3 header:

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                  680 / length of dimension 1
NAXIS2  =                   21 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                   85 / number of table fields
EXTNAME = 'MU_SOH  '          / extension name
TTYPE1  = 'mu_ms_offset'
TFORM1  = 'D      '
TTYPE2  = '00_Laser_osc1_Temp'
TFORM2  = 'D      '
TTYPE3  = '01_Laser_osc2_Temp'
TFORM3  = 'D      '
TTYPE4  = '02_Laser_doub1_Temp'
TFORM4  = 'D      '
TTYPE5  = '03_Laser_doub2_Temp'
TFORM5  = 'D      '
TTYPE6  = '04_Laser_15V'
TFORM6  = 'D      '
TTYPE7  = '05_Laser_HV'
TFORM7  = 'D      '
TTYPE8  = '06_Laser_Limiter_Temp'
TFORM8  = 'D      '
TTYPE9  = '07_DPU_Motor_Driver_Temp'
TFORM9  = 'D      '
TTYPE10 = '08_DPU_FPGA_Temp'
TFORM10 = 'D      '
TTYPE11 = '09_Vref_+2.5V'
TFORM11 = 'D      '
TTYPE12 = '10_+1.5V'
TFORM12 = 'D      '
TTYPE13 = '11_+3.3V'
TFORM13 = 'D      '
TTYPE14 = '12_Motor_Temperature'
TFORM14 = 'D      '
TTYPE15 = '13_Primary_Mirror_Temp'
TFORM15 = 'D      '
TTYPE16 = '14_CWL_Pd_Current'
TFORM16 = 'D      '
TTYPE17 = '15_Micro_Temp'
TFORM17 = 'D      '
TTYPE18 = '16_CWL_Temp'
TFORM18 = 'D      '
TTYPE19 = '17_+3.3_IRS'
TFORM19 = 'D      '
TTYPE20 = '18_+20V_RF_IRS'
TFORM20 = 'D      '
TTYPE21 = '19_+5V_RF_IRS'
TFORM21 = 'D      '
TTYPE22 = '20_-5V_RF_IRS'
TFORM22 = 'D      '
```

TTYPE23 = '21_+5V_DT_IRS'
TFORM23 = 'D '
TTYPE24 = '22_-5V_DT_IRS'
TFORM24 = 'D '
TTYPE25 = '23_LVPS_Board_Temp'
TFORM25 = 'D '
TTYPE26 = '24_Primary_Current'
TFORM26 = 'D '
TTYPE27 = '25_IRS_HK_Temp_AOTF'
TFORM27 = 'D '
TTYPE28 = '26_IRS_HK_TEMP_HOT_TEC'
TFORM28 = 'D '
TTYPE29 = '27_IRS_HK_Temp_board'
TFORM29 = 'D '
TTYPE30 = '28_IRS_HK_Temp_DET'
TFORM30 = 'D '
TTYPE31 = '29_Remaining_laser_pulses'
TFORM31 = 'D '
TTYPE32 = '30_ONOFF_shutter'
TFORM32 = 'D '
TTYPE33 = '31_ONOFF_limiter'
TFORM33 = 'D '
TTYPE34 = '32_ONOFF_High_voltage_15V'
TFORM34 = 'D '
TTYPE35 = '33_ONOFF_Microphone'
TFORM35 = 'D '
TTYPE36 = '34_ONOFF_RMI'
TFORM36 = 'D '
TTYPE37 = '35_ONOFF_DCDC'
TFORM37 = 'D '
TTYPE38 = '36_ONOFF_heater_doubler_laser'
TFORM38 = 'D '
TTYPE39 = '37_ONOFF_heater_stack_laser'
TFORM39 = 'D '
TTYPE40 = '38_ONOFF_heater_CWL'
TFORM40 = 'D '
TTYPE41 = '39_Heater_Doubler_Reached'
TFORM41 = 'D '
TTYPE42 = '40_Heater_Stack_Reached'
TFORM42 = 'D '
TTYPE43 = '41_Heater_CWL_Reached'
TFORM43 = 'D '
TTYPE44 = '42_IRS_DET_Sel'
TFORM44 = 'D '
TTYPE45 = '43_IRS_TEC_ONOFF'
TFORM45 = 'D '
TTYPE46 = '44_IRS_TEC_Ready'
TFORM46 = 'D '
TTYPE47 = '45_IRS_Measure_Done'
TFORM47 = 'D '
TTYPE48 = '46_Motor_driver_circuit_thermal_flag'
TFORM48 = 'D '
TTYPE49 = '47_AF_gain_status_MSB'
TFORM49 = 'D '
TTYPE50 = '48_AF_gain_status_LSB'
TFORM50 = 'D '
TTYPE51 = '49_ONOFF_CWL'
TFORM51 = 'D '
TTYPE52 = '50_ONOFF_CWL_modulation'
TFORM52 = 'D '
TTYPE53 = '51_ONOFF_motor_driver'

TFORM53 = 'D '
TTYPE54 = '52_Infinite_limit_switch_status'
TFORM54 = 'D '
TTYPE55 = '53_Close_limit_switch_status'
TFORM55 = 'D '
TTYPE56 = 'C00_Laser_osc1_Temp'
TFORM56 = 'D '
TTYPE57 = 'C01_Laser_osc2_Temp'
TFORM57 = 'D '
TTYPE58 = 'C02_Laser_doub1_Temp'
TFORM58 = 'D '
TTYPE59 = 'C03_Laser_doub2_Temp'
TFORM59 = 'D '
TTYPE60 = 'C04_Laser_15V'
TFORM60 = 'D '
TTYPE61 = 'C05_Laser_HV'
TFORM61 = 'D '
TTYPE62 = 'C06_Laser_Limiter_Temp'
TFORM62 = 'D '
TTYPE63 = 'C07_DPU_Motor_Driver_Temp'
TFORM63 = 'D '
TTYPE64 = 'C08_DPU_FPGA_Temp'
TFORM64 = 'D '
TTYPE65 = 'C09_Vref_+2.5V'
TFORM65 = 'D '
TTYPE66 = 'C10_+1.5V'
TFORM66 = 'D '
TTYPE67 = 'C11_+3.3V'
TFORM67 = 'D '
TTYPE68 = 'C12_Motor_Temperature'
TFORM68 = 'D '
TTYPE69 = 'C13_Primary_Mirror_Temp'
TFORM69 = 'D '
TTYPE70 = 'C14_CWL_Pd_Current'
TFORM70 = 'D '
TTYPE71 = 'C15_Micro_Temp'
TFORM71 = 'D '
TTYPE72 = 'C16_CWL_Temp'
TFORM72 = 'D '
TTYPE73 = 'C17_+3.3_IRS'
TFORM73 = 'D '
TTYPE74 = 'C18_+20V_RF_IRS'
TFORM74 = 'D '
TTYPE75 = 'C19_+5V_RF_IRS'
TFORM75 = 'D '
TTYPE76 = 'C20_-5V_RF_IRS'
TFORM76 = 'D '
TTYPE77 = 'C21_+5V_DT_IRS'
TFORM77 = 'D '
TTYPE78 = 'C22_-5V_DT_IRS'
TFORM78 = 'D '
TTYPE79 = 'C23_LVPS_Board_Temp'
TFORM79 = 'D '
TTYPE80 = 'C24_Primary_Current'
TFORM80 = 'D '
TTYPE81 = 'C25_IRS_HK_Temp_AOTF'
TFORM81 = 'D '
TTYPE82 = 'C26_IRS_HK_TEMP_HOT_TEC'
TFORM82 = 'D '
TTYPE83 = 'C27_IRS_HK_Temp_board'
TFORM83 = 'D '

TTYPE84 = 'C28_IRS_HK_Temp_DET'
TFORM84 = 'D '
TTYPE85 = 'C29_Remaining_laser_pulses'
TFORM85 = 'D '

An example of the contents of HDU 3 data:

FITS_rec([(1298105., 50788., 51038., 53192., 53037., 6.55340000e+04, 82., 46885., 48373., 47697., 24558., 14724., 16092., 20753., 45733., 65514., 6.55350000e+04, 45855., 20004., 21887., 16139., 16516., 27567., 28433., 42936., 1881., 12657., 12862., 15265., 3631., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.974036, -14.99327 , -10.184592, -10.265389, -1.22354000e-03, 8.3414664, -23.525429, -19.720044, -21.033127, 2.49558396, 1.49625288, 3.31559568, -22.422027, -24.183392, 61.956, -255.9253208, -25.295315, 3.70554096, 16.58662521, 5.08346222, -5.05373084, 8.8186833, -8.8341331, -19.3108 , 0.27356657, -25.81257, -25.40462, -20.62265, -18.70638658, 0.),

(1298400., 50787., 51037., 53177., 53025., 6.55350000e+04, 81., 46885., 48369., 47698., 24558., 14724., 16094., 20752., 45431., 65513., 6.54010000e+04, 43604., 19945., 28108., 16301., 16522., 27585., 28479., 42942., 2752., 12660., 12851., 15268., 3619., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 1., 0., 0., -14.976143, -14.995385, -10.216362, -10.290721, -6.11770000e-04, 8.2397412, -23.525429, -19.727996, -21.031134, 2.49558396, 1.49625288, 3.31600776, -22.432768, -24.80672 , 61.954, -259.318308 , -30.05618 , 3.6946118 , 21.30108564, 5.13448898, -5.05556678, 8.8244415, -8.8484253, -19.295752, 0.3575755 , -25.8066 , -25.42651, -20.61668, -18.63034224, 0.),

(1298535., 50786., 51039., 53173., 53021., 6.55350000e+04, 83., 46884., 48364., 47700., 24558., 14724., 16095., 20359., 44349., 65512., 6.53960000e+04, 43617., 19951., 28916., 16316., 16515., 27568., 28510., 42943., 2942., 12657., 12859., 15272., 3629., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 1., 0., 0., -14.97825 , -14.991155, -10.224834, -10.299165, -6.11770000e-04, 8.4431916, -23.527508, -19.737936, -21.027148, 2.49558396, 1.49625288, 3.3162138 , -26.653981, -27.039968, 61.952, -259.444912 , -30.028685, 3.69572324, 21.91341228, 5.13921368, -5.05342485, 8.8190032, -8.858057 , -19.293244, 0.3748281 , -25.81257, -25.41059, -20.60872, -18.69372897, 0.),

(1326450., 50785., 51037., 53827., 53594., 6.55340000e+04, 79., 46907., 50514., 47803., 24558., 14724., 16095., 20818., 44805., 65509., 1.20000000e+01, 45849., 20011., 27307., 16268., 16529., 27645., 28428., 43072., 2084., 12653., 12856., 15421., 3631., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.980357, -14.995385, -8.839662, -9.089562, -1.22354000e-03, 8.0362908, -23.479691, -15.463736, -20.821869, 2.49558396, 1.49625288, 3.3162138 , -21.723862, -26.098784, 61.946, -255.5961504, -25.308005, 3.70683764, 20.69406381, 5.12409464, -5.05770871, 8.8436355, -8.8325796, -18.969712, 0.29416521, -25.82053, -25.41656, -20.31221, -18.70638658, 0.),

(1328105., 50788., 51041., 53784., 53568., 6.55340000e+04, 81., 46909., 50533., 47813., 24558., 14724., 16095., 20958., 45725., 65514., 6.55350000e+04, 45842., 20012., 22029., 16140., 16533., 27642., 28437., 43082., 2010., 12652., 12847., 15427., 3631., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.974036, -14.986925, -8.930736, -9.144448, -1.22354000e-03, 8.2397412, -23.475533, -15.425964, -20.801939, 2.49558396, 1.49625288, 3.3162138 , -20.220122, -24.199904, 61.956, -255.9253208, -25.32281 , 3.70702288, 16.69423707, 5.0837772 , -5.05893267, 8.8426758, -8.8353759, -18.944632, 0.28675457, -25.82252, -25.43447, -20.30027, -18.70638658, 0.),

(1328400., 50789., 51042., 53773., 53561., 6.55340000e+04, 81., 46911., 50510., 47815., 24558., 14724., 16095., 20836., 44723., 65511., 3.00000000e+00, 44017., 19963., 28902., 16144., 16531., 27640., 28546., 43085., 1901., 12657., 12848., 15431., 3632., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 1., 0., 0., -14.971929, -14.98481 , -8.954034, -9.159225, -1.22354000e-03, 8.2397412, -23.471375, -15.471688, -20.797953, 2.49558396, 1.49625288, 3.3162138 , -21.530524, -26.268032, 61.95 , -255.8240376, -29.182685, 3.69794612, 21.90280266, 5.08503712, -5.05832069, 8.842036 , -8.8692422, -18.937108, 0.27563581, -25.81257, -25.43248, -20.29231, -18.71271292, 0.),

(1328610., 50789., 51041., 53766., 53555., 6.55350000e+04, 81., 46910., 50502., 47817., 24558., 14724., 16095., 20838., 44680., 65511., 2.90000000e+01, 44084., 19970., 28902., 16318., 16538., 27640., 28454., 43089., 3487., 12650., 12852., 15430., 3626., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 1., 0., 0., -14.971929, -14.986925, -8.96886 , -9.171891, -6.11770000e-04, 8.2397412, -23.473454, -15.487592, -20.793967, 2.49558396, 1.49625288, 3.3162138 , -21.509042, -26.356784, 61.95 , -255.1656968, -29.04098 , 3.6992428 , 21.90280266, 5.13984364, -5.06046262, 8.842036 , -8.8406578, -18.927076, 0.42316552, -25.8265 , -25.42452, -20.2943 , -18.67473023, 0.),

(1330145., 50782., 51032., 53668., 53479., 6.55340000e+04, 82., 46912., 50424., 47824., 24557., 14722., 16032., 20840., 44685., 65514., 6.55100000e+04, 44182., 20010., 29024., 16322., 16526., 27499., 28309., 44063., 3733., 12644., 12829., 15439., 3631., 0., 0., 0., 0., 0., 1., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 1., 0., 0., -14.986678, -15.00596 , -9.176424, -9.332327, -1.22354000e-03, 8.3414664, -23.469296, -15.642656, -20.780016, 2.49548234, 1.49604964, 3.30323328, -21.48756 , -26.346464, 61.956, -256.5583408, -28.83371 , 3.7066524 , 21.99525792,

5.14110356, -5.05679074, 8.7969301, -8.7956063, -16.484284, 0.44457195, -25.83844, -25.47029, -20.27639, -18.70638658, 0.),

(1398035., 50796., 51048., 53072., 52920., 6.55340000e+04, 82., 46981., 51246., 48268., 24558., 14724., 16102., 20783., 44314., 65509., 6.55350000e+04, 45823., 20026., 26589., 16250., 16539., 27645., 28508., 43455., 1881., 12637., 12835., 15701., 3637., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., 0., -14.95718 , -14.97212 , -10.438752, -10.512376, -1.22354000e-03, 8.3414664, -23.325845, -14.00852 , -19.895124, 2.49558396, 1.49625288, 3.31765608, -22.099797, -27.112208, 61.946, -255.9253208, -25.362995, 3.70961624, 20.14994187, 5.118425 , -5.06076861, 8.8436355, -8.8574356, -18.009148, 0.27356657, -25.85237, -25.45835, -19.75501, -18.74432007, 0.),

(1401110., 50792., 51046., 52981., 52830., 6.55330000e+04, 80., 46984., 51126., 48291., 24558., 14724., 16099., 21142., 45703., 65514., 6.55350000e+04, 45821., 20026., 21489., 16127., 16520., 27625., 28522., 43484., 1832., 12633., 12847., 15708., 3635., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., 0., -14.965608, -14.97635 , -10.63149 , -10.702366, -1.83531000e-03, 8.138016 , -23.319608, -14.24708 , -19.849285, 2.49558396, 1.49625288, 3.31703796, -18.243778, -24.245312, 61.956, -255.9253208, -25.367225, 3.70961624, 16.28500887, 5.07968246, -5.0549548 , 8.8372375, -8.8617854, -17.936416, 0.2684551 , -25.86033, -25.43447, -19.74108, -18.73168212, 0.),

(1401405., 50792., 51045., 52973., 52822., 6.55340000e+04, 80., 46984., 51085., 48291., 24558., 14724., 16099., 20756., 44264., 65506., 6.55020000e+04, 43581., 19969., 28626., 16310., 16492., 27606., 28507., 43489., 2817., 12632., 12828., 15710., 3637., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 1., 0., 0., -14.965608, -14.978465, -10.648434, -10.719254, -1.22354000e-03, 8.138016 , -23.319608, -14.328588, -19.849285, 2.49558396, 1.49625288, 3.31703796, -22.389804, -27.215408, 61.94 , -256.7609072, -30.104825, 3.69905756, 21.69364158, 5.1373238 , -5.04638708, 8.8311594, -8.8571249, -17.923876, 0.36350659, -25.86232, -25.47228, -19.7371 , -18.74432007, 0.),

(1401825., 50792., 51045., 52958., 52808., 6.55340000e+04, 82., 46985., 51054., 48294., 24558., 14724., 16099., 20635., 44520., 65510., 6.55000000e+04, 45797., 20026., 27994., 16284., 16495., 27622., 28531., 43486., 1977., 12634., 12834., 15709., 3637., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.965608, -14.978465, -10.680204, -10.748808, -1.22354000e-03, 8.3414664, -23.317529, -14.390216, -19.843306, 2.49558396, 1.49625288, 3.31703796, -23.689465, -26.687024, 61.948, -256.8115488, -25.417985, 3.70961624, 21.21469302, 5.12913432, -5.04730505, 8.8362778, -8.8645817, -17.9314 , 0.28341525, -25.85834, -25.46034, -19.73909, -18.74432007, 0.),

(1401970., 50792., 51045., 52955., 52805., 6.55340000e+04, 82., 46987., 51037., 48298., 24558., 14724., 16101., 21134., 45704., 65514., 6.55350000e+04, 45819., 20026., 21854., 16135., 16504., 27621., 28504., 43488., 1833., 12634., 12840., 15711., 3636., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.965608, -14.978465, -10.686558, -10.755141, -1.22354000e-03, 8.3414664, -23.313371, -14.424012, -19.835334, 2.49558396, 1.49625288, 3.31745004, -18.329706, -24.243248, 61.956, -255.9253208, -25.371455, 3.70961624, 16.56161682, 5.0822023 , -5.05005896, 8.8359579, -8.8561928, -17.926384, 0.26856003, -25.85834, -25.4484 , -19.73511, -18.73800191, 0.),

(1404285., 50789., 51042., 52889., 52739., 6.55340000e+04, 81., 46988., 50812., 48308., 24558., 14724., 16099., 21111., 45702., 65514., 6.55340000e+04, 45816., 20025., 21870., 16135., 16491., 27620., 28526., 43503., 1954., 12634., 12842., 15701., 3635., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.971929, -14.98481 , -10.826346, -10.894467, -1.22354000e-03, 8.2397412, -23.311292, -14.871312, -19.815404, 2.49558396, 1.49625288, 3.31703796, -18.576749, -24.247376, 61.956, -255.9506416, -25.3778 , 3.709431 , 16.5737421 , 5.0822023 , -5.04608109, 8.835638 , -8.8630282, -17.888764, 0.28107441, -25.85834, -25.44442, -19.75501, -18.73168212, 0.),

(1404470., 50789., 51042., 52882., 52742., 1.40000000e+01, 97., 47008., 50790., 48309., 24558., 14723., 16094., 21099., 45686., 65513., 6.55350000e+04, 45794., 20031., 23155., 16167., 16491., 27614., 28499., 43503., 2142., 12633., 12838., 15703., 3634., 0., 0., 1., 1., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.971929, -14.98481 , -10.841172, -10.888134, 8.56478000e-03, 9.8673444, -23.269712, -14.915048, -19.813411, 2.49558396, 1.49615126, 3.31600776, -18.705641, -24.2804 , 61.954, -255.9253208, -25.42433 , 3.71054244, 17.54755365, 5.09228166, -5.04608109, 8.8337186, -8.8546393, -17.888764, 0.29990437, -25.86033, -25.45238, -19.75103, -18.72536069, 0.),

(1405575., 50785., 51039., 52862., 52702., 2.45210000e+04, 11842., 47241., 50669., 48318., 24558., 14724., 16069., 21096., 45695., 65514., 8.73400000e+03, 45841., 20050., 28070., 16303., 16493., 27609., 28495., 43584., 3535., 12632., 12839., 15703., 3636., 0., 0., 1., 1., 1., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.980357, -14.991155, -10.883532, -10.972574, 1.50012122e+01, 1204.6298184, -22.785305, -15.155596, -19.795474, 2.49558396, 1.49625288, 3.31085676, -18.737864, -24.261824, 61.956, -34.7481328, -25.324925, 3.714062 , 21.2722881 , 5.13511894, -5.04669307, 8.8321191, -8.8533965, -17.685616, 0.42735913, -25.86232, -25.45039, -19.75103, -18.73800191, 0.),

(1416730., 50808., 51057., 53733., 53347., 2.45200000e+04, 11841., 47814., 49719., 48381., 24558., 14724., 16070., 21003., 45694., 65514., 8.74800000e+03, 45841., 20053., 28884., 16316., 16513., 27615., 28450., 43684., 3697., 12630., 12833., 15733., 3638., 0., 0., 1., 1., 1., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0.,

0., 0., -14.931896, -14.953085, -9.038754, -9.610979, 1.50006004e+01, 1204.5280932, -21.594038, -17.044196, -19.669915, 2.49558396, 1.49625288, 3.3110628 , -19.736777, -24.263888, 61.956, -34.3936416, -25.324925, 3.71461772, 21.88916172, 5.13921368, -5.05281287, 8.8340385, -8.839415 , -17.434816, 0.44145204, -25.8663 , -25.46233, -19.69133, -18.75063659, 0.),

(1416920., 50808., 51057., 53749., 53364., 2.45210000e+04, 11844., 47808., 49706., 48381., 24558., 14723., 16071., 21000., 45691., 65513., 8.72800000e+03, 45837., 20053., 28270., 16298., 16536., 27612., 28503., 43642., 2602., 12628., 12832., 15735., 3636., 0., 0., 1., 1., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.931896, -14.953085, -9.004866, -9.575092, 1.50012122e+01, 1204.8332688, -21.606512, -17.07004 , -19.669915, 2.49558396, 1.49615126, 3.31126884, -19.769 , -24.27008 , 61.954, -34.9000576, -25.333385, 3.71461772, 21.4238541 , 5.13354404, -5.05985064, 8.8330788, -8.8558821, -17.540152, 0.34375878, -25.87028, -25.46432, -19.68735, -18.73800191, 0.),

(1417715., 50806., 51056., 53805., 53432., 2.45200000e+04, 11842., 47792., 49662., 48386., 24558., 14723., 16096., 20992., 45693., 65513., 6.55350000e+04, 45802., 20030., 28318., 16298., 16525., 27609., 28535., 43612., 2719., 12630., 12839., 15737., 3651., 30., 0., 1., 1., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.93611 , -14.9552 , -8.886258, -9.431544, 1.50006004e+01, 1204.6298184, -21.639776, -17.157512, -19.65995 , 2.49558396, 1.49615126, 3.31641984, -19.854928, -24.265952, 61.954, -255.9253208, -25.40741 , 3.7103572 , 21.46022994, 5.13354404, -5.05648475, 8.8321191, -8.8658245, -17.615392, 0.3545519 , -25.8663 , -25.45039, -19.68337, -18.83260299, 30.),

(1431780., 50777., 51030., 53592., 53416., 2.45200000e+04, 11842., 47447., 49224., 48434., 24558., 14723., 16095., 20933., 45685., 65514., 6.55350000e+04, 45801., 20034., 27902., 16288., 16532., 27659., 28457., 43690., 2537., 12619., 12832., 15783., 3636., 30., 0., 1., 1., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.997213, -15.01019 , -9.337392, -9.46532 , 1.50006004e+01, 1204.6298184, -22.357031, -18.028256, -19.564286, 2.49558396, 1.49615126, 3.3162138 , -20.488647, -24.282464, 61.956, -255.9253208, -25.409525, 3.71109816, 21.14497266, 5.13039424, -5.05862668, 8.8481141, -8.8415899, -17.419768, 0.33770916, -25.88819, -25.46432, -19.59183, -18.73800191, 30.),

(1432880., 50777., 51030., 53557., 53384., 2.45200000e+04, 11841., 47441., 49207., 48436., 24558., 14723., 16095., 20930., 45689., 65513., 6.55350000e+04, 45798., 20034., 27594., 16280., 16533., 27661., 28499., 43696., 2814., 12626., 12830., 15789., 3638., 30., 0., 1., 1., 0., 0., 1., 1., 1., 0., 1., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., -14.997213, -15.01019 , -9.411522, -9.532872, 1.50006004e+01, 1204.5280932, -22.369505, -18.062052, -19.5603 , 2.49558396, 1.49615126, 3.3162138 , -20.52087 , -24.274208, 61.954, -255.9253208, -25.41587 , 3.71109816, 20.91156102, 5.1278744 , -5.05893267, 8.8487539, -8.8546393, -17.40472 , 0.36323354, -25.87426, -25.4683 , -19.57989, -18.75063659, 30.)],

dtype=(numpy.record, [('mu_ms_offset', '>f8'), ('00_Laser_osc1_Temp', '>f8'), ('01_Laser_osc2_Temp', '>f8'), ('02_Laser_doub1_Temp', '>f8'), ('03_Laser_doub2_Temp', '>f8'), ('04_Laser_15V', '>f8'), ('05_Laser_HV', '>f8'), ('06_Laser_Limiter_Temp', '>f8'), ('07_DPU_Motor_Driver_Temp', '>f8'), ('08_DPU_FPGA_Temp', '>f8'), ('09_Vref_+2.5V', '>f8'), ('10_+1.5V', '>f8'), ('11_+3.3V', '>f8'), ('12_Motor_Temperature', '>f8'), ('13_Primary_Mirror_Temp', '>f8'), ('14_CWL_Pd_Current', '>f8'), ('15_Micro_Temp', '>f8'), ('16_CWL_Temp', '>f8'), ('17_+3.3_IRS', '>f8'), ('18_+20V_RF_IRS', '>f8'), ('19_+5V_RF_IRS', '>f8'), ('20_-5V_RF_IRS', '>f8'), ('21_+5V_DT_IRS', '>f8'), ('22_-5V_DT_IRS', '>f8'), ('23_LVPS_Board_Temp', '>f8'), ('24_Primary_Current', '>f8'), ('25_IRS_HK_Temp_AOTF', '>f8'), ('26_IRS_HK_TEMP_HOT_TEC', '>f8'), ('27_IRS_HK_Temp_board', '>f8'), ('28_IRS_HK_Temp_DET', '>f8'), ('29_Remaining_laser_pulses', '>f8'), ('30_ONOFF_shutter', '>f8'), ('31_ONOFF_limiter', '>f8'), ('32_ONOFF_High_voltage_15V', '>f8'), ('33_ONOFF_Microphone', '>f8'), ('34_ONOFF_RMI', '>f8'), ('35_ONOFF_DCDC', '>f8'), ('36_ONOFF_heater_doubler_laser', '>f8'), ('37_ONOFF_heater_stack_laser', '>f8'), ('38_ONOFF_heater_CWL', '>f8'), ('39_Heater_Doubler_Reached', '>f8'), ('40_Heater_Stack_Reached', '>f8'), ('41_Heater_CWL_Reached', '>f8'), ('42_IRS_DET_Sel', '>f8'), ('43_IRS_TEC_ONOFF', '>f8'), ('44_IRS_TEC_Ready', '>f8'), ('45_IRS_Measure_Done', '>f8'), ('46_Motor_driver_circuit_thermal_flag', '>f8'), ('47_AF_gain_status_MSB', '>f8'), ('48_AF_gain_status_LSB', '>f8'), ('49_ONOFF_CWL', '>f8'), ('50_ONOFF_CWL_modulation', '>f8'), ('51_ONOFF_motor_driver', '>f8'), ('52_Infinite_limit_switch_status', '>f8'), ('53_Close_limit_switch_status', '>f8'), ('C00_Laser_osc1_Temp', '>f8'), ('C01_Laser_osc2_Temp', '>f8'), ('C02_Laser_doub1_Temp', '>f8'), ('C03_Laser_doub2_Temp', '>f8'), ('C04_Laser_15V', '>f8'), ('C05_Laser_HV', '>f8'), ('C06_Laser_Limiter_Temp', '>f8'), ('C07_DPU_Motor_Driver_Temp', '>f8'), ('C08_DPU_FPGA_Temp', '>f8'), ('C09_Vref_+2.5V', '>f8'), ('C10_+1.5V', '>f8'), ('C11_+3.3V', '>f8'), ('C12_Motor_Temperature', '>f8'), ('C13_Primary_Mirror_Temp', '>f8'), ('C14_CWL_Pd_Current', '>f8'), ('C15_Micro_Temp', '>f8'), ('C16_CWL_Temp', '>f8'), ('C17_+3.3_IRS', '>f8'), ('C18_+20V_RF_IRS', '>f8'), ('C19_+5V_RF_IRS', '>f8'), ('C20_-5V_RF_IRS', '>f8'), ('C21_+5V_DT_IRS', '>f8'), ('C22_-5V_DT_IRS', '>f8'), ('C23_LVPS_Board_Temp', '>f8'), ('C24_Primary_Current', '>f8'), ('C25_IRS_HK_Temp_AOTF', '>f8'), ('C26_IRS_HK_TEMP_HOT_TEC', '>f8'), ('C27_IRS_HK_Temp_board', '>f8'), ('C28_IRS_HK_Temp_DET', '>f8'), ('C29_Remaining_laser_pulses', '>f8')]))

HDU 4 - BU State of Health (SOH) :

An example of the contents of HDU 4 header:

XTENSION= 'BINTABLE' / binary table extension
BITPIX = 8 / array data type

```
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                  984 / length of dimension 1
NAXIS2  =                   21 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                  123 / number of table fields
EXTNAME = 'BU_SOH  '           / extension name
TTYPE1  = 'bu_ms_offset'
TFORM1  = 'D       '
TTYPE2  = '00_tlm_format_version_cmd_dict_version'
TFORM2  = 'D       '
TTYPE3  = '01_last_BIST_result'
TFORM3  = 'D       '
TTYPE4  = '02_current_status_flags'
TFORM4  = 'D       '
TTYPE5  = '03_boot_bank_selected'
TFORM5  = 'D       '
TTYPE6  = '04_boot_bank_actual'
TFORM6  = 'D       '
TTYPE7  = '05_commands_received'
TFORM7  = 'D       '
TTYPE8  = '06_commands_completed'
TFORM8  = 'D       '
TTYPE9  = '07_commands_rejected'
TFORM9  = 'D       '
TTYPE10 = '08_number_of_error_log_entries_since_boot'
TFORM10 = 'D       '
TTYPE11 = '09_bank_A_kernel_calculated_checksum_NV'
TFORM11 = 'D       '
TTYPE12 = '10_bank_A_application_calculated_checksum_NV'
TFORM12 = 'D       '
TTYPE13 = '11_bank_B_kernel_calculated_checksum_NV'
TFORM13 = 'D       '
TTYPE14 = '12_bank_B_application_calculated_checksum_NV'
TFORM14 = 'D       '
TTYPE15 = '13_rce_comm_side'
TFORM15 = 'D       '
TTYPE16 = '14_spacewire_comm_error_count_NV'
TFORM16 = 'D       '
TTYPE17 = '15_last_spacewire_error_status_register'
TFORM17 = 'D       '
TTYPE18 = '16_single_bit_MRAM_memory_errors_NV'
TFORM18 = 'D       '
TTYPE19 = '17_single_bit_SDRAM_memory_errors_NV'
TFORM19 = 'D       '
TTYPE20 = '18_last_single_bit_memory_address'
TFORM20 = 'D       '
TTYPE21 = '19_software_version'
TFORM21 = 'D       '
TTYPE22 = '20_PULSES_ID_REG'
TFORM22 = 'D       '
TTYPE23 = '21_ROVER_HSS_TX_WD_CNT_REG'
TFORM23 = 'D       '
TTYPE24 = '22_IRQ_CLR_REG'
TFORM24 = 'D       '
TTYPE25 = '23_ROVER_HSS_CNTRL_REG'
TFORM25 = 'D       '
TTYPE26 = '24_ROVER_HSS_TX_REG'
TFORM26 = 'D       '
TTYPE27 = '25_IRQ_EN_REG'
TFORM27 = 'D       '
```

TTYPE28 = '26_UART_TX_DATA_CNTRL_REG'
TFORM28 = 'D '
TTYPE29 = '27_UART_CNTRL_REG'
TFORM29 = 'D '
TTYPE30 = '28_LVPS_CTRL_REG'
TFORM30 = 'D '
TTYPE31 = '29_MRAM_CNTRL_REG'
TFORM31 = 'D '
TTYPE32 = '30_LED_REG'
TFORM32 = 'D '
TTYPE33 = '31_INT_TIME_REG'
TFORM33 = 'D '
TTYPE34 = '32_NSPS_REG'
TFORM34 = 'D '
TTYPE35 = '33_LZR_REP_RATE_REG'
TFORM35 = 'D '
TTYPE36 = '34_SPW_CTRL_REG'
TFORM36 = 'D '
TTYPE37 = '35_TEST_CTRL_REG'
TFORM37 = 'D '
TTYPE38 = '36_MU_HSS_EMU_REG'
TFORM38 = 'D '
TTYPE39 = '37_NUM_SPECTRA_REG'
TFORM39 = 'D '
TTYPE40 = '38_HVPS_DLY_REG'
TFORM40 = 'D '
TTYPE41 = '39_HVPS_DUR_REG'
TFORM41 = 'D '
TTYPE42 = '40_STATUS0_REG'
TFORM42 = 'D '
TTYPE43 = '41_IRQ_STAT_REG'
TFORM43 = 'D '
TTYPE44 = '42_ROVER_HSS_FRAME_STAT_REG'
TFORM44 = 'D '
TTYPE45 = '43_UART_STAT_REG'
TFORM45 = 'D '
TTYPE46 = '44_ROVER_HSS_STAT_REG'
TFORM46 = 'D '
TTYPE47 = '45_SPW_STAT_REG'
TFORM47 = 'D '
TTYPE48 = '46_CNDH_PCB_TEMP'
TFORM48 = 'D '
TTYPE49 = '47_CNDH_1_2_V'
TFORM49 = 'D '
TTYPE50 = '48_CNDH_LVPS_TEMP'
TFORM50 = 'D '
TTYPE51 = '49_CNDH_3_3_V'
TFORM51 = 'D '
TTYPE52 = '50_CNDH_VUI_UV_SPECT_TEMP'
TFORM52 = 'D '
TTYPE53 = '51_CNDH_NEG_15_V'
TFORM53 = 'D '
TTYPE54 = '52_CNDH_15_V'
TFORM54 = 'D '
TTYPE55 = '53_CNDH_1_5_V'
TFORM55 = 'D '
TTYPE56 = '54_TEST_STAT_REG'
TFORM56 = 'D '
TTYPE57 = '55_IDENTITY_STAT_REG'
TFORM57 = 'D '
TTYPE58 = '56_TEST2_STAT_REG'

TFORM58 = 'D '
TTYPE59 = '57_MISSED_PULSE_REG'
TFORM59 = 'D '
TTYPE60 = '58_SE_TX_TEMP'
TFORM60 = 'D '
TTYPE61 = '59_SE_VIO_TEMP'
TFORM61 = 'D '
TTYPE62 = '60_SE_UV_TEMP'
TFORM62 = 'D '
TTYPE63 = '61_SE_TM_TEMP'
TFORM63 = 'D '
TTYPE64 = '62_SE_24_V'
TFORM64 = 'D '
TTYPE65 = '63_SE_HVPS_REAR'
TFORM65 = 'D '
TTYPE66 = '64_SE_HVPS_CURRENT'
TFORM66 = 'D '
TTYPE67 = '65_SE_HVPS_TEMP'
TFORM67 = 'D '
TTYPE68 = '66_number_of_commands_sent_to_MU'
TFORM68 = 'D '
TTYPE69 = '67_MU_commands_ACKed_by_MU'
TFORM69 = 'D '
TTYPE70 = '68_MU_commands_NAKed_by_MU'
TFORM70 = 'D '
TTYPE71 = '69_MU_packets_received_success'
TFORM71 = 'D '
TTYPE72 = '70_MU_packets_received_error'
TFORM72 = 'D '
TTYPE73 = '71_number_of_BU_spectra_read_out_NV'
TFORM73 = 'D '
TTYPE74 = '72_number_of_RMI_received_from_MU_NV'
TFORM74 = 'D '
TTYPE75 = '73_number_of_microphone_recordings_NV'
TFORM75 = 'D '
TTYPE76 = '74_number_of_science_laser_shots_commanded_NV'
TFORM76 = 'D '
TTYPE77 = '75_current_absolute_focus_table_position'
TFORM77 = 'D '
TTYPE78 = '76_close_limit_switch_position_difference'
TFORM78 = 'D '
TTYPE79 = '77_far_limit_switch_position_difference'
TFORM79 = 'D '
TTYPE80 = '78_current_autofocus_baseline_position'
TFORM80 = 'D '
TTYPE81 = '79_current_spacewire_link_0_status_register'
TFORM81 = 'D '
TTYPE82 = '80_current_spacewire_link_1_status_register'
TFORM82 = 'D '
TTYPE83 = '81_current_spacewire_link_2_status_register'
TFORM83 = 'D '
TTYPE84 = '82_current_spacewire_link_3_status_register'
TFORM84 = 'D '
TTYPE85 = '83_current_focus_table_position_in_mm'
TFORM85 = 'D '
TTYPE86 = '84_reserved'
TFORM86 = 'D '
TTYPE87 = '85_status_flags'
TFORM87 = 'D '
TTYPE88 = '86_motor_speed_inhibited'
TFORM88 = 'D '

TTYPE89 = '87_laser_current_inhibited'
TFORM89 = 'D '
TTYPE90 = '88_CCD_is_clocking'
TFORM90 = 'D '
TTYPE91 = '89_limit_swithch_arg_changed_to_computed_value'
TFORM91 = 'D '
TTYPE92 = '90_focus_motor_inhibited'
TFORM92 = 'D '
TTYPE93 = '02a_sys_error'
TFORM93 = 'D '
TTYPE94 = '02b_send_evr'
TFORM94 = 'D '
TTYPE95 = '02c_shutdown'
TFORM95 = 'D '
TTYPE96 = '02d_sun_safe'
TFORM96 = 'D '
TTYPE97 = '02e_bu_hvps_on'
TFORM97 = 'D '
TTYPE98 = '02f_mu_shutter'
TFORM98 = 'D '
TTYPE99 = '02g_mu_laser_on'
TFORM99 = 'D '
TTYPE100= '02h_mu_dc_chain_on'
TFORM100= 'D '
TTYPE101= '02i_mu_on'
TFORM101= 'D '
TTYPE102= '02j_ccd_almost_ready'
TFORM102= 'D '
TTYPE103= '02k_ccd_ready'
TFORM103= 'D '
TTYPE104= '02l_irs_ready'
TFORM104= 'D '
TTYPE105= '02m_laser_doubler_ready'
TFORM105= 'D '
TTYPE106= '02n_laser_stack_ready'
TFORM106= 'D '
TTYPE107= '02o_cwl_ready'
TFORM107= 'D '
TTYPE108= 'C46_CNDH_PCB_TEMP'
TFORM108= 'D '
TTYPE109= 'C47_CNDH_1_2_V'
TFORM109= 'D '
TTYPE110= 'C48_CNDH_LVPS_TEMP'
TFORM110= 'D '
TTYPE111= 'C49_CNDH_3_3_V'
TFORM111= 'D '
TTYPE112= 'C50_CNDH_VUI_UV_SPECT_TEMP'
TFORM112= 'D '
TTYPE113= 'C51_CNDH_NEG_15_V'
TFORM113= 'D '
TTYPE114= 'C52_CNDH_15_V'
TFORM114= 'D '
TTYPE115= 'C53_CNDH_1_5_V'
TFORM115= 'D '
TTYPE116= 'C58_SE_TX_TEMP'
TFORM116= 'D '
TTYPE117= 'C59_SE_VIO_TEMP'
TFORM117= 'D '
TTYPE118= 'C60_SE_UV_TEMP'
TFORM118= 'D '
TTYPE119= 'C61_SE_TM_TEMP'

TFORM119= 'D '
TTYPE120= 'C62_SE_24_V'
TFORM120= 'D '
TTYPE121= 'C63_SE_HVPS_REAR'
TFORM121= 'D '
TTYPE122= 'C64_SE_HVPS_CURRENT'
TFORM122= 'D '
TTYPE123= 'C65_SE_HVPS_TEMP'
TFORM123= 'D '

An example of the contents of HDU 4 data:

FITS_rec([(1298115., 23., 0., 2246., 0., 0., 82., 81., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27473., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2158., 990., 2022., 2074., 1764., 2135., 2140., 1232., 48879., 100., 305., 0., 1432., 1445., 1450., 1810., 2111., 12., 58., 1913., 63., 63., 0., 109., 0., 17616., 489., 152., 8257., 4615., 4., 0., 0., 0., 0., 8., 16., 1997., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20849609, 26.4244, 3.37227539, 19.1408, 14.98565674, 15.02075195, 1.50390625, -1.66600000e-01, -0.9515, -2.017 , 20.072 , 24.29968934, 7.32421875, 0.00566405, 23.4621),

(1298410., 23., 0., 2246., 0., 0., 87., 86., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27473., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2158., 990., 2022., 2074., 1763., 2135., 2140., 1232., 48879., 100., 309., 0., 1435., 1447., 1449., 1812., 2111., 13., 58., 1913., 67., 67., 0., 114., 0., 17616., 489., 152., 8257., 4615., 4., 0., 0., 0., 0., 8., 16., 1997., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20849609, 26.4244, 3.37227539, 19.0861, 14.98565674, 15.02075195, 1.50390625, -2.50000000e-03, -0.8421, -2.0717, 20.1814, 24.29968934, 7.93457031, 0.00566405, 23.4621),

(1298545., 23., 0., 2246., 0., 0., 89., 88., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27473., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2158., 990., 2022., 2071., 1766., 2135., 2140., 1232., 48879., 100., 313., 0., 1435., 1449., 1448., 1815., 2111., 13., 58., 1913., 68., 68., 0., 116., 0., 17616., 489., 152., 8257., 4615., 4., 0., 0., 0., 0., 8., 16., 1995., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20849609, 26.4244, 3.36739746, 19.2502, 14.98565674, 15.02075195, 1.50390625, -2.50000000e-03, -0.7327, -2.1264, 20.3455, 24.29968934, 7.93457031, 0.00566405, 23.4621),

(1326460., 23., 0., 198., 0., 0., 93., 92., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2157., 989., 2022., 2074., 1769., 2135., 2140., 1232., 48879., 100., 317., 0., 1432., 1444., 1454., 1809., 2113., 13., 58., 1913., 72., 72., 0., 123., 0., 17616., 489., 152., 8257., 7824., 4., 0., 0., 0., 0., 8., 16., 5183., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8089, 1.20727539, 26.4244, 3.37227539, 19.4143, 14.98565674, 15.02075195, 1.50390625, -1.66600000e-01, -1.0062, -1.7982, 20.0173, 24.3227113 , 7.93457031, 0.00566405, 23.4621),

(1328115., 23., 0., 198., 0., 0., 96., 95., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2158., 989., 2022., 2073., 1762., 2135., 2140., 1232., 48879., 100., 321., 0., 1431., 1446., 1452., 1811., 2113., 13., 58., 1913., 74., 74., 0., 127., 0., 17616., 489., 152., 8257., 7824., 4., 0., 0., 0., 0., 8., 16., 5191., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20727539, 26.4244, 3.37064941, 19.0314, 14.98565674, 15.02075195, 1.50390625, -2.21300000e-01, -0.8968, -1.9076, 20.1267, 24.3227113 , 7.93457031, 0.00566405, 23.4621),

(1328445., 23., 0., 198., 0., 0., 101., 100., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2157., 989., 2022., 2075., 1764., 2135., 2140., 1232., 48879., 100., 325., 0., 1432., 1444., 1448., 1812., 2101., 13., 58., 1914., 78., 78., 0., 132., 0., 17616., 489., 152., 8257., 7824., 4., 0., 0., 0., 0., 8., 16., 5183., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8089, 1.20727539, 26.4244, 3.37390137, 19.1408, 14.98565674, 15.02075195, 1.50390625, -1.66600000e-01, -1.0062, -2.1264, 20.1814, 24.18457949, 7.93457031, 0.00566405, 23.5168),

(1328620., 23., 0., 198., 0., 0., 103., 102., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2158., 989., 2022., 2074., 1765., 2135., 2140., 1232., 48879., 100., 329., 0., 1432., 1443., 1448., 1811., 2110., 13., 59., 1915., 79., 79., 0., 134., 0., 17616., 489., 152., 8257., 7824., 4., 0., 0., 0., 0., 8., 16., 5183., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20727539, 26.4244, 3.37227539, 19.1955, 14.98565674, 15.02075195, 1.50390625, -1.66600000e-01, -1.0609, -2.1264, 20.1267, 24.28817835, 7.93457031, 0.0057617 , 23.5715),

(1330155., 23., 0., 198., 0., 0., 110., 109., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2158., 990., 2022., 2074., 1765., 2135., 2140., 1232., 48879., 100., 333., 0., 1435., 1443., 1448., 1810., 2101., 13., 58., 1913., 85., 85., 0., 142., 0., 17616., 489., 152., 8257., 7824., 4., 0., 0., 0., 0., 8., 16., 5183., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20849609, 26.4244, 3.37227539, 19.1955, 14.98565674, 15.02075195, 1.50390625, -2.50000000e-03, -1.0609, -2.1264, 20.072 , 24.18457949, 7.93457031, 0.00566405, 23.4621),

(1398050., 23., 0., 198., 0., 0., 115., 114., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2157., 990., 2022., 2074., 1762., 2135., 2140., 1232., 48879., 100., 337., 0., 1429., 1440., 1445., 1813., 2104., 13., 58., 1916., 89., 89., 0., 148., 0., 17616., 489., 152., 8257., 7813., 4., 0., 7813., 0., 0., 8., 16., 5150., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8089, 1.20849609, 26.4244, 3.37227539, 19.0314, 14.98565674, 15.02075195, 1.50390625, -3.30700000e-01, -1.225 , -2.2905, 20.2361, 24.21911244, 7.93457031, 0.00566405, 23.6262),

(1401120., 23., 0., 198., 0., 0., 118., 117., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2158., 989., 2021., 2072., 1764., 2135., 2140., 1232., 48879., 100., 341., 0., 1428., 1440., 1444., 1813., 2113., 13., 58., 1916., 90., 90., 0., 150., 0., 17616., 489., 152., 8257., 7813., 4., 0., 7813., 0., 0., 8., 16., 5163., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20727539, 26.3697, 3.36902344, 19.1408, 14.98565674, 15.02075195, 1.50390625, -3.85400000e-01, -1.225 , -2.3452, 20.2361, 24.3227113 , 7.93457031, 0.00566405, 23.6262),

(1401415., 23., 0., 198., 0., 0., 123., 122., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2157., 990., 2022., 2074., 1762., 2135., 2140., 1232., 48879., 100., 345., 0., 1428., 1440., 1443., 1810., 2113., 13., 58., 1914., 94., 94., 0., 155., 0., 17616., 489., 152., 8257., 7813., 4., 0., 7813., 0., 0., 8., 16., 5150., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8089, 1.20849609, 26.4244, 3.37227539, 19.0314, 14.98565674, 15.02075195, 1.50390625, -3.85400000e-01, -1.225 , -2.3999, 20.072 , 24.3227113 , 7.93457031, 0.00566405, 23.5168),

(1401835., 23., 0., 198., 0., 0., 127., 126., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2157., 990., 2021., 2073., 1756., 2135., 2140., 1232., 48879., 100., 349., 0., 1431., 1443., 1443., 1812., 2102., 13., 58., 1915., 97., 97., 0., 160., 0., 17616., 489., 152., 8257., 7790., 4., 0., 7813., 0., 0., 8., 16., 5093., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8089, 1.20849609, 26.3697, 3.37064941, 18.7032, 14.98565674, 15.02075195, 1.50390625, -2.21300000e-01, -1.0609, -2.3999, 20.1814, 24.19609047, 7.93457031, 0.00566405, 23.5715),

(1401980., 23., 0., 198., 0., 0., 130., 129., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 27472., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 0., 0., 1., 0., 0., 2056., 41216., 10., 2157., 989., 2022., 2074., 1763., 2135., 2140., 1232., 48879., 100., 353., 0., 1432., 1443., 1443., 1812., 2108., 13., 58., 1918., 98., 98., 0., 162., 0., 17616., 489., 152., 8257., 7790., 4., 0., 7813., 0., 0., 8., 16., 5105., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8089, 1.20727539, 26.4244, 3.37227539, 19.0861, 14.98565674, 15.02075195, 1.50390625, -1.66600000e-01, -1.0609, -2.3999, 20.1814, 24.26515638, 7.93457031, 0.00566405, 23.7356),

(1404300., 23., 0., 1222., 0., 0., 143., 142., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 60240., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 65., 1000., 1., 0., 0., 2056., 41216., 10., 2157., 990., 2022., 2074., 1762., 2112., 2140., 1232., 48879., 100., 357., 0., 1483., 1447., 1402., 1828., 2111., 1355., 399., 1935., 100., 100., 0., 165., 0., 17616., 489., 152., 8257., 7790., 4., 0., 7813., 0., 0., 0., 0., 5105., 0., 4., 0., 0., 1., 0., 0., 0., 0., 0., 0., 1., 0., 0., 1., 1., 0., 0., 0., 1., 1., 0., 33.8089, 1.20849609, 26.4244, 3.37227539, 19.0314, 14.82421875, 15.02075195, 1.50390625, 2.62310000e+00, -0.8421, -4.6426, 21.0566, 24.29968934, 827.02636719, 0.03896474, 24.6655),

(1404480., 23., 0., 1478., 0., 0., 146., 145., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 2896., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 65., 1000., 1., 0., 0., 2056., 41216., 10., 2157., 989., 2022., 2073., 1760., 2111., 2140., 1232., 48879., 100., 361., 0., 1488., 1486., 1491., 1830., 2112., 1362., 441., 1931., 102., 102., 0., 168., 0., 17616., 489., 152., 8257., 7790., 4., 0., 7813., 0., 0., 0., 0., 5105., 0., 4., 0., 0., 1., 0., 0., 0., 0., 0., 0., 1., 0., 1., 1., 1., 0., 0., 0., 1., 1., 0., 33.8089, 1.20727539, 26.4244, 3.37064941, 18.922 , 14.81719971, 15.02075195, 1.50390625, 2.89660000e+00, 1.2912, 0.2257, 21.166 , 24.31120032, 831.29882812, 0.0430663 , 24.4467),

(1405585., 23., 0., 1478., 0., 0., 150., 149., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 2896., 182., 170., 1., 3., 4., 0., 0., 0., 0., 0., 48879., 0., 0., 65., 1000., 1., 0., 0., 2056., 41216., 10., 2157., 990., 2022., 2070., 1764., 2112., 2140., 1232., 48879., 100., 365., 0., 1477., 1486., 1471., 1834., 2111., 1359., 425., 1934., 105., 105., 0., 172., 0., 17616., 489., 152., 8257., 7790., 4., 0., 7813., 0., 0., 0., 0., 5105., 0., 4., 0., 0., 1., 0., 0., 0., 0., 0., 0., 1., 0., 1., 1., 1., 0., 0., 0., 1., 1., 0., 33.8089, 1.20849609, 26.4244, 3.36577148,

19.1408, 14.82421875, 15.02075195, 1.50390625, 2.29490000e+00, 1.2912, -0.8683, 21.3848, 24.29968934, 829.46777344, 0.0415038 , 24.6108),
(1416740., 23., 0., 1478., 0., 0., 154., 153., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 2896., 182., 170., 1., 3., 4., 0., 0., 0., 63808., 0., 48879., 0., 30., 65., 1000., 1., 0., 0., 2056., 41216., 10., 2158., 990., 2021., 2073., 1762., 2111., 2140., 1232., 48879., 100., 369., 0., 1419., 1474., 1427., 1827., 2104., 1361., 432., 1935., 107., 107., 0., 176., 0., 17706., 489., 152., 8287., 7790., 4., 0., 7813., 0., 0., 0., 0., 5105., 0., 4., 0., 0., 1., 0., 0., 0., 0., 0., 0., 1., 0., 1., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20849609, 26.3697, 3.37064941, 19.0314, 14.81719971, 15.02075195, 1.50390625, -8.77700000e-01, 0.6348, -3.2751, 21.0019, 24.21911244, 830.68847656, 0.04218739, 24.6655),
(1416930., 23., 0., 1478., 0., 0., 157., 156., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 2896., 182., 170., 1., 3., 4., 0., 0., 0., 63808., 0., 48879., 0., 30., 65., 1000., 1., 0., 0., 2056., 41216., 10., 2158., 990., 2021., 2074., 1761., 2111., 2140., 1232., 48879., 100., 373., 0., 1479., 1476., 1495., 1831., 2102., 1356., 445., 1936., 109., 109., 0., 179., 0., 17706., 489., 152., 8287., 7790., 4., 0., 7813., 0., 0., 0., 0., 5105., 0., 4., 0., 0., 1., 0., 0., 0., 0., 0., 0., 1., 0., 1., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20849609, 26.3697, 3.37227539, 18.9767, 14.81719971, 15.02075195, 1.50390625, 2.40430000e+00, 0.7442, 0.4445, 21.2207, 24.19609047, 827.63671875, 0.04345692, 24.7202),
(1417725., 23., 0., 1478., 0., 0., 162., 161., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 2896., 182., 170., 1., 3., 4., 0., 0., 0., 63808., 0., 48879., 0., 30., 65., 1000., 1., 0., 0., 2056., 41216., 10., 2158., 990., 2021., 2073., 1762., 2112., 2140., 1232., 48879., 100., 377., 0., 1475., 1407., 1438., 1828., 2113., 1362., 391., 1932., 113., 113., 0., 185., 0., 17706., 489., 153., 8287., 7790., 4., 0., 7813., 0., 0., 0., 0., 5105., 0., 4., 0., 0., 1., 0., 0., 0., 0., 0., 0., 1., 0., 1., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20849609, 26.3697, 3.37064941, 19.0314, 14.82421875, 15.02075195, 1.50390625, 2.18550000e+00, -3.0301, -2.6734, 21.0566, 24.3227113 , 831.29882812, 0.0381835 , 24.5014),
(1431790., 23., 0., 1478., 0., 0., 166., 165., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 2896., 182., 170., 1., 3., 4., 0., 0., 0., 63808., 0., 48879., 0., 30., 65., 1000., 1., 0., 0., 2056., 41216., 10., 2158., 990., 2022., 2074., 1762., 2112., 2140., 1232., 48879., 100., 381., 0., 1490., 1443., 1411., 1830., 2099., 1354., 443., 1932., 115., 115., 0., 188., 0., 17796., 489., 153., 8287., 7790., 4., 0., 7813., 0., 0., 0., 0., 5105., 0., 4., 0., 0., 1., 0., 0., 0., 0., 0., 0., 1., 0., 1., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20849609, 26.4244, 3.37227539, 19.0314, 14.82421875, 15.02075195, 1.50390625, 3.00600000e+00, -1.0609, -4.1503, 21.166 , 24.16155751, 826.41601562, 0.04326161, 24.5014),
(1432910., 23., 0., 454., 0., 0., 170., 169., 0., 0., 1890., 65509., 1890., 3859., 1., 1., 0., 0., 0., 0., 65111., 65370., 2., 128., 0., 35664., 182., 170., 1., 3., 4., 0., 0., 0., 63808., 0., 48879., 0., 30., 65., 1000., 1., 0., 0., 2056., 41216., 10., 2158., 989., 2020., 2075., 1753., 2134., 2140., 1232., 48879., 100., 385., 0., 1431., 1443., 1447., 1809., 2114., 143., 58., 1922., 116., 116., 0., 190., 0., 17796., 489., 153., 8287., 7790., 4., 0., 7813., 0., 0., 8., 8., 5105., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 1., 0., 0., 0., 1., 1., 0., 33.8636, 1.20727539, 26.315 , 3.37390137, 18.5391, 14.9786377 , 15.02075195, 1.50390625, -2.21300000e-01, -1.0609, -2.1811, 20.0173, 24.33422229, 87.28027344, 0.00566405, 23.9544)],
dtype=(numpy.record, [('bu_ms_offset', '>f8'), ('00_tlm_format_version_cmd_dict_version', '>f8'), ('01_last_BIST_result', '>f8'), ('02_current_status_flags', '>f8'), ('03_boot_bank_selected', '>f8'), ('04_boot_bank_actual', '>f8'), ('05_commands_received', '>f8'), ('06_commands_completed', '>f8'), ('07_commands_rejected', '>f8'), ('08_number_of_error_log_entries_since_boot', '>f8'), ('09_bank_A_kernel_calculated_checksum_NV', '>f8'), ('10_bank_A_application_calculated_checksum_NV', '>f8'), ('11_bank_B_kernel_calculated_checksum_NV', '>f8'), ('12_bank_B_application_calculated_checksum_NV', '>f8'), ('13_rce_comm_side', '>f8'), ('14_spacewire_comm_error_count_NV', '>f8'), ('15_last_spacewire_error_status_register', '>f8'), ('16_single_bit_MRAM_memory_errors_NV', '>f8'), ('17_single_bit_SDRAM_memory_errors_NV', '>f8'), ('18_last_single_bit_memory_address', '>f8'), ('19_software_version', '>f8'), ('20_PULSES_ID_REG', '>f8'), ('21_ROVER_HSS_TX_WD_CNT_REG', '>f8'), ('22_IRQ_CLR_REG', '>f8'), ('23_ROVER_HSS_CNTRL_REG', '>f8'), ('24_ROVER_HSS_TX_REG', '>f8'), ('25_IRQ_EN_REG', '>f8'), ('26_UART_TX_DATA_CNTRL_REG', '>f8'), ('27_UART_CNTRL_REG', '>f8'), ('28_LVPS_CTRL_REG', '>f8'), ('29_MRAM_CNTRL_REG', '>f8'), ('30_LED_REG', '>f8'), ('31_INT_TIME_REG', '>f8'), ('32_NSPS_REG', '>f8'), ('33_LZR_REP_RATE_REG', '>f8'), ('34_SPW_CTRL_REG', '>f8'), ('35_TEST_CTRL_REG', '>f8'), ('36_MU_HSS_EMU_REG', '>f8'), ('37_NUM_SPECTRA_REG', '>f8'), ('38_HVPS_DLY_REG', '>f8'), ('39_HVPS_DUR_REG', '>f8'), ('40_STATUS0_REG', '>f8'), ('41_IRQ_STAT_REG', '>f8'), ('42_ROVER_HSS_FRAME_STAT_REG', '>f8'), ('43_UART_STAT_REG', '>f8'), ('44_ROVER_HSS_STAT_REG', '>f8'), ('45_SPW_STAT_REG', '>f8'), ('46_CNDH_PCB_TEMP', '>f8'), ('47_CNDH_1_2_V', '>f8'), ('48_CNDH_LVPS_TEMP', '>f8'), ('49_CNDH_3_3_V', '>f8'), ('50_CNDH_VUI_UV_SPECT_TEMP', '>f8'), ('51_CNDH_NEG_15_V', '>f8'), ('52_CNDH_15_V', '>f8'), ('53_CNDH_1_5_V', '>f8'), ('54_TEST_STAT_REG', '>f8'), ('55_IDENTITY_STAT_REG', '>f8'), ('56_TEST2_STAT_REG', '>f8'), ('57_MISSED_PULSE_REG', '>f8'), ('58_SE_TX_TEMP', '>f8'), ('59_SE_VIO_TEMP', '>f8'), ('60_SE_UV_TEMP', '>f8'), ('61_SE_TM_TEMP', '>f8'), ('62_SE_24_V', '>f8'), ('63_SE_HVPS_REAR', '>f8'), ('64_SE_HVPS_CURRENT', '>f8'), ('65_SE_HVPS_TEMP', '>f8'), ('66_number_of_commands_sent_to_MU', '>f8'), ('67_MU_commands_ACKed_by_MU', '>f8'), ('68_MU_commands_NAKed_by_MU', '>f8'), ('69_MU_packets_received_success', '>f8'), ('70_MU_packets_received_error', '>f8'),

('71_number_of_BU_spectra_read_out_NV', '>f8'), ('72_number_of_RMI_received_from_MU_NV', '>f8'),
('73_number_of_microphone_recordings_NV', '>f8'), ('74_number_of_science_laser_shots_commanded_NV', '>f8'),
('75_current_absolute_focus_table_position', '>f8'), ('76_close_limit_switch_position_difference', '>f8'),
('77_far_limit_switch_position_difference', '>f8'), ('78_current_autofocus_baseline_position', '>f8'),
('79_current_spacewire_link_0_status_register', '>f8'), ('80_current_spacewire_link_1_status_register', '>f8'),
('81_current_spacewire_link_2_status_register', '>f8'), ('82_current_spacewire_link_3_status_register', '>f8'),
('83_current_focus_table_position_in_mm', '>f8'), ('84_reserved', '>f8'), ('85_status_flags', '>f8'), ('86_motor_speed_inhibited',
'>f8'), ('87_laser_current_inhibited', '>f8'), ('88_CCD_is_clocking', '>f8'), ('89_limit_swithch_arg_changed_to_computed_value',
'>f8'), ('90_focus_motor_inhibited', '>f8'), ('02a_sys_error', '>f8'), ('02b_send_evr', '>f8'), ('02c_shutdown', '>f8'), ('02d_sun_safe',
'>f8'), ('02e_bu_hvps_on', '>f8'), ('02f_mu_shutter', '>f8'), ('02g_mu_laser_on', '>f8'), ('02h_mu_dc_chain_on', '>f8'),
('02i_mu_on', '>f8'), ('02j_ccd_almost_ready', '>f8'), ('02k_ccd_ready', '>f8'), ('02l_irs_ready', '>f8'), ('02m_laser_doubler_ready',
'>f8'), ('02n_laser_stack_ready', '>f8'), ('02o_cwl_ready', '>f8'), ('C46_CNDH_PCB_TEMP', '>f8'), ('C47_CNDH_1_2_V', '>f8'),
('C48_CNDH_LVPS_TEMP', '>f8'), ('C49_CNDH_3_3_V', '>f8'), ('C50_CNDH_VUI_UV_SPECT_TEMP', '>f8'),
('C51_CNDH_NEG_15_V', '>f8'), ('C52_CNDH_15_V', '>f8'), ('C53_CNDH_1_5_V', '>f8'), ('C58_SE_TX_TEMP', '>f8'),
('C59_SE_VIO_TEMP', '>f8'), ('C60_SE_UV_TEMP', '>f8'), ('C61_SE_TM_TEMP', '>f8'), ('C62_SE_24_V', '>f8'),
('C63_SE_HVPS_REAR', '>f8'), ('C64_SE_HVPS_CURRENT', '>f8'), ('C65_SE_HVPS_TEMP', '>f8')]))

HDU 5-9 Technique specific HDUs

These HDUs contain both header and data objects.

HDUs Contents for LIBS (example)

An example of the contents of HDU 5 header (Laser Data):

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                   56 / length of dimension 1
NAXIS2  =                   30 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                    7 / number of table fields
EXTNAME = 'LASERDATA'         / extension name
TTYPE1  = 'Shot Number'
TFORM1  = 'D      '
TTYPE2  = 'Stack voltage'
TFORM2  = 'D      '
TTYPE3  = 'Pumping Current'
TFORM3  = 'D      '
TTYPE4  = 'Optical Power'
TFORM4  = 'D      '
TTYPE5  = 'Stack voltage (V)'
TFORM5  = 'D      '
TTYPE6  = 'Pumping Current (A)'
TFORM6  = 'D      '
TTYPE7  = 'Optical Power (mJ)'
TFORM7  = 'D      '
```

An example of the contents of HDU 5 data (Laser Data):

```
FITS_rec([( 1., 1711., 1044., 2481., 25.1, 155.5, 10.3),
        ( 2., 1617., 1046., 2298., 23.7, 155.7,  9.6),
        ( 3., 1631., 1046., 2269., 23.9, 155.7,  9.5),
        ( 4., 1650., 1046., 2367., 24.2, 155.7,  9.9),
        ( 5., 1616., 1046., 2241., 23.7, 155.7,  9.4),
        ( 6., 1649., 1046., 2460., 24.2, 155.7, 10.2),
        ( 7., 1609., 1046., 2320., 23.6, 155.7,  9.7),
        ( 8., 1637., 1045., 2372., 24. , 155.6,  9.9),
        ( 9., 1613., 1046., 2414., 23.6, 155.7, 10. ),
        (10., 1610., 1046., 2430., 23.6, 155.7, 10.1),
        (11., 1612., 1047., 2382., 23.6, 155.9,  9.9),
        (12., 1613., 1045., 2361., 23.6, 155.6,  9.8),
```

```
(13., 1617., 1046., 2446., 23.7, 155.7, 10.1),
(14., 1610., 1046., 2339., 23.6, 155.7,  9.8),
(15., 1618., 1046., 2482., 23.7, 155.7, 10.3),
(16., 1617., 1046., 2450., 23.7, 155.7, 10.1),
(17., 1610., 1046., 2421., 23.6, 155.7, 10. ),
(18., 1611., 1046., 2465., 23.6, 155.7, 10.2),
(19., 1616., 1046., 2401., 23.7, 155.7, 10. ),
(20., 1611., 1046., 2393., 23.6, 155.7,  9.9),
(21., 1613., 1045., 2415., 23.6, 155.6, 10. ),
(22., 1610., 1046., 2398., 23.6, 155.7, 10. ),
(23., 1612., 1047., 2376., 23.6, 155.9,  9.9),
(24., 1612., 1046., 2428., 23.6, 155.7, 10.1),
(25., 1610., 1046., 2328., 23.6, 155.7,  9.7),
(26., 1637., 1046., 2465., 24. , 155.7, 10.2),
(27., 1618., 1047., 2444., 23.7, 155.9, 10.1),
(28., 1607., 1046., 2333., 23.5, 155.7,  9.7),
(29., 1635., 1045., 2442., 24. , 155.6, 10.1),
(30., 1610., 1046., 2401., 23.6, 155.7, 10. )],
dtype=(numpy.record, [('Shot Number', '>f8'), ('Stack voltage', '>f8'), ('Pumping Current', '>f8'), ('Optical Power', '>f8'),
('Stack voltage (V)', '>f8'), ('Pumping Current (A)', '>f8'), ('Optical Power (mJ)', '>f8')]))
```

An example of the contents of HDU 6 header (Darks Before):

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                    0 / length of dimension 1
NAXIS2  =                    0 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                    0 / number of table fields
EXTNAME = 'DARKSBEFORE'       / extension name
```

An example of the contents of HDU 6 data (Darks Before):

NOTE: IF TFIELDS in the header = 0 then there is no data in HDU6. Dark data was not collected before active data.

An example of the contents of HDU 7 header (Actives):

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                   60 / length of dimension 1
NAXIS2  =                10740 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                   30 / number of table fields
EXTNAME = 'ACTIVES '          / extension name
TTYPE1  = 'Shot0   '
TFORM1  = 'I       '
TZERO1  =                32768
TTYPE2  = 'Shot1   '
TFORM2  = 'I       '
TZERO2  =                32768
TTYPE3  = 'Shot2   '
TFORM3  = 'I       '
TZERO3  =                32768
TTYPE4  = 'Shot3   '
TFORM4  = 'I       '
TZERO4  =                32768
TTYPE5  = 'Shot4   '
TFORM5  = 'I       '
TZERO5  =                32768
```

```
TTYPE6  = 'Shot5   '
TFORM6  = 'I       '
TZERO6  =                32768
TTYPE7  = 'Shot6   '
TFORM7  = 'I       '
TZERO7  =                32768
TTYPE8  = 'Shot7   '
TFORM8  = 'I       '
TZERO8  =                32768
TTYPE9  = 'Shot8   '
TFORM9  = 'I       '
TZERO9  =                32768
TTYPE10 = 'Shot9   '
TFORM10 = 'I       '
TZERO10 =                32768
TTYPE11 = 'Shot10  '
TFORM11 = 'I       '
TZERO11 =                32768
TTYPE12 = 'Shot11  '
TFORM12 = 'I       '
TZERO12 =                32768
TTYPE13 = 'Shot12  '
TFORM13 = 'I       '
TZERO13 =                32768
TTYPE14 = 'Shot13  '
TFORM14 = 'I       '
TZERO14 =                32768
TTYPE15 = 'Shot14  '
TFORM15 = 'I       '
TZERO15 =                32768
TTYPE16 = 'Shot15  '
TFORM16 = 'I       '
TZERO16 =                32768
TTYPE17 = 'Shot16  '
TFORM17 = 'I       '
TZERO17 =                32768
TTYPE18 = 'Shot17  '
TFORM18 = 'I       '
TZERO18 =                32768
TTYPE19 = 'Shot18  '
TFORM19 = 'I       '
TZERO19 =                32768
TTYPE20 = 'Shot19  '
TFORM20 = 'I       '
TZERO20 =                32768
TTYPE21 = 'Shot20  '
TFORM21 = 'I       '
TZERO21 =                32768
TTYPE22 = 'Shot21  '
TFORM22 = 'I       '
TZERO22 =                32768
TTYPE23 = 'Shot22  '
TFORM23 = 'I       '
TZERO23 =                32768
TTYPE24 = 'Shot23  '
TFORM24 = 'I       '
TZERO24 =                32768
TTYPE25 = 'Shot24  '
TFORM25 = 'I       '
TZERO25 =                32768
TTYPE26 = 'Shot25  '
```

```
TFORM26 = 'I      '
TZERO26 =                32768
TTYPE27 = 'Shot26  '
TFORM27 = 'I      '
TZERO27 =                32768
TTYPE28 = 'Shot27  '
TFORM28 = 'I      '
TZERO28 =                32768
TTYPE29 = 'Shot28  '
TFORM29 = 'I      '
TZERO29 =                32768
TTYPE30 = 'Shot29  '
TFORM30 = 'I      '
TZERO30 =                32768
```

An example of the contents of HDU 7 data (Actives):

```
FITS_rec([(    6,    5,    0,   13,    8,    3,    0,    7,   11,    6,   10,   11,    1,    5,   12,    0,    0,    2,    1,    0,
3,    9,    0,    4,    6,    0,    7,    8,    4,    5),
        (  226,  155,  111,  114,  115,  114,  124,  124,  124,  108,  118,  112,  125,  113,  119,  122,  114,
122,  126,  115,  117,  113,  118,  105,  115,  111,  117,  115,  112,  112),
        ( 1531,  552,  293,  283,  282,  286,  284,  272,  280,  278,  272,  275,  283,  274,  277,  291,  300,
279,  282,  277,  294,  281,  295,  288,  288,  293,  285,  289,  288,  284),
        ...,
        ( 1323,  322,  335,  302,  310,  301,  321,  314,  317,  307,  307,  312,  310,  310,  317,  314,  308,
311,  316,  324,  307,  325,  286,  308,  320,  315,  304,  307,  327,  310),
        (  671,  179,  186,  195,  190,  180,  174,  181,  177,  187,  179,  184,  180,  173,  185,  182,  173,
197,  185,  183,  189,  184,  183,  191,  175,  180,  181,  184,  181,  182),
        (   20,   13,   18,   11,    8,   19,   12,   16,   25,    8,   10,    8,   18,   13,   17,   13,   26,    8,   14,   18,
22,   17,   11,   14,   13,   13,    3,   11,   14,   10)],
      dtype=(numpy.record, [('Shot0', '>i2'), ('Shot1', '>i2'), ('Shot2', '>i2'), ('Shot3', '>i2'), ('Shot4', '>i2'), ('Shot5', '>i2'), ('Shot6',
'>i2'), ('Shot7', '>i2'), ('Shot8', '>i2'), ('Shot9', '>i2'), ('Shot10', '>i2'), ('Shot11', '>i2'), ('Shot12', '>i2'), ('Shot13', '>i2'), ('Shot14',
'>i2'), ('Shot15', '>i2'), ('Shot16', '>i2'), ('Shot17', '>i2'), ('Shot18', '>i2'), ('Shot19', '>i2'), ('Shot20', '>i2'), ('Shot21', '>i2'),
('Shot22', '>i2'), ('Shot23', '>i2'), ('Shot24', '>i2'), ('Shot25', '>i2'), ('Shot26', '>i2'), ('Shot27', '>i2'), ('Shot28', '>i2'), ('Shot29',
'>i2')]))
```

An example of the contents of HDU 8 header (Darks After):

```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                   24 / length of dimension 1
NAXIS2  =                10740 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                    3 / number of table fields
EXTNAME = 'DARKSAFTER'         / extension name
TTYPE1  = 'Mean    '
TFORM1  = 'K       '
TTYPE2  = 'Median  '
TFORM2  = 'K       '
TTYPE3  = 'StdDev  '
TFORM3  = 'K       '
```

An example of the contents of HDU 8 data (Darks After):

```
FITS_rec([(  5,   4,   3),
          (118, 114,  17),
          (325, 289, 169),
 ...,
          (339, 315, 133),
          (196, 184,  62),
          ( 14,  13,   5)],
```

dtype=(numpy.record, [('Mean', '>i8'), ('Median', '>i8'), ('StdDev', '>i8')]))

An example of the contents of HDU 6 Header (Spectra):

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                  120 / length of dimension 1
NAXIS2  =                 7933 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                   30 / number of table fields
EXTNAME = 'SPECTRA '          / extension name
TTYPE1  = 'Spectrum0'
TFORM1  = 'E      '
TTYPE2  = 'Spectrum1'
TFORM2  = 'E      '
TTYPE3  = 'Spectrum2'
TFORM3  = 'E      '
TTYPE4  = 'Spectrum3'
TFORM4  = 'E      '
TTYPE5  = 'Spectrum4'
TFORM5  = 'E      '
TTYPE6  = 'Spectrum5'
TFORM6  = 'E      '
TTYPE7  = 'Spectrum6'
TFORM7  = 'E      '
TTYPE8  = 'Spectrum7'
TFORM8  = 'E      '
TTYPE9  = 'Spectrum8'
TFORM9  = 'E      '
TTYPE10 = 'Spectrum9'
TFORM10 = 'E      '
TTYPE11 = 'Spectrum10'
TFORM11 = 'E      '
TTYPE12 = 'Spectrum11'
TFORM12 = 'E      '
TTYPE13 = 'Spectrum12'
TFORM13 = 'E      '
TTYPE14 = 'Spectrum13'
TFORM14 = 'E      '
TTYPE15 = 'Spectrum14'
TFORM15 = 'E      '
TTYPE16 = 'Spectrum15'
TFORM16 = 'E      '
TTYPE17 = 'Spectrum16'
TFORM17 = 'E      '
TTYPE18 = 'Spectrum17'
TFORM18 = 'E      '
TTYPE19 = 'Spectrum18'
TFORM19 = 'E      '
TTYPE20 = 'Spectrum19'
TFORM20 = 'E      '
TTYPE21 = 'Spectrum20'
TFORM21 = 'E      '
TTYPE22 = 'Spectrum21'
TFORM22 = 'E      '
TTYPE23 = 'Spectrum22'
TFORM23 = 'E      '
TTYPE24 = 'Spectrum23'
TFORM24 = 'E      '
TTYPE25 = 'Spectrum24'
```

TFORM25 = 'E '
TTYPE26 = 'Spectrum25'
TFORM26 = 'E '
TTYPE27 = 'Spectrum26'
TFORM27 = 'E '
TTYPE28 = 'Spectrum27'
TFORM28 = 'E '
TTYPE29 = 'Spectrum28'
TFORM29 = 'E '
TTYPE30 = 'Spectrum29'
TFORM30 = 'E '

An example of the contents of HDU 6 data (Spectra):

FITS_rec([(1.05104335e+11, 1.26019625e+11, 1.9919474e+11, 1.2659676e+11, 1.9241879e+11, 1.5361512e+11, 1.9008145e+11, 1.7986996e+11, 2.6296852e+11, 2.3736449e+11, 2.1718062e+11, 2.5595416e+11, 2.8328906e+11, 2.9295398e+11, 2.8465893e+11, 3.4947098e+11, 3.5167024e+11, 3.5961258e+11, 3.4318071e+11, 3.7057947e+11, 4.2535961e+11, 3.2731038e+11, 4.8578118e+11, 4.4263231e+11, 4.1595991e+11, 4.6002527e+11, 4.6233892e+11, 4.2183413e+11, 4.3537600e+11, 4.8338046e+11),
(1.22822246e+11, 1.72790333e+11, 2.0576615e+11, 1.7442950e+11, 2.0095523e+11, 1.8076000e+11, 2.1751362e+11, 2.2518016e+11, 2.8506345e+11, 2.6614712e+11, 2.4459364e+11, 2.7781779e+11, 3.0087135e+11, 3.3542806e+11, 3.2354379e+11, 3.7128320e+11, 3.8198703e+11, 3.9803788e+11, 3.8304295e+11, 4.0290563e+11, 4.2388396e+11, 3.4188027e+11, 5.4184998e+11, 4.9830943e+11, 4.6256718e+11, 5.0912343e+11, 5.1339867e+11, 5.1442526e+11, 5.0830269e+11, 5.4513530e+11),
(1.70236707e+11, 2.57598833e+11, 2.4578851e+11, 2.6861771e+11, 2.4409342e+11, 2.6096966e+11, 2.6389443e+11, 3.0462748e+11, 3.3981235e+11, 3.3365420e+11, 3.1728615e+11, 3.4862734e+11, 3.8316720e+11, 4.3427280e+11, 4.3765439e+11, 4.4796061e+11, 4.7082485e+11, 5.1515634e+11, 4.8000510e+11, 5.0534200e+11, 4.5467474e+11, 4.1702873e+11, 6.7141783e+11, 6.3652377e+11, 5.9379863e+11, 6.2926370e+11, 6.3693357e+11, 6.1431303e+11, 6.9432790e+11, 6.9677508e+11),
...,
(6.43342592e+09, 1.04437434e+09, -5.9325530e+08, -2.6654475e+08, 5.0081684e+09, 3.9291331e+09, -3.2025309e+08, -9.4886584e+07, 2.7795244e+09, 4.7400730e+08, 3.6956528e+08, 1.2401500e+09, 1.2668109e+09, 4.0070397e+09, 4.0500311e+09, 1.0790678e+10, -7.5958790e+08, 4.5597015e+09, 4.6541691e+09, 3.3406840e+09, 3.9742988e+07, 2.0429374e+07, 4.8657475e+09, -1.2231246e+09, 6.3760799e+09, 1.7780079e+09, -4.2421341e+08, 6.4799770e+09, -5.2334438e+08, 2.5935624e+09),
(6.91260621e+09, -1.58125504e+08, -4.5699564e+07, -9.4856250e+08, 5.9251907e+09, 5.6402540e+09, -3.0559549e+08, -6.3432051e+08, 3.2122944e+09, 1.5524890e+08, 8.6648390e+08, 1.7908772e+09, 9.2947942e+08, 4.3099172e+09, 4.5023314e+09, 1.0764807e+10, -5.7904941e+08, 5.7563023e+09, 5.0033628e+09, 3.7368812e+09, -3.6339318e+08, -5.0861347e+08, 4.3757676e+09, -2.5914925e+08, 6.3966182e+09, -7.2008422e+08, -3.5386016e+08, 6.4546545e+09, -2.2052008e+08, 1.2641856e+09),
(7.13851904e+09, -4.31835328e+08, 9.3023994e+08, -9.8608346e+08, 7.0693012e+09, 7.1647887e+09, 3.7169370e+08, -4.8626166e+08, 3.7560765e+09, -1.9003544e+07, 1.4751766e+09, 2.0035092e+09, 7.2432115e+08, 4.8637645e+09, 5.1574241e+09, 1.0364423e+10, 2.3122779e+08, 6.5800044e+09, 5.4568187e+09, 4.5500595e+09, -5.1243037e+08, -9.2118362e+08, 3.7914844e+09, 1.0809116e+09, 6.1460086e+09, -2.4902861e+09, 3.8016288e+08, 6.8130734e+09, 9.0574195e+08, 3.9381110e+08)],
dtype=(numpy.record, [('Spectrum0', '>f4'), ('Spectrum1', '>f4'), ('Spectrum2', '>f4'), ('Spectrum3', '>f4'), ('Spectrum4', '>f4'), ('Spectrum5', '>f4'), ('Spectrum6', '>f4'), ('Spectrum7', '>f4'), ('Spectrum8', '>f4'), ('Spectrum9', '>f4'), ('Spectrum10', '>f4'), ('Spectrum11', '>f4'), ('Spectrum12', '>f4'), ('Spectrum13', '>f4'), ('Spectrum14', '>f4'), ('Spectrum15', '>f4'), ('Spectrum16', '>f4'), ('Spectrum17', '>f4'), ('Spectrum18', '>f4'), ('Spectrum19', '>f4'), ('Spectrum20', '>f4'), ('Spectrum21', '>f4'), ('Spectrum22', '>f4'), ('Spectrum23', '>f4'), ('Spectrum24', '>f4'), ('Spectrum25', '>f4'), ('Spectrum26', '>f4'), ('Spectrum27', '>f4'), ('Spectrum28', '>f4'), ('Spectrum29', '>f4')]))

An example of the contents of HDU 7 header (Statistics):

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                   12 / length of dimension 1
NAXIS2  =                 7933 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                    3 / number of table fields
```

```
EXTNAME = 'STATISTICS'        / extension name
TTYPE1  = 'Mean    '
TFORM1  = 'E       '
TTYPE2  = 'Median  '
TFORM2  = 'E       '
TTYPE3  = 'StDev   '
TFORM3  = 'E       '
```

An example of the contents of HDU 7 Data (Statistics):

```
FITS_rec([(3.27556006e+11, 3.3518387e+11, 2.4977875e+11),
        (3.89059576e+11, 3.8673731e+11, 2.6419696e+11),
        (3.98702674e+11, 3.4869346e+11, 2.6738380e+11),
...,
        (7.27379648e+08, 9.9642566e+08, 1.0408081e+10),
        (7.93902912e+08, 1.4864356e+09, 9.3307904e+09),
        (1.06988576e+09, 2.1089558e+09, 8.9337283e+09)],
       dtype=(numpy.record, [('Mean', '>f4'), ('Median', '>f4'), ('StDev', '>f4')]))
```

An example of the contents of HDU 8 header (Wavelength):

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                   12 / length of dimension 1
NAXIS2  =                 7933 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                    2 / number of table fields
EXTNAME = 'WAVELENGTH'        / extension name
TTYPE1  = 'Wavelength'
TFORM1  = 'E       '
TTYPE2  = 'IRF     '
TFORM2  = 'D       '
```

An example of the contents of HDU 8 Data (Wavelength):

```
FITS_rec([(243.78943, 23052.00740366),
            (243.84216, 22811.66668478),
            (243.8949 , 22544.59644689),
 ...,
            (852.64246,  2637.50885207),
            (852.7074 ,  2668.60664421),
            (852.7723 ,  2706.31755713)],
       dtype=(numpy.record, [('Wavelength', '>f4'), ('IRF', '>f8')]))
```

An example of the contents of HDU 9 header (Saturation):

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                  240 / length of dimension 1
NAXIS2  =                 7933 / length of dimension 2
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
TFIELDS =                   30 / number of table fields
EXTNAME = 'SATURATION'        / extension name
TTYPE1  = 'SaturationMask0'
TFORM1  = 'D       '
TTYPE2  = 'SaturationMask1'
TFORM2  = 'D       '
TTYPE3  = 'SaturationMask2'
TFORM3  = 'D       '
TTYPE4  = 'SaturationMask3'
```

```
TFORM4  = 'D       '
TTYPE5  = 'SaturationMask4'
TFORM5  = 'D       '
TTYPE6  = 'SaturationMask5'
TFORM6  = 'D       '
TTYPE7  = 'SaturationMask6'
TFORM7  = 'D       '
TTYPE8  = 'SaturationMask7'
TFORM8  = 'D       '
TTYPE9  = 'SaturationMask8'
TFORM9  = 'D       '
TTYPE10 = 'SaturationMask9'
TFORM10 = 'D       '
TTYPE11 = 'SaturationMask10'
TFORM11 = 'D       '
TTYPE12 = 'SaturationMask11'
TFORM12 = 'D       '
TTYPE13 = 'SaturationMask12'
TFORM13 = 'D       '
TTYPE14 = 'SaturationMask13'
TFORM14 = 'D       '
TTYPE15 = 'SaturationMask14'
TFORM15 = 'D       '
TTYPE16 = 'SaturationMask15'
TFORM16 = 'D       '
TTYPE17 = 'SaturationMask16'
TFORM17 = 'D       '
TTYPE18 = 'SaturationMask17'
TFORM18 = 'D       '
TTYPE19 = 'SaturationMask18'
TFORM19 = 'D       '
TTYPE20 = 'SaturationMask19'
TFORM20 = 'D       '
TTYPE21 = 'SaturationMask20'
TFORM21 = 'D       '
TTYPE22 = 'SaturationMask21'
TFORM22 = 'D       '
TTYPE23 = 'SaturationMask22'
TFORM23 = 'D       '
TTYPE24 = 'SaturationMask23'
TFORM24 = 'D       '
TTYPE25 = 'SaturationMask24'
TFORM25 = 'D       '
TTYPE26 = 'SaturationMask25'
TFORM26 = 'D       '
TTYPE27 = 'SaturationMask26'
TFORM27 = 'D       '
TTYPE28 = 'SaturationMask27'
TFORM28 = 'D       '
TTYPE29 = 'SaturationMask28'
TFORM29 = 'D       '
TTYPE30 = 'SaturationMask29'
TFORM30 = 'D       '
```

An example of the contents of HDU 9 header (Saturation):

```
FITS_rec([(0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.),
        (0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.),
        (0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.),
        ...,
        (0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.),
        (0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.),
```

(0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.)],
dtype=(numpy.record, [('SaturationMask0', '>f8'), ('SaturationMask1', '>f8'), ('SaturationMask2', '>f8'), ('SaturationMask3', '>f8'), ('SaturationMask4', '>f8'), ('SaturationMask5', '>f8'), ('SaturationMask6', '>f8'), ('SaturationMask7', '>f8'), ('SaturationMask8', '>f8'), ('SaturationMask9', '>f8'), ('SaturationMask10', '>f8'), ('SaturationMask11', '>f8'), ('SaturationMask12', '>f8'), ('SaturationMask13', '>f8'), ('SaturationMask14', '>f8'), ('SaturationMask15', '>f8'), ('SaturationMask16', '>f8'), ('SaturationMask17', '>f8'), ('SaturationMask18', '>f8'), ('SaturationMask19', '>f8'), ('SaturationMask20', '>f8'), ('SaturationMask21', '>f8'), ('SaturationMask22', '>f8'), ('SaturationMask23', '>f8'), ('SaturationMask24', '>f8'), ('SaturationMask25', '>f8'), ('SaturationMask26', '>f8'), ('SaturationMask27', '>f8'), ('SaturationMask28', '>f8'), ('SaturationMask29', '>f8')]))

8 Appendix B: Examples of CDR FITS Contents

All CDRs have HDU 0 – 4. HDU 1 – 4 have header and data objects similar to examples in Appendix A.

HDU 0 - Primary Header Updated with parameters used in data processing such as processing versions and calibration settings.
HDU 1 - ODL LABEL Same information that is in the EDR HDU 1
HDU 2 - TIMELINE Same information that is in the EDR HDU 2
HDU 3 - MU SOH Same information that is in the EDR HDU 3
HSU 4 – BU SOH Same information that is in the EDR HDU 4

HDU 5 to 9 are unique to each technique.

LIBS, RAMAN and TRLS: (HDU 5 to 9)

HDU 5	Laser Data
HDU 6	Signal (Active – Darks) For TRLS: group by time sweep
HDU 7	Statistics (3 columns: mean, median,stdev))
HDU 8	Wavelength
HDU 9	Saturated pixels mask

IRSpec: (HDU 5 to 9**)**

HDU 5: IR HK table [4,256]

Detector Temp. *(°C)*	**RF power** *(W)*	**Status: PLL_Lock** *(flag 0 or 1)*	**Status: TEC_Ready** *(flag 0 or 1)*

HDU 6: SPECTRA table [4,256]

Spectrum *(DN)*	**Radiance** *(W/m²/sr/µm)* Calibrated Spectrum	**I_F** *(unit-less)* Calibrated spectrum I/F (corrected from solar irradiance)	**I_F_Atm** Reflectance, with additional correction for atmospheric absorption (no	**F_sky** *(W/m²/sr/µm)* Solar spectrum that was used to compute I_F	**Rad_Atm_Corr** *(AU)* Atmospheric transmission spectrum that was used to

			units, varies between 0 and 1)		compute the I_F_Atm

HDU 7: WAVELENGTH table [2,256]

Wavelength *(µm)*	***FWHM*** *(cm^{-1})*

HDU 8: IR_SPEC_SOH Instrument parameters table [13,1]

ablenacc_spectı 1	t_integ 1	rfpower_offset 1	nacc_offset 1	hk_t_aotf_init 1	meas_conf 1	meas_tint 1	ieas_tec_setpoir 1	hk_t_aotf_end 1	hk_t_tec_hot 1	hk_t_board 1	IR_DETSL 1	IR_TAKEM 1
4	0	0	0	51	0	60	156	51	55	111	DET1	SPECTRUM

HDU 9: DATA_QUALITY table [3,256]

Saturation	Spike	Spike

0 = False, 1 = True, NaN if spectel not used

VIS: HDU 5 to 9

HDU 5	Empty
HDU 6	Spectra (Empty data hdu if statistics collected)
HDU 7	Statistics (Mean, Median, Standard deviation) (empty if all shots collected)
HDU 8	Wavelength and IRF
HDU 9	Saturated pixels mask

9 Appendix C: Type argument to SCAM_SEND_DATA

Description of the SCAM_SEND_DATA type argument.

MISC	IR	LIBS	RAMAN	VIS	MIC		TYPE	meaning
0	0	0	0	0	0		0	SOH
0	0	0	0	0	1		1	Microphone
0	0	0	0	1	0		2	VIS- Only
0	0	0	1	0	0		4	Raman
0	0	1	0	0	0		8	LIBS
0	0	1	0	0	1		9	LIBS + Mic
0	1	0	0	0	0		16	IRSpec - IR only
0	1	0	0	1	0		18	VISIR
1	0	0	1	0	0		36	TRLS
1	0	1	0	0	0		40	LIBS dust removal only
1	0	1	0	0	1		41	LIBS + Pulse Mic
1	1	0	0	0	0		48	IRS Scan/Raster

10 Appendix D: XML Meta Data

Keywords and description of meta data in XML labels.

XML Keyword	Description
RCE time sync	Last time sync value received from RCE
MS_SINCE_LAST_SYNC	Number of milliseconds since last time sync value. Indicates when the command or data was added to buffer.
CMD_NAME	Command to instrument
OPCODE	Opcode of the instrument command being sent
TYPE	Bit field containing one or more active bits describing the contents of the data
DATA_LENGTH	Length of Data to follow
ARGS	Arguments to the instrument commands
DATA	Data returned from the instrument command
MU_MS_OFFSET	Offset from SCLK time sync
00_LASER_OSC1_TEMP	Main thermal sensor for the Laser stack
01_LASER_OSC2_TEMP	Redundant thermal sensor for the Laser stack
02_LASER_DOUB1_TEMP	Main thermal sensor for the Laser stack
03_LASER_DOUB2_TEMP	Redundant thermal sensor for the Laser stack
04_LASER_15V	Laser 15V limiter sec voltage (close to 0 from OFF/15V when ON)
05_LASER_HV	Laser High Voltage HK (close to 20V when OFF, 1200V when ON)
06_LASER_LIMITER_TEMP	Laser board thermal sensor closed to the limiter (hot case)
07_DPU_MOTOR_DRIVER_TEMP	DPU board thermal sensor on Motor Driver (hot case)
08_DPU_FPGA_TEMP	DPU board thermal sensor on DPU
09_VREF_+2.5V	2.5V reference voltage
10_+1.5V	1.5V FPGA core voltage
11_+3.3V	3.3V FPGA I/O voltage
12_MOTOR_TEMPERATURE	Thermal sensor inside the Motor (hot case)
13_PRIMARY_MIRROR_TEMP	Reference thermal sensor for the AFT range check (on the bench now)
14_CWL_PD_CURRENT	Compensation current of the CWL
15_MICRO_TEMP	Thermal sensor inside the Microphone finger when MICRO ON
16_CWL_TEMP	Thermal sensor used for CWL heater control
17_+3.3_IRS	3.3V IRS voltage (4.3V when IRS TEC OFF, 3.3V when IRS TEC ON)
18_+20V_RF_IRS	20V IRS voltage (20V when IRS TEC & DCDC ON)
19_+5V_RF_IRS	5V IRS voltage
20_-5V_RF_IRS	-5V IRS Voltage
21_+5V_DT_IRS	8V IRS Voltage
22_-5V_DT_IRS	-8V IRS Voltage
23_LVPS_BOARD_TEMP	Thermal sensor on the LVPS board (hot case)
24_PRIMARY_CURRENT	28V current measured on the LVPS board
25_IRS_HK_TEMP_AOTF	AOTF temperature (saturated at -51°C)
26_IRS_HK_TEMP_HOT_TEC	Hot side of TEC temperature (saturated at -51°C)

27_IRS_HK_TEMP_BOARD	Thermal sensor on the IRBoard (saturated at -51°C)
28_IRS_HK_TEMP_DET	TEC cold side temperature (saturated at -51°C)
29_REMAINING_LASER_PULSES	Number of remaining shots
30_ON/OFF_SHUTTER	0 = shutter is not activited, 1 = shutter is activated
31_ON/OFF_LIMITER	0 = Laser board Limiter OFF, 1 = Laser board Limiter ON
32_ON/OFF_HIGH_VOLTAGE_15_V	0 = Laser board +15V OFF, 1 = Laser board +15V ON
33_ON/OFF_MICROPHONE	0 = Microphone OFF, 1 = Microphone ON
34_ON/OFF_RMI	0 = RMI OFF, 1 = RMI ON
35_ON/OFF_DC/DC	0 = Microphone OFF, 1 = Microphone ON
36_ON/OFF_HEATER_DOUBLER_LASER	0 = heater doubler laser OFF, 1= heater doubler laser ON
37_ON/OFF_HEATER_STACK_LASER	0 = heater stack laser OFF, 1= heater stack laser ON
38_ON/OFF_HEATER_CWL	0 = heater CWL OFF, 1 = heater CWL ON
39_HEATER_DOUBLER_RECEIVED	0 = Doubler setpoint not reached, 1 = Doubler setpoint reached
40_HEATER_STACK_RECEIVED	0 = Stack setpoint not reached, 1 = Stack setpoint reached
41_HEATER_CWL_RECEIVED	0 = CWL setpoint not reached, 1 = CWL setpoint reached
42_ON/OFF_TEC_IR	0 = nominal photodiode (DET1), 1 = redundant photodiode(DET2)
43_TEC_IR_READY	0 = TEC is OFF, 1 = TEC is ON
44_IRS_MEAS_ONGOING	0 = TEC temp setpoint not reached, 1 = TEC temp setpoint reached
45_IR_DET_SEL	0 = IRS Measurement ongoing, 1 = IRS Measurement done
46_MOTOR_DRIVER_CIRCUIT_THERMAL_FLAG	To be discussed, watchdog à implémenter dans DPU MU??
47_AF_GAIN_STATUS_MSB	AF gain status_MSB
48_AF_GAIN_STATUS_LSB	AF gain status_LSB
49_ON/OFF_CWL	0 = CWL is not turn OFF, 1 = CWl is turn ON
50_ON/OFF_CWL_MODULATION	0 = no modulation of CWL, 1 = modulation of CWL
51_ON/OFF_MOTOR_DRIVER	0 = Motor driver is OFF, 1 = Motor driver is ON
52_INFINITE_LIMIT_SWITCH_STATUS	0 = Infinite switch not reached, 1 = Infinite switch reached
53_CLOSE_LIMIT_SWITCH_STATUS	0 = Close switch not reached, 1 = Close switch reached
C00_LASER_OSC1_TEMP	Main thermal sensor for the Laser stack
C01_LASER_OSC2_TEMP	Redundant thermal sensor for the Laser stack
C02_LASER_DOUB1_TEMP	Main thermal sensor for the Laser stack
C03_LASER_DOUB2_TEMP	Redundant thermal sensor for the Laser stack
C04_LASER_15V	Laser 15V limiter sec voltage (close to 0 from OFF/15V when ON)
C05_LASER_HV	Laser High Voltage HK (close to 20V when OFF, 1200V when ON)
C06_LASER_LIMITER_TEMP	Laser board thermal sensor closed to the limiter (hot case)
C07_DPU_MOTOR_DRIVER_TEMP	DPU board thermal sensor on Motor Driver (hot case)
C08_DPU_FPGA_TEMP	DPU board thermal sensor on DPU

C09_VREF_+2.5V	2.5V reference voltage
C10_+1.5V	1.5V FPGA core voltage
C11_+3.3V	3.3V FPGA I/O voltage
C12_MOTOR_TEMPERATURE	Thermal sensor inside the Motor (hot case)
C13_PRIMARY_MIRROR_TEMP	Reference thermal sensor for the AFT range check (on the bench now)
C14_CWL_PD_CURRENT	Compensation current of the CWL
C15_MICRO_TEMP	Thermal sensor inside the Microphone finger when MICRO ON
C16_CWL_TEMP	Thermal sensor used for CWL heater control
C17_+3.3_IRS	3.3V IRS voltage (4.3V when IRS TEC OFF, 3.3V when IRS TEC ON)
C18_+20V_RF_IRS	20V IRS voltage (20V when IRS TEC & DCDC ON)
C19_+5V_RF_IRS	5V IRS voltage
C20_-5V_RF_IRS	-5V IRS Voltage
C21_+5V_DT_IRS	8V IRS Voltage
C22_-5V_DT_IRS	-8V IRS Voltage
C23_LVPS_BOARD_TEMP	Thermal sensor on the LVPS board (hot case)
C24_PRIMARY_CURRENT	28V current measured on the LVPS board
C25_IRS_HK_TEMP_AOTF	AOTF temperature (saturated at -51°C)
C26_IRS_HK_TEMP_HOT_TEC	Hot side of TEC temperature (saturated at -51°C)
C27_IRS_HK_TEMP_BOARD	Thermal sensor on the IRBoard (saturated at -51°C)
C28_IRS_HK_TEMP_DET	TEC cold side temperature (saturated at -51°C)
C29_REMAINING_LASER_PULSES	Number of remaining shots
BU_MS_OFFSET	Millisecond offset time from sclk
00_TLM_FORMAT_VERSION_(CMD_DICT_VERSION)	I-Command Dictionary version
01_LAST_BIST_RESULT	Last BU BIST result
02_CURRENT_STATUS_FLAGS	Current Status Flag state
03_BOOT_BANK_SELECTED	MRAM iFSW boot bank selected by Init discretes. 0 = Bank A, 1 = Bank B
04_BOOT_BANK_ACTUAL	MRAM iFSW boot bank that was actually used to boot the instrument. 0 = Bank A, 1 = Bank B
05_COMMANDS_RECEIVED	Number of i-commands sent to the instrument
06_COMMANDS_COMPLETED	Number of i-commands successfully completed (not rejected)
07_COMMANDS_REJECTED	Number of i-commands rejected by the instrument
08_NUMBER_OF_ERROR_LOG_ENTRIES_SINCE_BOOT	A non-zero value indicates that an error has occurred since the instrument was powered on
09_BANK_A_KERNEL_CALCULATED_CHECKSUM_-_NV	Checksum of the MRAM iFSW Bank A kernel
10_BANK_A_APPLICATION_CALCULATED_CHECKSUM_-_NV	Checksum of the MRAM iFSW Bank A application
11_BANK_B_KERNEL_CALCULATED_CHECKSUM_-_NV	Checksum of the MRAM iFSW Bank B kernel
12_BANK_B_APPLICATION_CALCULATED_CHECKSUM_-_NV	Checksum of the MRAM iFSW Bank B application
13_RCE_COMM_SIDE	Indicates which RCE is active 0 = RCE B, 1 = RCE A
14_SPACEWIRE_COMM_ERROR_COUNT_-_NV	Nonvolatile counter of the number of SpaceWire errors, indicating problems on the spectrometer or MU HSS intefaces
15_LAST_SPACEWIRE_ERROR_STATUS_REGISTER	A copy of the SpaceWire error status register from the Leon3FT
16_SINGLE_BIT_MRAM_MEMORY_ERRORS_-_NV	Nonvolatile counter of the number of single-bit (correctable) MRAM EDAC errors

17_SINGLE_BIT_SDRAM_MEMORY_ERRORS_-_NV	Nonvolatile counter of the number of single-bit (correctable) SDRAM EDAC errors
18_LAST_SINGLE_BIT_MEMORY_ADDRESS	Last error memory address from Leon3FT EDAC
19_SOFTWARE_VERSION	iFSW version number
20_PULSES_ID_REG	Copy of C&DH FPGA pulses register, used to pulse bits in the register for one clock cycle
21_ROVER_HSS_TX_WD_CNT_REG	Copy of C&DH FPGA control register, the data to be transmitted on the MU HSS link
22_IRQ_CLR_REG	Copy of C&DH FPGA control register, the interrupt clear register
23_ROVER_HSS_CNTRL_REG	Copy of C&DH FPGA control register, the RCE interface control bits
24_ROVER_HSS_TX_REG	Copy of C&DH FPGA control register, the data to be transmitted to the RCE
25_IRQ_EN_REG	Copy of C&DH FPGA control register, the interrupt enable register
26_UART_TX_DATA_CNTRL_REG	Copy of C&DH FPGA control register, the data to be trasmitted to the MU on the UART link
27_UART_CNTRL_REG	Copy of C&DH FPGA control register, the MU UART link control register
28_LVPS_CTRL_REG	Copy of C&DH FPGA control register, the bits to enable/disable the TEC and MU power relays
29_MRAM_CNTRL_REG	Copy of C&DH FPGA control register, containing write enable bits for the C&DH MRAMs
30_LED_REG	Copy of C&DH FPGA control register, on EDU and TBU units, this enables LEDs on the C&DH for debug purposes
31_INT_TIME_REG	Copy of C&DH FPGA control register, test register for intensifier shutter control
32_NSPS_REG	Copy of C&DH FPGA control register, number of shots per spectra
33_LZR_REP_RATE_REG	Copy of C&DH FPGA control register, laser rep rate in units of system clock
34_SPW_CTRL_REG	Copy of C&DH FPGA control register, SpaceWire control register for MU HSS interface
35_TEST_CTRL_REG	Copy of C&DH FPGA control register, used as test register and attached to TEST_STAT_REG
36_MU_HSS_EMU_REG	HSS_not_used
37_NUM_SPECTRA_REG	Copy of C&DH FPGA control register, number of spectra to collect
38_HVPS_DLY_REG	Copy of C&DH FPGA control register, number of 10ns steps to delay from MU trigger input to intensifier shutter open time
39_HVPS_DUR_REG	Copy of C&DH FPGA control register, number of 10ns steps to keep intensifier shutter open
40_STATUS0_REG	Copy of C&DH FPGA status register, contains boot bank select bit the status of inits received
41_IRQ_STAT_REG	Copy of C&DH FPGA status register, interrupt status register, same bits as control register
42_ROVER_HSS_FRAME_STAT_REG	Copy of C&DH FPGA status register, RCE HSS RX interface data

43_UART_STAT_REG	Copy of C&DH FPGA status register, MU status register bits
44_ROVER_HSS_STAT_REG	Copy of C&DH FPGA status register, RCE HSS TX and RX FIFO status bits
45_SPW_STAT_REG	Copy of C&DH FPGA status register, MU HSS SpaceWire interface status bits
46_CNDH_PCB_TEMP	Temperature of the C&DH PCB, usually the warmest part of the BU EBOX
47_CNDH_1_2_V	1.2v monitor on the C&DH, used for Leon3FT processor core
48_CNDH_LVPS_TEMP	Temperature of the LVPS PCB
49_CNDH_3_3_V	3.3v monitor on the C&DH, main digital supply on C&DH and SE
50_CNDH_VUI_UV_SPECT_TEMP	Temperature of the reflection spectrometer housing
51_CNDH_NEG_15_V	-15v monitor on the C&DH, used on SE and HVPS
52_CNDH_15_V	15v monitor on the C&DH, used on C&DH, SE, and HVPS
53_CNDH_1_5_V	1.2v monitor on the C&DH, used for FPGA core
54_TEST_STAT_REG	Copy of C&DH status register, attached to TEST_CTRL_REG
55_IDENTITY_STAT_REG	Copy of C&DH status register, reports model number
56_TEST2_STAT_REG	Copy of C&DH status register, attached to TEST_CTRL_REG
57_MISSED_PULSE_REG	Copy of C&DH status register, most significant bit is an indicator that the laser timer logic is ready
58_SE_TX_TEMP	Temperature of the Transmission spectrometer CCD
59_SE_VIO_TEMP	Temperature of the Violet spectrometer CCD
60_SE_UV_TEMP	Temperature of the UV spectrometer CCD
61_SE_TM_TEMP	Temperature of the Transmission spectrometer housing
62_SE_24_V	24v monitor on the SE, used to bias CCDs
63_SE_HVPS_REAR	HVPS read plate voltage monitor
64_SE_HVPS_CURRENT	HVPS current monitor
65_SE_HVPS_TEMP	Temperature of the HVPS PCB
66_NUMBER_OF_COMMANDS_SENT_TO_MU	Number of MU_* commands sent from the BU to the MU
67_MU_COMMANDS_ACK'D_BY_MU	Number of MU_* commands acknowledged by the MU
68_MU_COMMANDS_NAK'D_BY_MU	Number of MU_* commands rejected by the MU
69_MU_PACKETS_RECEIVED_SUCCESS	Number of packets the MU has received successfully
70_MU_PACKETS_RECEIVED_ERROR	Number of packets the MU has received in error
71_NUMBER_OF_BU_SPECTRA_READ_OUT_-_NV	Nonvolatile counter of the number of BU spectra read out from the SE
72_NUMBER_OF_RMI_RECEIVED_FROM_MU_-_NV	Nonvolatile counter of the number of RMI received from the MU
73_NUMBER_OF_MICROPHONE_RECORDINGS_-_NV	Nonvolatile counter of the number of microphone recordings made
74_NUMBER_OF_SCIENCE_LASER_SHOTS_COMMANDED_-_NV	Nonvolatile counter of the number of science laser shots commanded
75_CURRENT_ABSOLUTE_FOCUS_TABLE_POSITION	Nonvolatile absolute focus table position

76_CLOSE_LIMIT_SWITCH_POSITION_DIFFERENCE	Difference between calculated and actual close limit switch position
77_FAR_LIMIT_SWITCH_POSITION_DIFFERENCE	Difference between calculated and actual infinity/far limit switch position
78_CURRENT_AUTOFOCUS_BASELINE_POSITION	Current autofocus baseline position, from which offsets are performed
79_CURRENT_SPACEWIRE_LINK_0_STATUS_REGISTER	SpaceWire link 0 Leon3FT status, for MU HSS interface
80_CURRENT_SPACEWIRE_LINK_1_STATUS_REGISTER	SpaceWire link 1 Leon3FT status, for Transmission spectrometer
81_CURRENT_SPACEWIRE_LINK_2_STATUS_REGISTER	SpaceWire link 2 Leon3FT status, for Violet spectrometer
82_CURRENT_SPACEWIRE_LINK_3_STATUS_REGISTER	SpaceWire link 3 Leon3FT status, for UV spectrometer
83_CURRENT_FOCUS_TABLE_POSITION_IN_MM	Focus table position converted to mm
84_RESERVED	Reserved for future
85_STATUS_FLAGS	Status Flag bits
86_MOTOR_SPEED_INHIBITED	indicates the MU is cold the BU automatically reduces the motor speed to 100 steps/second
87_LASER_CURRENT_INHIBITED	indicates when the MU is warm the BU can limit the pumping current for the laser
88_CCD_IS_CLOCKING	indicates when the CCDs are clocking possible temperture noise
89_LIMIT_SWITHCH_ARG_CHANGED_TO_COMPUTED_VALUE	indicates limit switch arg changed to computed value
90_FOCUS_MOTOR_INHIBITED	MU attempts to go to the limit switch but a NO_LIMIT_SWITCH_FOUND
02A_SYS_ERROR	RCE should download diagnostic data, power off and mark SICK
02B_SEND_EVR	RCE to generate an EVR but let operation continue
02C_SHUTDOWN	RCE to shutdown instrument but not mark sick
02D_SUN_SAFE	BU knows that the MU telescope is in a sun-safe condition.
02E_BU_HVPS_ON	BU HVPS to intensifier on.
02F_MU_SHUTTER	Status of the MU red/green shutter.
02G_MU_LASER_ON	MU HVPS to laser is on.
02H_MU_DC_CHAIN_ON	MU DC/DC supply chain on.
02I_MU_ON	Power to MU is on.
02J_CCD_ALMOST_READY	CCDs approaching operating temperature range so turn on MU.
02K_CCD_READY	CCDs in operating temperature range and ready for use.
02L_IRS_READY	IR spectrometer in operating temperature range and ready for use.
02M_LASER_DOUBLER_READY	Laser doubler in operating temperature range and ready for use.
02N_LASER_STACK_READY	Laser in operating temperature range and ready for use.
02O_CWL_READY	CWL in operating temperature range and ready for use.
C46_CNDH_PCB_TEMP	Temperature of the C&DH PCB, usually the warmest part of the BU EBOX

C47_CNDH_1_2_V	1.2v monitor on the C&DH, used for Leon3FT processor core
C48_CNDH_LVPS_TEMP	Temperature of the LVPS PCB
C49_CNDH_3_3_V	3.3v monitor on the C&DH, main digital supply on C&DH and SE
C50_CNDH_VUI_UV_SPECT_TEMP	Temperature of the reflection spectrometer housing
C51_CNDH_NEG_15_V	-15v monitor on the C&DH, used on SE and HVPS
C52_CNDH_15_V	15v monitor on the C&DH, used on C&DH, SE, and HVPS
C53_CNDH_1_5_V	1.2v monitor on the C&DH, used for FPGA core
C58_SE_TX_TEMP	Temperature of the Transmission spectrometer CCD
C59_SE_VIO_TEMP	Temperature of the Violet spectrometer CCD
C60_SE_UV_TEMP	Temperature of the UV spectrometer CCD
C61_SE_TM_TEMP	Temperature of the Transmission spectrometer housing
C62_SE_24_V	24v monitor on the SE, used to bias CCDs
C63_SE_HVPS_REAR	HVPS read plate voltage monitor
C64_SE_HVPS_CURRENT	HVPS current monitor
C65_SE_HVPS_TEMP	Temperature of the HVPS PCB

11 Appendix E: More Detail on processing for CDRs

Additional detail on common processing steps (LIBS/RAMAN/TRLS)

Dark subtraction (LIBS/RAMAN/TRLS)
First, if all darks (no laser-spectra) are returned on the ground, we compute its mean spectra or if statistics are collected for the darks the mean of the darks averaged onboard are used. Then, this is subtracted from each of the active spectra to obtain dark-subtracted signal.

Computation of Statistics (if shot to shot spectra acquired) (LIBS/RAMAN/TRLS)
We compute a spectra of the mean, median and standard deviation (pixel-to-pixel) using the spectra from shot number 6 and above, since the first 5 spectra are usually associated with signal from dust. If less then 5 shots are performed (non-standard activity, usually dust removal activity or spectra of cal targets) all the spectra are used to calculate the statistics.

Stitching of the spectral bands in the VNIR range (LIBS/RAMAN/TRLS)
The three parts of the VINIR spectrometer (a.k.a. green, orange and red) will be merged, selecting the best signal-to-noise vs resolution compromise. Each spectrum in LIBS EDRs is composed of 2148 pixels x 5 ranges. Each spectrum in RAMAN and TRLS EDRs is composed of 2148 x 3 ranges. Pixels in the [0:50] and [2098:2148] in each range are blind, and are removed from the CDRs. Other pixels on the edge of each spectrometer have a low instrument response, so these are removed as well. Finally, the three ranges coming from the transmission spectrometer (Green/Orange/Red) overlap. In the overlapping region, we chose those part of the spectrometer that have the best IRF and spectral resolution.

Denoise (LIBS/RAMAN/TRLS)
The same wavelet algorithm used for CCAM is applied to denoise and remove the continuum from the spectra. See Wiens et al 2013, *Spectrochimica Acta Part B: Atomic Spectroscopy, doi:10.1016/j.sab.2013.02.003, 2013.*

Wavelength calibration (LIBS/RAMAN/TRLS)
Currently, each pixel is assigned a wavelength based on measurement during testing at JPL under martian atmosphere. Each spectrum is then resampled to a common wavelength grid, that is used also for ground testing.

Correction for the Instrument Response function (LIBS/RAMAN/TRLS)
The number of digital counts from the spectrometer is converted to photons by multiplying by the pixel-to-pixel instrument response function, that was measured during the ground testing at JPL. This curve varies with instrument parameters (e.g. number of rows selected in each spectrometers, gain of the intensifier) and this step takes this dependencies into account.

Continuum removal (LIBS only)
This is done similar as for CCAM, as described in Wiens et al. 2013

Convert Photons-to-radiance. (LIBS only)
This is done similar as for CCAM, as described in Wiens et al. 2013

12 Appendix F: Example python codes

This is simple python script to read Raman CDR fits and plot wavenumber vs the mean spectra:

```
from astropy.io import fits
import matplotlib.pyplot as plt
# open fits file
hdulist=fits.open(
'scam_0188_0683629751_417_cr0_scam01188_bellegarde_188_scam__050.fits')
x = hdulist[8].data['Wavelength']
y = hdulist[7].data['Mean']
plt.figure()
plt.plot(x,y)
plt.xlabel('Raman Shift($cm^{-1}$)')
plt.ylabel('Normalized Intensity')
plt.title(
'scam_0188_0683629751_417_cr0_scam01188_bellegarde_188_scam__05p0.fits')
plt.savefig('1188_bellegarde_188_scam__05p0.png') # save png of plot
plt.show() # plot to display
exit()
```

By replacing the HDUs used and the labels similar code can be used for the other SuperCam fits data.

This is a simple python script to read LIBS CDR fits file and save a csv of the wavelength vs the mean spectra:

```
from astropy.io import fits
import pandas as pd
# open fits file
hdulist=fits.open(
'scam_0188_0683629751_417_cr0_scam01188_bellegarde_188_scam__05p0.fits')
x = hdulist[8].data['Wavelength']
y = hdulist[7].data['Mean']
df = pd.DataFrame({"Wavelength" : x, "Intensity" : y})
df.to_csv(
"scam01188_bellegarde_188_scam__05.csv",index=False)
exit()
```

13 Appendix G: Meaning of TBDs in EDR xml labels (sol 0-89)

There are a series of TBD descriptions in the EDR xml labels. The descriptions are provided in this table.

PRIMARY HEADER	Primary FITS Header
ODL LABEL HEADER	FITS header for ODL Label Table
ODL LABEL TABLE	Metadata in Object Description Language (ODL)
TIMELINE HEADER	FITS header for Timeline Table
TIMELINE TABLE	Timeline Table: I-commands and their arguments
MS_SINCE_LAST_SYNC	SCLK time Sync
CMD_NAME	I-Command
OPCODE	Operation code
TYPE	Command or data
DATA_LENGTH	Size of data to follow
ARGS	Arguments to icommand
DATA	Data returned from icommand
MU SOH HEADER	FITS header for Mast Unit State of Health Table
MU SOH TABLE	Mast Unit State of Health Table
MU_MS_OFFSET	Offset from SCLK time sync
00_LASER_OSC1_TEMP	Main thermal sensor for the Laser stack
01_LASER_OSC2_TEMP	Redundant thermal sensor for the Laser stack
02_LASER_DOUB1_TEMP	Main thermal sensor for the Laser stack
03_LASER_DOUB2_TEMP	Redundant thermal sensor for the Laser stack
04_LASER_15V	Laser 15V limiter sec voltage (close to 0 from OFF/15V when ON)
05_LASER_HV	Laser High Voltage HK (close to 20V when OFF

06_LASER_LIMITER_TEMP	Laser board thermal sensor closed to the limiter (hot case)
07_DPU_MOTOR_DRIVER_TEMP	DPU board thermal sensor on Motor Driver (hot case)
08_DPU_FPGA_TEMP	DPU board thermal sensor on DPU
09_VREF_+2.5V	2.5V reference voltage
10_+1.5V	1.5V FPGA core voltage
11_+3.3V	3.3V FPGA I/O voltage
12_MOTOR_TEMPERATURE	Thermal sensor inside the Motor (hot case)
13_PRIMARY_MIRROR_TEMP	Reference thermal sensor for the AFT range check (on the bench now)
14_CWL_PD_CURRENT	Compensation current of the CWL
15_MICRO_TEMP	Thermal sensor inside the Microphone finger when MICRO ON
16_CWL_TEMP	Thermal sensor used for CWL heater control
17_+3.3_IRS	3.3V IRS voltage (4.3V when IRS TEC OFF
18_+20V_RF_IRS	20V IRS voltage (20V when IRS TEC N DCDC ON)
19_+5V_RF_IRS	5V IRS voltage
20_-5V_RF_IRS	-5V IRS Voltage
21_+5V_DT_IRS	8V IRS Voltage
22_-5V_DT_IRS	-8V IRS Voltage
23_LVPS_BOARD_TEMP	Thermal sensor on the LVPS board (hot case)
24_PRIMARY_CURRENT	28V current measured on the LVPS board
25_IRS_HK_TEMP_AOTF	AOTF temperature (saturated at -51¬°C)
26_IRS_HK_TEMP_HOT_TEC	Hot side of TEC temperature (saturated at -51¬°C)
27_IRS_HK_TEMP_BOARD	Thermal sensor on the IRBoard (saturated at -51¬°C)
28_IRS_HK_TEMP_DET	TEC cold side temperature (saturated at -51¬°C)
29_REMAINING_LASER_PULSES	Number of remaining shots
30_ON/OFF_SHUTTER	0 = shutter is not activited
31_ON/OFF_LIMITER	0 = Laser board Limiter OFF
32_ON/OFF_HIGH_VOLTAGE_15_V	0 = Laser board +15V OFF
33_ON/OFF_MICROPHONE	0 = Microphone OFF
34_ON/OFF_RMI	0 = RMI OFF
35_ON/OFF_DC/DC	0 = Microphone OFF
36_ON/OFF_HEATER_DOUBLER_LASER	0 = heater doubler laser OFF
37_ON/OFF_HEATER_STACK_LASER	0 = heater stack laser OFF
38_ON/OFF_HEATER_CWL	0 = heater CWL OFF
39_HEATER_DOUBLER_RECEIVED	0 = Doubler setpoint not reached
40_HEATER_STACK_RECEIVED	0 = Stack setpoint not reached
41_HEATER_CWL_RECEIVED	0 = CWL setpoint not reached
42_ON/OFF_TEC_IR	0 = nominal photodiode (DET1)

43_TEC_IR_READY	0 = TEC is OFF
44_IRS_MEAS_ONGOING	0 = TEC temp setpoint not reached
45_IR_DET_SEL	0 = IRS Measurement ongoing
46_MOTOR_DRIVER_CIRCUIT_THERMAL_FLAG	To be discussed
47_AF_GAIN_STATUS_MSB	AF gain status_MSB
48_AF_GAIN_STATUS_LSB	AF gain status_LSB
49_ON/OFF_CWL	0 = CWL is not turn OFF
50_ON/OFF_CWL_MODULATION	0 = no modulation of CWL
51_ON/OFF_MOTOR_DRIVER	0 = Motor driver is OFF
52_INFINITE_LIMIT_SWITCH_STATUS	0 = Infinite switch not reached
53_CLOSE_LIMIT_SWITCH_STATUS	0 = Close switch not reached
C00_LASER_OSC1_TEMP	Main thermal sensor for the Laser stack
C01_LASER_OSC2_TEMP	Redundant thermal sensor for the Laser stack
C02_LASER_DOUB1_TEMP	Main thermal sensor for the Laser stack
C03_LASER_DOUB2_TEMP	Redundant thermal sensor for the Laser stack
C04_LASER_15V	Laser 15V limiter sec voltage (close to 0 from OFF/15V when ON)
C05_LASER_HV	Laser High Voltage HK (close to 20V when OFF
C06_LASER_LIMITER_TEMP	Laser board thermal sensor closed to the limiter (hot case)
C07_DPU_MOTOR_DRIVER_TEMP	DPU board thermal sensor on Motor Driver (hot case)
C08_DPU_FPGA_TEMP	DPU board thermal sensor on DPU
C09_VREF_+2.5V	2.5V reference voltage
C10_+1.5V	1.5V FPGA core voltage
C11_+3.3V	3.3V FPGA I/O voltage
C12_MOTOR_TEMPERATURE	Thermal sensor inside the Motor (hot case)
C13_PRIMARY_MIRROR_TEMP	Reference thermal sensor for the AFT range check (on the bench now)
C14_CWL_PD_CURRENT	Compensation current of the CWL
C15_MICRO_TEMP	Thermal sensor inside the Microphone finger when MICRO ON
C16_CWL_TEMP	Thermal sensor used for CWL heater control
C17_+3.3_IRS	3.3V IRS voltage (4.3V when IRS TEC OFF
C18_+20V_RF_IRS	20V IRS voltage (20V when IRS TEC N DCDC ON)
C19_+5V_RF_IRS	5V IRS voltage
C20_-5V_RF_IRS	-5V IRS Voltage
C21_+5V_DT_IRS	8V IRS Voltage
C22_-5V_DT_IRS	-8V IRS Voltage
C23_LVPS_BOARD_TEMP	Thermal sensor on the LVPS board (hot case)
C24_PRIMARY_CURRENT	28V current measured on the LVPS board
C25_IRS_HK_TEMP_AOTF	AOTF temperature (saturated at -51¬°C)

C26_IRS_HK_TEMP_HOT_TEC	Hot side of TEC temperature (saturated at -51¬°C)
C27_IRS_HK_TEMP_BOARD	Thermal sensor on the IRBoard (saturated at -51¬°C)
C28_IRS_HK_TEMP_DET	TEC cold side temperature (saturated at -51¬°C)
C29_REMAINING_LASER_PULSES	Number of remaining shots
BU SOH HEADER	FITS header for Body Unit State of Health Table
BU SOH TABLE	Body Unit State of Health Table
BU_MS_OFFSET	Millisecond offset time from sclk
00_TLM_FORMAT_VERSION_(CMD_DICT_VERSION)	I-Command Dictionary version
01_LAST_BIST_RESULT	Last BU BIST result
02_CURRENT_STATUS_FLAGS	Current Status Flag state
03_BOOT_BANK_SELECTED	MRAM iFSW boot bank selected by Init discretes. 0 = Bank A
04_BOOT_BANK_ACTUAL	MRAM iFSW boot bank that was actually used to boot the instrument. 0 = Bank A
05_COMMANDS_RECEIVED	Number of i-commands sent to the instrument
06_COMMANDS_COMPLETED	Number of i-commands successfully completed (not rejected)
07_COMMANDS_REJECTED	Number of i-commands rejected by the instrument
08_NUMBER_OF_ERROR_LOG_ENTRIES_SINCE_BOOT	A non-zero value indicates that an error has occurred since the instrument was powered on
09_BANK_A_KERNEL_CALCULATED_CHECKSUM_-_NV	Checksum of the MRAM iFSW Bank A kernel
10_BANK_A_APPLICATION_CALCULATED_CHECKSUM_-_NV	Checksum of the MRAM iFSW Bank A application
11_BANK_B_KERNEL_CALCULATED_CHECKSUM_-_NV	Checksum of the MRAM iFSW Bank B kernel
12_BANK_B_APPLICATION_CALCULATED_CHECKSUM_-_NV	Checksum of the MRAM iFSW Bank B application
13_RCE_COMM_SIDE	Indicates which RCE is active 0 = RCE B
14_SPACEWIRE_COMM_ERROR_COUNT_-_NV	Nonvolatile counter of the number of SpaceWire errors
15_LAST_SPACEWIRE_ERROR_STATUS_REGISTER	A copy of the SpaceWire error status register from the Leon3FT
16_SINGLE_BIT_MRAM_MEMORY_ERRORS_-_NV	Nonvolatile counter of the number of single-bit (correctable) MRAM EDAC errors
17_SINGLE_BIT_SDRAM_MEMORY_ERRORS_-_NV	Nonvolatile counter of the number of single-bit (correctable) SDRAM EDAC errors
18_LAST_SINGLE_BIT_MEMORY_ADDRESS	Last error memory address from Leon3FT EDAC
19_SOFTWARE_VERSION	iFSW version number
20_PULSES_ID_REG	Copy of CNDH FPGA pulses register
21_ROVER_HSS_TX_WD_CNT_REG	Copy of CNDH FPGA control register
22_IRQ_CLR_REG	Copy of CNDH FPGA control register
23_ROVER_HSS_CNTRL_REG	Copy of CNDH FPGA control register
24_ROVER_HSS_TX_REG	Copy of CNDH FPGA control register
25_IRQ_EN_REG	Copy of CNDH FPGA control register
26_UART_TX_DATA_CNTRL_REG	Copy of CNDH FPGA control register
27_UART_CNTRL_REG	Copy of CNDH FPGA control register
28_LVPS_CTRL_REG	Copy of CNDH FPGA control register
29_MRAM_CNTRL_REG	Copy of CNDH FPGA control register

30_LED_REG	Copy of CNDH FPGA control register
31_INT_TIME_REG	Copy of CNDH FPGA control register
32_NSPS_REG	Copy of CNDH FPGA control register
33_LZR_REP_RATE_REG	Copy of CNDH FPGA control register
34_SPW_CTRL_REG	Copy of CNDH FPGA control register
35_TEST_CTRL_REG	Copy of CNDH FPGA control register
36_MU_HSS_EMU_REG	HSS_not_used
37_NUM_SPECTRA_REG	Copy of CNDH FPGA control register
38_HVPS_DLY_REG	Copy of CNDH FPGA control register
39_HVPS_DUR_REG	Copy of CNDH FPGA control register
40_STATUS0_REG	Copy of CNDH FPGA status register
41_IRQ_STAT_REG	Copy of CNDH FPGA status register
42_ROVER_HSS_FRAME_STAT_REG	Copy of CNDH FPGA status register
43_UART_STAT_REG	Copy of CNDH FPGA status register
44_ROVER_HSS_STAT_REG	Copy of CNDH FPGA status register
45_SPW_STAT_REG	Copy of CNDH FPGA status register
46_CNDH_PCB_TEMP	Temperature of the CNDH PCB
47_CNDH_1_2_V	1.2v monitor on the CNDH
48_CNDH_LVPS_TEMP	Temperature of the LVPS PCB
49_CNDH_3_3_V	3.3v monitor on the CNDH
50_CNDH_VUI_UV_SPECT_TEMP	Temperature of the reflection spectrometer housing
51_CNDH_NEG_15_V	-15v monitor on the CNDH
52_CNDH_15_V	15v monitor on the CNDH
53_CNDH_1_5_V	1.2v monitor on the CNDH
54_TEST_STAT_REG	Copy of CNDH status register
55_IDENTITY_STAT_REG	Copy of CNDH status register
56_TEST2_STAT_REG	Copy of CNDH status register
57_MISSED_PULSE_REG	Copy of CNDH status register
58_SE_TX_TEMP	Temperature of the Transmission spectrometer CCD
59_SE_VIO_TEMP	Temperature of the Violet spectrometer CCD
60_SE_UV_TEMP	Temperature of the UV spectrometer CCD
61_SE_TM_TEMP	Temperature of the Transmission spectrometer housing
62_SE_24_V	24v monitor on the SE
63_SE_HVPS_REAR	HVPS read plate voltage monitor
64_SE_HVPS_CURRENT	HVPS current monitor
65_SE_HVPS_TEMP	Temperature of the HVPS PCB
66_NUMBER_OF_COMMANDS_SENT_TO_MU	Number of MU_* commands sent from the BU to the MU

67_MU_COMMANDS_ACK'D_BY_MU	Number of MU_* commands acknowledged by the MU
68_MU_COMMANDS_NAK'D_BY_MU	Number of MU_* commands rejected by the MU
69_MU_PACKETS_RECEIVED_SUCCESS	Number of packets the MU has received successfully
70_MU_PACKETS_RECEIVED_ERROR	Number of packets the MU has received in error
71_NUMBER_OF_BU_SPECTRA_READ_OUT_-_NV	Nonvolatile counter of the number of BU spectra read out from the SE
72_NUMBER_OF_RMI_RECEIVED_FROM_MU_-_NV	Nonvolatile counter of the number of RMI received from the MU
73_NUMBER_OF_MICROPHONE_RECORDINGS_-_NV	Nonvolatile counter of the number of microphone recordings made
74_NUMBER_OF_SCIENCE_LASER_SHOTS_COMMANDED_-_NV	Nonvolatile counter of the number of science laser shots commanded
75_CURRENT_ABSOLUTE_FOCUS_TABLE_POSITION	Nonvolatile absolute focus table position
76_CLOSE_LIMIT_SWITCH_POSITION_DIFFERENCE	Difference between calculated and actual close limit switch position
77_FAR_LIMIT_SWITCH_POSITION_DIFFERENCE	Difference between calculated and actual infinity/far limit switch position
78_CURRENT_AUTOFOCUS_BASELINE_POSITION	Current autofocus baseline position
79_CURRENT_SPACEWIRE_LINK_0_STATUS_REGISTER	SpaceWire link 0 Leon3FT status
80_CURRENT_SPACEWIRE_LINK_1_STATUS_REGISTER	SpaceWire link 1 Leon3FT status
81_CURRENT_SPACEWIRE_LINK_2_STATUS_REGISTER	SpaceWire link 2 Leon3FT status
82_CURRENT_SPACEWIRE_LINK_3_STATUS_REGISTER	SpaceWire link 3 Leon3FT status
83_CURRENT_FOCUS_TABLE_POSITION_IN_MM	Focus table position converted to mm
84_RESERVED	Reserved for future
85_STATUS_FLAGS	Status Flag bits
86_MOTOR_SPEED_INHIBITED	Motor Speed Inhibited status
87_LASER_CURRENT_INHIBITED	Laser current inhibited status
88_CCD_IS_CLOCKING	Is CCD clocking
89_LIMIT_SWITHCH_ARG_CHANGED_TO_COMPUTED_VALUE	Limit switch changed to computed value
90_FOCUS_MOTOR_INHIBITED	Focus Motor inhibited status
02A_SYS_ERROR	RCE should download diagnostic data
02B_SEND_EVR	RCE to generate an EVR but let operation continue
02C_SHUTDOWN	RCE to shutdown instrument but not mark sick
02D_SUN_SAFE	BU knows that the MU telescope is in a sun-safe condition.
02E_BU_HVPS_ON	BU HVPS to intensifier on.
02F_MU_SHUTTER	Status of the MU red/green shutter.
02G_MU_LASER_ON	MU HVPS to laser is on.
02H_MU_DC_CHAIN_ON	MU DC/DC supply chain on.
02I_MU_ON	Power to MU is on.
02J_CCD_ALMOST_READY	CCDs approaching operating temperature range so turn on MU.
02K_CCD_READY	CCDs in operating temperature range and ready for use.
02L_IRS_READY	IR spectrometer in operating temperature range and ready for use.
02M_LASER_DOUBLER_READY	Laser doubler in operating temperature range and ready for use.

02N_LASER_STACK_READY	Laser in operating temperature range and ready for use.
02O_CWL_READY	CWL in operating temperature range and ready for use.
C46_CNDH_PCB_TEMP	Temperature of the CNDH PCB
C47_CNDH_1_2_V	1.2v monitor on the CNDH
C48_CNDH_LVPS_TEMP	Temperature of the LVPS PCB
C49_CNDH_3_3_V	3.3v monitor on the CNDH
C50_CNDH_VUI_UV_SPECT_TEMP	Temperature of the reflection spectrometer housing
C51_CNDH_NEG_15_V	-15v monitor on the CNDH
C52_CNDH_15_V	15v monitor on the CNDH
C53_CNDH_1_5_V	1.2v monitor on the CNDH
C58_SE_TX_TEMP	Temperature of the Transmission spectrometer CCD
C59_SE_VIO_TEMP	Temperature of the Violet spectrometer CCD
C60_SE_UV_TEMP	Temperature of the UV spectrometer CCD
C61_SE_TM_TEMP	Temperature of the Transmission spectrometer housing
C62_SE_24_V	24v monitor on the SE
C63_SE_HVPS_REAR	HVPS read plate voltage monitor
C64_SE_HVPS_CURRENT	HVPS current monitor
C65_SE_HVPS_TEMP	Temperature of the HVPS PCB
LASERDATA HEADER	FITS header for Laser Data Table
LASERDATA TABLE	Laser Data Table
Shot Number	Shot Number
Stack voltage	Stack voltage
Pumping Current	Pumping Current
Optical Power	Optical Power
Stack voltage (V)	Stack voltage (V)
Pumping Current (A)	Pumping Current (A)
Optical Power (mJ)	Pumping Current
SPECTRA HEADER	FITS header for Spectra Table
SPECTRA TABLE	Spectra Table
Spectrum	Calibrated Spectrum
STATISTICS HEADER	FITS header for Wavelength Table
STATISTICS TABLE	Statistics Table
Mean	Mean of all shots.
Median	Median of all shots
StDev	Standard Deviation of all shots
WAVELENGTH HEADER	FITS header for Wavelength Table
WAVELENGTH TABLE	Wavelength Table

Wavelength	Wavelength - Mapping of CCD pixels to the expected wavelength of light incident for each pixel.
IRF	Instrument Response Function - The IRF maps the number of photons incident on the telescope aperture to an expected signal recorded by the CCD.
SATURATION HEADER	FITS header for Saturation Table
SATURATION TABLE	Saturation Table
SaturationMask	Saturation Mask Table