Mars Science Laboratory (MSL)

Software Interface Specification

Interface Title: **Mast Camera (Mastcam), Mars Hand Lens Imager (MAHLI), and Mars Descent Imager (MARDI) Experiment Data Record (EDR) and Reduced Data Record (RDR) PDS Data Products**

Mission: MSL Date: October 29, 2013

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Mars Science Laboratory Project

Software Interface Specification (SIS)

Mast Camera (Mastcam), Mars Hand Lens Imager (MAHLI), and Mars Descent Imager (MARDI)
Experiment Data Record (EDR) and Reduced Data Record (RDR)
PDS Data Products

Version 1.2

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Jet Propulsion Laboratory
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CHANGE LOG

DATE	SECTIONS CHANGED	REASON FOR CHANGE	REVISION
05/20/13	Initial Release, Version 1.0		
07/30/13	1.3, 3.4.1, 4.4.5.8.2, 5.1, 5.1.1, 5.1.2.11, Appendix A	1.3: updated dates, versions, added document control info 3.4.1: added example processing codes 4.4.5.8.2: unbolded characters, added a space 5.1: added cross-reference to Figure 5.1-1 5.1.1: removed superfulous sentence 5.1.2.11: added period Appendix A: updated valid values, added “N/A”, “NULL”, and “UNK” as possible values for all keywords; updated example .LBL files	1.1
10/29/13	1.3, 3.4.1, 4.4.3, Appendix A, D, F and G	1.3: updated dates, version 3.4.1: added reference sentence to added Appendix F and G 4.4.3: updated values in table 4.4-3 Appendix A: added new keywords; updated valid values and definitions Appendix D: added graphics Appendix F and G: new appendicies	1.2

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ACRONYMS AND ABBREVIATIONS

ADC	Analog-to-Digital Converters
APID	Application Process Identifier
APSS	Activity Planning and Sequencing Subsystem
ASCII	American Standard Code for Information Interchange
ATLO	Assembly, Test, and Launch Operations
Caltech	California Institute of Technology
CCD	Charged Coupled Device
CCBU	Chemistry Camera Body Unit
CCMU	Chemistry Camera Mast Unit
CDPID	Camera Data Product IDentifier (assigned aboard each MMM camera)
ChemCam	Chemistry Camera aboard MSL rover
CHIMRA	Collection and Handling for Interior Martian Rock Analysis
CNES	Centre National d'Etudes spatiales (French Space Agency)
CODMAC	Committee on Data Management and Computation
DAN	Dynamic Albedo of Neutrons Experiment
DC	Direct Current
DCT	Direct Cosine Transform
DEA	Digital Electronics Assembly, the compute element within each MMM camera
DN	Data Number
DP	Data Product (telemetry)
DPO	Data Product Object
DRAM	Dynamic Random-Access Memory (type of volatile memory)
DRT	Dust Removal Tool
DTE	Direct To Earth
DVT	Data Validity Time
EDL	Entry, Descent and Landing
EDR	Experiment Data Record
EHA	Engineering, Housekeeping & Accountability (EH&A)
EM	Engineering Model
EMD	Earth Metadata file (".emd")
EPDU	End-of-Product PDU
ERT	Earth Received Time
FDD	Functional Design Document
FEI	File Exchange Interface
FGICD	Flight-Ground ICD
FM	Flight Model
FOV	Field of View
FPGA	Field Programmable Gate Array

FSW	Flight Software
GSFC	Goddard Space Flight Center
GDS	Ground Data System
GOP	Group of Pictures
GSE	Ground Support Equipment
Hazcam	Hazard Avoidance Camera
HGA	High Gain Antenna
HWHM	Half-Width Half-Maximum
IC	Inlet Cover
ICD	Interface Control Document
ICER	Image compression algorithm (not an acronym)
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
IFOV	Instantaneous Field of View
IPE	Integrated Planning and Execution (MS element)
IRAP	Institut de Recherche en Astrophysique et Planétologie
ISIS	Integrated Software for Imagers and Spectrometers
IVP	Inertial Vector Propagation
JMS	Java Message Server
JPEG	Joint Photographic Experts Group
JPL	Jet Propulsion Laboratory
KSC	Kennedy Space Center
LANL	Los Alamos National Laboratory
LIBS	Laser-Induced Breakdown Spectrometer (ChemCam)
LOCO	LOw-COmplexity, LOssless Compression
LSB	Least Significant Byte
MAHLI	Mars Hand Lens Imager (MSSS)
MARDI	Mars Descent Imager (MSSS)
MastCam	Mast Camera (MSSS)
MCU	Minimum Compression Unit
MER	Mars Exploration Rover
MGS	Mars Global Surveyor
MIPL	Multimission Instrument Processing Laboratory
MMM	MastCam, MAHLI, MARDI (MSSS cameras)
MOS	Mission Operations System
MPCS	Mission data Processing and Control Subsystem
MPDU	Metadata Protocol Data Unit
MPF	Mars Pathfinder
MRO	Mars Reconnaissance Orbiter
MS	Mission System
MSB	Most Significant Byte

MSL	Mars Science Laboratory
MSLICE	MSL InterfaCE
MSSS	Malin Space Science Systems
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
Navcam	Navigation Camera
ND	Neutral Density
NIST	National Institute of Standards and Technology
NVM	Non-Volatile Memory
ODL	Object Description Language
ODS	Operations Data Store
OPGS	Operations Product Generation Subsystem
PI	Principal Investigator
PDS	Planetary Data System
PDU	Protocol Data Unit
PPDU	Product Data Protocol Data Unit
PRT	Platinum Resistance Thermometer
PSDD	Planetary Science Data Dictionary
RA	Robotic Arm
RCE	Rover Compute Element
RDR	Reduced Data Record
RGB	Red Green Blue
RMI	Remote Micro-Imager (ChemCam)
RSM	Remote Sensing Mast
RSVP	Rover Sequencing and Visualization Program
RTG	Radioisotope Thermoelectric Generator
RTO	Real Time Operations (MS element)
SAPP	Surface Attitude, Positioning and Pointing
SCID	Spacecraft ID
SCLK	Spacecraft Clock
SCM	Spacecraft Configuration Manager
SFDU	Standard Format Data Unit
SIS	Software Interface Specification
SOAS	Science Operations Analysis Software
SNR	Signal-to-Noise Ratio
SOH	State of Health (ChemCam)
SOWG	Science Operations Working Group
SPaH	Sample Processing and Handling
SPICE	Spacecraft, Planet, Instrument, C-matrix, Events kernels
SRAM	Static Random Access Memory

SwRI	Southwest Research Institute
TBD	To Be Determined
TDS	Telemetry Delivery Subsystem
UDR	Unprocessed Data Record
USGS	United States Geological Survey
VCID	Virtual Channel Identifier
VICAR	Video Image Communication and Retrieval

GLOSSARY

TERM	DEFINITION
Bayer	A color filter array pattern with a 4-element unit cell of 1 red, 2 green and 1 blue cells with the green cells occupying diagonally opposite corners, invented by Bryce Bayer of Eastman Kodak.
Compand(ing)	Contraction of terms "compress and expand," generally used to describe a form of compression using look up tables. MMM decompanding tables reduce the bit depth of images from 12 bits to 8 bits. The primary table uses a modified square root encoding.
Focus Merge	Image source - data is a composite of up to 8 images of the same target, acquired at different lens focus positions aligned along the camera's optical axis, designed to provide a "best focus" image that accommodates changes in depth of field for a given target at a given working distance. This is also known as a z-stack product.
Frame	The MMM video command acquires individual, successive images for which each image is a single frame
GOP	Video storage - Group Of Pictures (GOP), a method of storing 1 to 16 compressed images as consecutive JPEGs in a single product
Huffman Compression	A form of data encoding where variable numbers of bits are used to encode values based on their probability of occurrence originally described by D.A. Huffman [Ref 8]. For image products, the differences between adjacent pixel values are typically the values being encoded, since these are exponentially distributed around zero for typical images.
Lossless	Raster 8 bit image is losslessly encoded using first difference Huffman compression
Luminance	Non-linearly encoded light intensity
Metadata	Structured data relevant or associated with contextually related data
Mini-header	A 64 byte binary header prepended to the image data by the MMM camera digital electronics assembly, that contains image parameter data
ND5	10^{-5} neutral density coating for solar imaging
PICNO	"Picture Number" -- a relatively short unique identifier for each image, intended to be used to refer to specific images in publications
Product Identifier	A numerical identifier assigned to images when they are commanded from the ground.
Range Map	Image source - data is a composite of up to 8 images of the same target, acquired at different lens focus positions aligned along the camera's optical axis, designed to provide information about linear range in grayscale DN values which can be translated to motor count units and distance. This is also known as a z-stack product.
Raster 8 bit	References pixel order and layout. Pixels are 8 bits in row major, column minor order. The first byte is the first pixel that is the upper-left pixel for the image. Pixels are aligned with the Bayer color filter pattern. Data are companded from 12 bits to 8 bits.

TERM	DEFINITION
Raster 16 bit	References pixel order and layout. Pixels are 16 bits in row major, column minor order. The first two bytes are the first pixel, which are the upper-left pixel for the image. Bytes are arranged in the big-endian form where the first byte is most significant. Pixels are aligned with the Bayer color filter pattern.
Sensor	Image source - data is acquired through the imaging sensor
Video	A series of consecutive images taken at a uniform frame rate
YCbCr	In general, one of a family of color spaces used to encode R(ed)G(reen)B(lue) color information. Specifically, the color space used by the MMM camera JPEG compressor. Y is the luminance and Cb and Cr the blue-difference and red-difference chroma components.
Z-Stack	A series of images of the same target taken at different focus positions, so that subsequent post-processing can merge them into a single image in optimal focus regardless of the varying distance of the target from the camera

INTRODUCTION

1.1 Purpose and Scope

The purpose of this Data Product Software Interface Specification (SIS) is to provide consumers of MSL instrument Experiment Data Record (EDR) and Reduced Data Record (RDR) data products with a description of the products and how they are generated, including data sources and destinations. Content in this document supports EDR and/or RDR data products generated by Malin Space Science Systems (MSSS) for the following instruments aboard the Mars Science Laboratory rover, Curiosity:

a. Mast Camera (Mastcam) (two cameras)
b. Mars Hand Lens Imager (MAHLI)
c. Mars Descent Imager (MARDI)

Note: For convenience, the above instruments are hereinafter referred to as “MMM”.

This SIS is addressed to the NASA Planetary Data System (PDS) and its community of users. This is the primary science authority for archiving planetary spacecraft data.

The EDR product delivered to the PDS and described in this document is raw but validated, uncalibrated, and uncorrected data acquired by the MMM instruments, some of which are in compressed format.

The RDR products delivered to the PDS and described in this document are validated, decompressed, and calibrated image-formatted data. Four processed versions of each image are created for the PDS delivery: 1) image-formatted, decompressed, and photometrically calibrated (16-bit/channel); 2) image-formatted, decompressed, photometrically calibrated, and color corrected (8-bit/channel); 3) image-formatted, decompressed, photometrically calibrated, and geometrically linearized (optical distortion corrected) (16-bit/channel); and 4) image-formatted, decompressed, photometrically calibrated, white-balanced, and geometrically linearized (optical distortion corrected) (8-bit/channel).

1.2 Contents

This Data Product SIS describes how the EDR data product is acquired by each MMM instrument aboard the MSL rover and how it is processed, formatted, labeled, and uniquely identified. It similarly describes how the image RDR data products are produced. The document describes and discusses software used to generate the products. The EDR and RDR data product structure and organization is described so as to enable a user to read the product. Finally, examples of EDR and RDR labels are provided, along with the definitions of the keywords in the label.

1.3 Constraints and Applicable Documents

This SIS is meant to be consistent with the contract negotiated between the MSL Project and the MSL Principal Investigator (PI)-led MMM cameras. By agreement with the MMM instrument PIs, any products generated by JPL-Caltech’s OPGS from its processing of MMM data are deliverable to the Project only in a backup capacity and will not be archived with the Planetary Data System (PDS). This SIS governs the specification of data products used during MSL mission operations and provided solely by MSSS. Changes to this SIS are not subject to "impact analysis" by other software subsystems who may be using this SIS in their efforts to support operations (e.g., APSS, OPGS, SOAS). However, this SIS is under change control and changes must be approved by both the PIs and the Project.

Based on the on-going changes in the nature of OPGS processing of the original MMM data and associated spacecraft generated metadata, it is possible that label information in the form of Keywords and Keyvalues may change during the mission. As the MMM software is very sensitive to the existence of an ancillary, but attending, metadata file, future revisions of this SIS may be needed to accommodate these changes. Users of MMM data should anticipate such changes in their future use.

This SIS is consistent with the following Planetary Data System documents:

1. Planetary Science Data Dictionary Document, Version 1.81, November 24, 2010.
2. Planetary Science Data MSL Local Data Dictionary, Version 1.0, October 15, 2013.
3. Planetary Data System Archive Preparation Guide, Version 1.4, JPL D-31224, April 1, 2010.
4. Planetary Data System Data Standards Reference, JPL D-7669, Version 3.8, Part 2, February 27, 2009.
5. Mars Science Laboratory (MSL) MAHLI, MARDI, Mastcam (MMM) Science Team and NASA PDS Imaging Node Science Data Archiving Interface Control Document (ICD), E. Jensen, Version 1.2, June 6, 2013.
6. Mars Science Laboratory (MSL) Mast Camera (Mastcam), Mars Hand Lens Imager (MAHLI), and Mars Descent Imager (MARDI) Experiment Data Record (EDR) and Reduced Data Record (RDR) Archive Volume Software Interface Specification (SIS), M. Malin and K. Edgett, JPL D-75411, SIS-SCI036-MSL, Version 1.1, October 29, 2013.
7. Mars Science Laboratory (MSL) Camera & LIBS Experiment Data Record (EDR) and Reduced Data Record (RDR) Data Products, D. Alexander and R. Deen, JPL D-38107, Version 2.0, February 7, 2013.

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

8. A Method for the Construction of Minimum-Redundancy Codes, D. A. Huffman, Proceedings of the I.R.E., pp 1098–1102, September 1952.
9. Mastcam Multispectral Imaging On The Mars Science Laboratory Rover: Wavelength Coverage And Imaging Strategies At The Gale Crater Field Site, J. F. Bell III et al., 43th Lunar and Planetary Science Conference, abstract 2541, 2012.
10. Curiosity's Mars Hand Lens Imager (MAHLI) Investigation, K. S. Edgett et al., Space Science Reviews, doi:10.1007/s11214-012-9910-4, Volume 170, Issue 1-4, pp 259-317, September 2012.
11. Information Technology – Digital Compression and Coding of Continuous-Tone Still Images – Requirements and Guidelines, Recommendation T.81, ITU-CCITT, September 1992.
12. Initial Multispectral Imaging Results From The Mars Science Laboratory Mastcam Investigation At The Gale Crater Field Site, J. F. Bell III et al., 44th Lunar and Planetary Science Conference, abstract 1417, 2013.
13. Introduction to Modern Photogrammetry, E. M. Mikhail, J. S. Bethel, and J. D. McGlone, John Wiley & Sons Inc., New York, 2001.
14. CAHVOR Camera Model and Its Photogrammetric Conversion for Planetary Applications, K. Di and R. Li, J. Geophys. Res.,109, E04004, doi:10.1029/2003JE002199, 2004.
15. High-Quality Linear Interpolation For Demosaicing Of Bayer-Patterned Color Images, H. S. Malvar, L. He, and R. Cutler, Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing, May 2004.

2. INSTRUMENT OVERVIEW

The MMM cameras represent 4 cameras out of a payload complement of 17 cameras. The MMM instruments are color cameras, including integral Bayer RGB color filter arrays on the photo-sensitive 1608 columns (samples) by 1200 rows (lines) Kodak interline-transfer Charge Coupled Device (CCD) detectors. The MMM cameras consist of identical camera head electronics with different optics, and 4 identical Digital Electronics Assemblies (DEA) that control the camera image acquisitions and processing. The Mastcam camera heads are attached to the Remote Sensing Mast (RSM), the MAHLI is located on the Turret at the end of the Robotic Arm (RA), and the MARDI is fix-body-mounted to the forward port (front left) side of the body of the rover (see Figure 2.1-1).

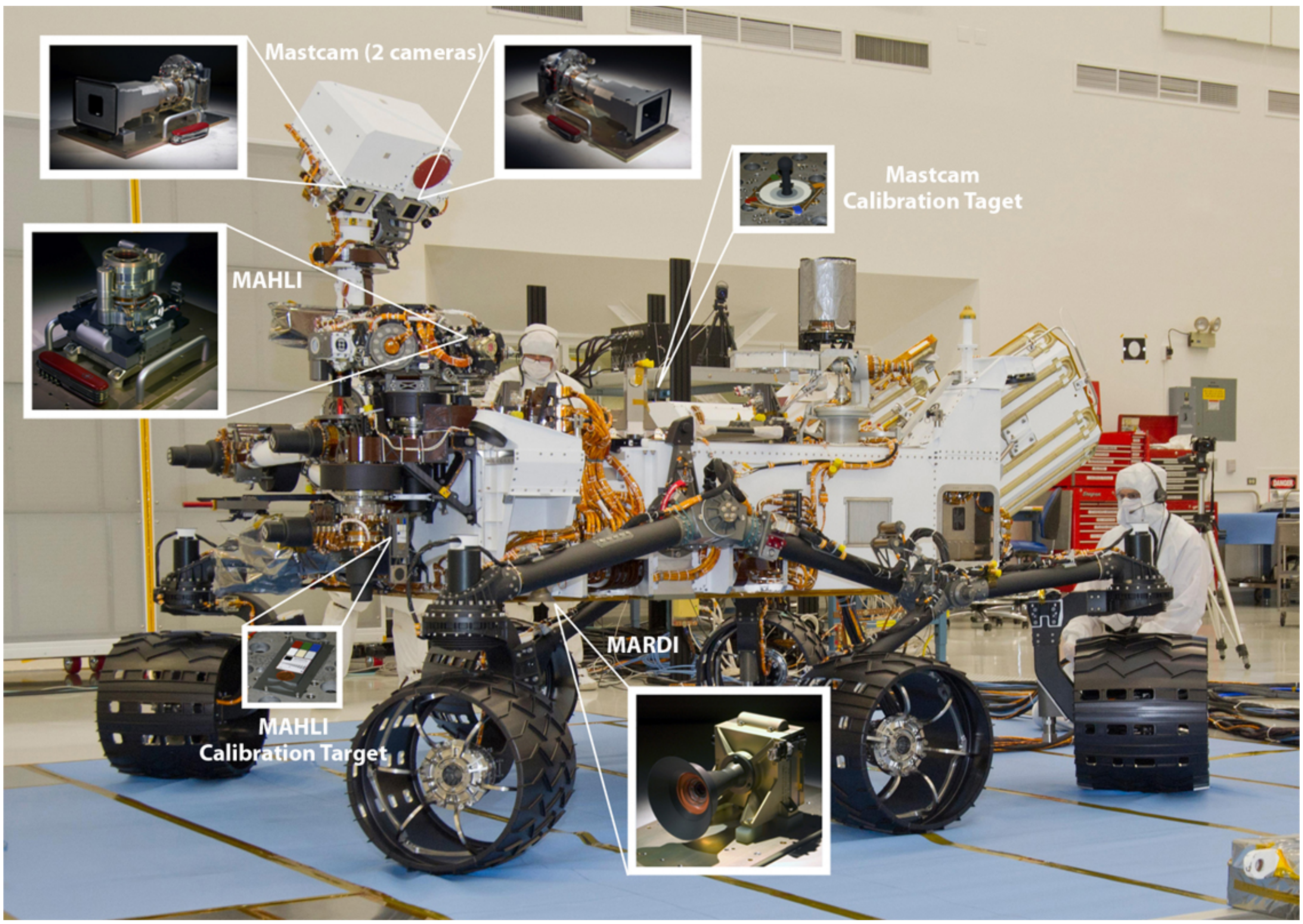


Figure 2.1-1 Mastcam, MAHLI, and MARDI camera mounting locations on the Mars Science Laboratory

2.1 MMM Camera Instrument Suite

2.1.1 Mast Camera (Mastcam)

The Mast Camera (Mastcam) consists of two focusable, color cameras mounted on the rover's Remote Sensing Mast (RSM). The two cameras have different focal lengths and science filters. The instrument acquires images of up to 1200 lines by 1648 samples (1200 by 1608 photoactive pixels), and are capable of consecutive images taken at a uniform frame rate (termed *video*). The cameras acquire color via Bayer-pattern filters on the CCD, but also have selectable science filters that image through the Bayer-pattern filters. Characteristics of the Mastcam optics useful in the analysis of EDR and RDR products are described in Table 2.1-1 below:

Table 2.1-1 Mastcam Operational Characteristics

Characteristic	M-34 (Left)	M-100 (Right)
Field of View (FOV) Note detectors have 4:3 aspect ratio, that permits slightly wider frames	15 x 20 deg	5.1 x 6.8 deg
Baseline Stereo Separation	24.5 cm	
Spatial Scale	450 µm/pixel at 2 m, 22 cm/pixel at 1 km distance	150 µm/pixel at 2 m, 7.4 cm/pixel at 1 km distance
Angular Instantaneous FOV	0.22 mrad/pixel	0.074 mrad/pixel
Focal Length	34 mm	100 mm
f/number	8	10
Focus Range	.5 m - infinity	1.6 m - infinity
Number of Spectral Filters	7 plus Bayer pattern	7 plus Bayer pattern

Each Mastcam camera has an 8-position filter wheel for a total of 16 filter positions. One of the positions in each camera is a broadband infrared cutoff filter for use with the Bayer color capability of the CCD. Twelve of the sixteen filter positions provide color-imaging capability at wavelengths from 400 to 1100 nm, including 3 filters shared by each camera. Additionally, 2 filters (one on each camera that differ in wavelength from each other) with neutral density coatings provide direct solar imaging capability in two colors. Table 2.1-2 provides a summary of the as-built system-level (CCD + optics + filter) effective wavelengths (λ_{eff}) and half-width at half-maximum bandwidths (HWHM) of the Mastcam filters [Ref 9]; the spectral bandwidths do not represent the sensitivity of the detector or solar spectrum.

Table 2.1-2 Mastcam Filter Wavelengths and Bandpasses

M-34 (Left)		M-100 (Right)	
Filter	λ_{eff} ± HWHM (nm)	Filter	λ_{eff} ± HWHM (nm)
L0	590 ± 88	R0	575 ± 90
L0R	640 ± 44	R0R	638 ± 44
L0G	554 ± 38	R0G	551 ± 39
L0B	495 ± 37	R0B	493 ± 38
L1	527 ± 7	R1	527 ± 7
L2	445 ± 10	R2	447 ± 10
L3	751 ± 10	R3	805 ± 10
L4	676 ± 10	R4	908 ± 11
L5	867 ± 10	R5	937 ± 11
L6	1012 ± 21	R6	1013 ± 21
L7	880 ± 10, ND5	R7	440 ± 20, ND5

Note: ND5 = 10^{-5} Neutral Density coating for solar imaging

2.1.2 Mars Hand Lens Imager (MAHLI)

The Mars Hand Lens Imager (MAHLI) is a focusable color camera located on the Turret at the end of the MSL robotic arm. The instrument acquires images of up to 1200 lines by 1648 samples (1200 by 1608 photoactive pixels), with color quality equivalent to that of consumer digital cameras using a Bayer pattern filter array integrated with the CCD detector. It is also capable of very low frame-rate video compared to Mastcam. Characteristics of the MAHLI optics useful in the analysis of EDR and RDR products are described in Table 2.1-3 below. The MAHLI investigation was further described in an Open Access paper by Edgett et al. 2012 [Ref 10].

Table 2.1-3 MAHLI Operational Characteristics

Characteristic	Value
Field of View (FOV)	34.0 – 38.5 deg diagonal
Spatial Scale	15 μm/pixel at 23 mm distance
Spectral Bandpass	395 - 670 nm
Focal Length	18.3 - 21.3 mm
f/number	9.8 - 8.5
Depth of Field	1 mm
Focus Range	21 mm - infinity
Number of Spectral Filters	Bayer pattern on CCD

2.1.3 Mars Descent Imager (MARDI)

The Mars Descent Imager (MARDI) is a fixed-focus color camera fixed-body-mounted to the fore-port-side of the MSL rover, with the optics level with the bottom of the rover chassis (a height of about 66 cm above ground). The optical axis points in the +Z direction (toward the ground in the Rover Nav coordinate system). Operating during Curiosity's descent to the martian surface, the camera acquired

1200 by 1648 pixel images (1200 by 1608 photoactive pixels) at ~4 frames per second throughout the period between heatshield separation and touchdown plus a few minutes. It has also been operated on the surface. Characteristics of the MARDI optics useful in the analysis of EDR and RDR products are described in Table 2.1-4 below:

Table 2.1-4 MARDI Operational Characteristics

Characteristic	Value
Field of View (FOV)	70 by 55 deg
Spatial Scale	1.5 m at 2 km distance - 1.5 mm at 2m distance
Angular Instantaneous FOV	0.76 mrad/pixel
Spectral Bandpass	FWHM 395 to 670 nm
Focal Length	9.6 mm
Depth of Field	2 m - infinity
Number of Spectral Filters	Bayer RGB pattern on CCD

3. GENERAL DATA PRODUCT OVERVIEW

3.1 Data Processing Levels

This documentation recognizes both the National Aeronautics and Space Administration (NASA) data processing scheme and the "Committee on Data Management and Computation" (CODMAC) data level numbering system. The MMM instrument PDS EDRs described in this document are "NASA Level 0" (CODMAC – Edited Level 2).

MMM instrument RDRs are considered to be no less than "NASA Level 1B" (CODMAC Resampled Level 4") (irreversibly transformed and/or calibrated). The RDRs are reconstructed from the PDS EDR product, and may include frequency-domain processing prior to assembly into spatial-domain images that will then experience radiometric and/or geometric corrections.

Table 3.1-1 presents a breakdown of the CODMAC and NASA data processing levels.

Table 3.1-1 Processing Levels for Science Data Sets

NASA	CODMAC	Description
Packet data	Raw - Level 1	Telemetry data stream as received at the ground station, with science and engineering data embedded.
Level 0	Edited - Level 2	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed.
Level 1A	Calibrated - Level 3	Level 0 data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied).
Level 1B	Resampled - Level 4	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength).
Level 1C	Derived - Level 5	Level 1A or 1B data that have been resampled and mapped onto uniform space-time grids. The data are calibrated (i.e., radiometrically corrected) and may have additional corrections applied (e.g., terrain correction).
Level 2	Derived - Level 5	Geophysical parameters, generally derived from Level 1 data, and located in space and time commensurate with instrument location, pointing, and sampling.
Level 3	Derived - Level 5	Geophysical parameters mapped onto uniform space-time grids.

3.2 Product Label and Header Descriptions

3.2.1 Overview of Labels

Labels are in ODL (Object Description Language) label format for EDR and RDR files.

The primary label in the NASA PDS archive is the PDS version 3 detached label. This is a separate file with the same base name as the image file, with an ".LBL" extension. Per PDS standards, the detached label file references the image with a pointer statement (described below). This label is fully compliant with PDS archive standards.

3.2.2 PDS and ODL Labels

MMM image PDS EDRs and RDRs have detached labels. Per PDS standards, the PDS label starts with the entry:

PDS_VERSION_ID = PDS3

A PDS label is object-oriented and describes the objects in the data file. The PDS label contains keywords for product identification. The label also contains descriptive information needed to interpret or process the data in the file.

PDS labels are written in Object Description Language (ODL) [Ref 4]. PDS label statements have the form of "keyword = value". Each label statement is terminated with a return character (ASCII 13) and a line feed character (ASCII 10) sequence to allow the label to be read by many operating systems. Pointer statements with the following format are used to indicate the location of data objects in the file:

^object = location

where the carat character (^, also called a pointer) is followed by the name of the specific data object. The location is the 1-based starting record number for the data object within the file. Alternatively, it could be the 1-based byte location within the file if it includes a <bytes> unit tag. The PDS detached label includes the filename as part of the pointer:

^object = (filename, location)

Pointers are used to define the locations of the image itself (^IMAGE).

3.2.2.1 **Keyword Length Limits**

All PDS keywords are limited to 30 characters in length [section 12.7.3 in Ref 4]. Therefore, software that reads MSL PDS labels must be able to ingest keywords up to 30 characters in length.

3.2.2.2 **Data Type Restrictions**

12-bit unsigned data from the cameras are stored in a 16-bit unsigned value. 8-bit data are unsigned.

3.2.2.3 **Interpretation of N/A, UNK, and NULL**

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

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

  INSTRUMENT_ID = "N/A"

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

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

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

  FILTER_NAME = "UNK"

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

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

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

  DATA_SET_RELEASE_DATE = "NULL"

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

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

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

3.2.2.4 **PDS Label Constructs "Class", "Object" and "Group"**

The PDS has designed a set of formal and informal constructs for labeling data products. In the PDS vernacular, "formal" implies a standardized design or set of rules that provides a protocol across multiple data products (e.g., multiple flight missions) for PDS validation tools, and involves a rigorous approval process. "Informal" implies a less rigorous process by which the construct meets PDS approval. For both formal and informal constructs, the PDS keywords must be defined in the Planetary Science Data Dictionary (PSDD) [Ref 1]. In the MMM Camera EDRs and RDRs, the PDS Label includes the following "formal" and "informal" constructs:

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

  In the MMM Camera PDS label, a Class of keywords is preceded by a comment string as follows:

  / comment string */*
  keyword = *keyword value*
  keyword = *keyword value*

- *Object* - The Object construct is formal and is a set of standard keywords used for a particular data product. In the PSDD, each Object definition lists the elements required to be present each time the Object is used in a product label. The PSDD also provides a list of additional, optional keywords that are frequently used in the Object. Any element defined in the PSDD may be included as an optional element in any Object definition, at the discretion of the data preparer.

  In the MSL Camera PDS/ODL label, an Object's set of keywords is specified as follows:

  OBJECT = *Object identifier*
  16 *keyword* = *keyword value*
  17 *keyword* = *keyword value*
  END_OBJECT = *Object identifier*

- *Group* - The Group construct can be either a formal or informal grouping of keywords that are not components of a larger Object. Group keywords may reside in more than one Group within the label.

  The Group construct is further described in section 12.4.5 of the PDS Standards Reference [Ref 4], "Object Description Language Specification and Usage: GROUP Statement".

  In the MSL Camera PDS/ODL label, a Group's set of keywords is specified as follows:

  GROUP = *Group identifier*
  18 *keyword* = *keyword value*
  19 *keyword* = *keyword value*
  END_GROUP = *Group identifier*

3.2.2.5 **PDS Image Object**

An IMAGE object is a one or three-band sequential array(s), all of the same bit or byte format, each of which is referred to as a *sample*. IMAGE objects are normally processed with special display tools to produce a visual representation of the samples by assigning brightness levels or display colors to the values. An IMAGE consists of a series of lines, each containing the same number of samples.

The required IMAGE keywords define the parameters for simple IMAGE objects:

- LINES is the number of lines in the image.
- LINE_SAMPLES is the number of samples in each line.
- SAMPLE_BITS is the number of bits in each individual sample.
- SAMPLE_TYPE defines the sample data type.

MMM IMAGE objects have additional keywords that indicate whether the data were received from the spacecraft (or stand-alone instrument during ground testing) in compressed form. This will be the case for instrument-compressed JPEG and lossless formats. These forms are described under Binary Data Storage Conventions. All EDR archived data are stored unmodified and as they were created by the instrument in their original compressed format. Compression keywords are:

- INST_CMPRS_MODE is the method used for on-board compression of data (1,2,3)
- INST_CMPRS_NAME is the type of on-board compression to use for data storage and transmission (1 = PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, 2 = RAW RASTER, and 3 = JPEG DISCRETE COSINE TRANSFORM (DCT))

The IMAGE object has a number of keywords relating to image statistics. These keywords are present in all EDRs. In RDRs, they are optionally populated. The statistics keywords are:

- MEAN
- MEDIAN
- MAXIMUM
- MINIMUM
- STANDARD_DEVIATION
- CHECKSUM

Many variations on the basic IMAGE object are possible with the addition of optional keywords and/or objects. The “^IMAGE” keyword identifies the start of the image. Recommended image formats are described and illustrated in Reference 4.

3.3 Binary Data Storage Conventions

MMM camera image EDR and RDR data are stored as binary data. For the image EDRs, the data formats include 8-bit integers stored in an unsigned byte, as well as 12-bit integers stored in unsigned 16-bit integers.

3.3.1 Bit and Byte Ordering

The ordering of bits and bytes is only significant for pixel and binary header data; all other labeling information is in ASCII.

For non-byte image data, which includes 8-bit unsigned shorts, 16-bit signed shorts, 32-bit signed integers, and 32- and 64-bit IEEE floating-point numbers, the data may be stored in either Most Significant Byte (MSB) first ("big-endian", as used by e.g. Sun computers and Java), or Least Significant Byte (LSB) first ("little-endian", as used by e.g. Linux and Windows computers). This follows PDS file format conventions.

For PDS labels, the SAMPLE_TYPE keyword in the IMAGE object defines which ordering is used in the file.

Both file formats specify that bit 0 is the least significant bit of a byte.

The binary headers for MMM instruments are of varying data types, as described in their OBJECT definitions. However, they are always in MSB or “big-endian” format.

Table 3.3-1 MSL Image EDR/RDR Bit Ordering

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

3.4 File Naming Convention

The MMM file naming convention is composed of 10 fields which uniquely identify the product.

The following diagram and table describes the MMM Image ID (filename) and its parametric coding:

Table 3.4-1 Image ID or PICNO

	Sol	Instrument	Product Identifier	CDPID Counter	CDPID	Product Type	GOP counter	Version	Separator	Processing code	Separator	Extension
Characters	4	2	9	2	5	1	1	1	1	4	1	3
Position	1-4	5-6	7-15	16-17	18-22	23	24	25	26	27-30	31	32-34

Field	Description	Values	
Sol	4 digit numeric value for Mars sol or 4 character name of ground testing phase	0000-9999	Sol on Mars
		DEV_	Development (instrument assembly)
		TVC_	Thermal/Vac (instrument stand-alone)
		CAL_	Calibration (instrument stand-alone)
		DEL_	Delivery (instrument delivery to JPL-Caltech)
		ATL_	ATLO (JPL and KSC venues)
		CRU_	Cruise
Instrument	Abbreviated name of MMM instrument	ML	Mastcam Left (34 mm)
		MR	Mastcam Right (100 mm)
		MH	MAHLI
		MD	MARDI
Product Identifier	9 digit numeric image identifier	Described below this table	
CDPID Counter	Counter for CDPID repeat use	00-99	Number of times a CDPID for this instrument has been used (product erasures in NVM will re-use a CDPID). This is a single natural number starting at 1.
CDPID	Camera Data Product Identifier	numeric	This value is uniquely assigned by the camera to an image product. It is a numeric handle within NVM. Compression variations or thumbnails will share the same CDPID. This is a single natural number starting at 1.
Product Type	Product type identifier based on all possible source products that may	A	Raster 16 bit image
		B	Raster 8 bit image
		C	Losslessly compressed raster 8 bit

	be generated by MMM instruments		image
		D	JPEG grayscale image
		E	JPEG 422 image
		F	JPEG 444 image
		G	Raster 8 bit thumbnail
		H	JPEG grayscale thumbnail
		I	JPEG 444 thumbnail
		J	Raster 8 bit video
		K	Losslessly compressed raster 8 bit video
		L	JPEG grayscale video
		M	JPEG 422 video
		N	JPEG 444 video
		O	Raster 8 bit video thumbnail
		P	JPEG grayscale video thumbnail
		Q	JPEG 444 video thumbnail
		R	JPEG 444 focus merge image
		S	JPEG grayscale range map image
		T	JPEG 444 focus merge thumbnail
		U	JPEG grayscale range map thumbnail
GOP Counter	Index of image within a GOP	0-9, A-F	Hexadecimal value, 0 for non-GOP products
Version	Value used to identify multiple versions of a product. Versions may be different compressions or duplicates for the same camera product.	0-9, A-Z	Versions start at 0 (indicating original image as stored on-board within each camera). For each image received, increment by 1. Versions are unique for each CDPID Counter and CDPID.
Separator	Underscore	_	
Processing code	Codes to indicate ground processing performed on the camera product. No processing (EDR) is indicated by all fill characters (XXXX)	D	Decompressed
		C	Color corrected or contrast stretched
		R	Radiometrically calibrated
		L	Linearized
		X	Fill character
Separator	Period	.	
File Extension	File content identifier	DAT	Original camera data product
		LBL	Label file for .DAT or .IMG files
		IMG	Binary image data

Note: unless otherwise specified, products are 8 bits per band.

3.4.1 PICNO and Product Identifier

The following is an example of what each character in the PICNO name maps to:

SSSSIIFFFFFFLLLXXCCCCCPGV_XXXX.ZZZ

S: sol - 4 digits
I: instrument - 2 letters
F: full seqid - 6 digits (sequence ID with additional digits for future seqid lengths, from tracking ID)
L: seq line - 3 digits (command number in sequence, from tracking ID)
X: CDPID counter - 2 digits (number of times this CDPID has been used over the lifetime of a mission)
C: complete CDPID - 5 digits
P: product type - 1 letter
G: GOP counter - 1 letter (0-9,A-F for GOP frame 0-15)
V: version - 1 digit
XXXX: processing code (can be XXXX, DRXX, DRCX, DRLX, or DRCL)
ZZZ: file extension (can be DAT, IMG, LBL)

Part of the PICNO, FFFFFFLLL, is also known as the Product Identifier, or a numerical identifier assigned to images when they are commanded from the ground. Depending on how the image was commanded, this number contains values related to the sequence used to command the image.

The product identifier is useful to group images commanded with the same imaging sequence such as for a panorama, video, or multi-spectral observations.

For example, take a command sequence named mhli01234 containing 3 imaging commands: these images will respectively be assigned the resulting product identifier, in Table 3.4-2 below.

Table 3.4-2 Product Identifier example

		Product Identifier				
Sol	Instrument	Sequence ID	Sequence Line (Command Number)	CDPID counter	CDPID	PICNO through CDPID (SSSSIIFFFFFFLLLXXCCCCC)
(4 digits)	(2 characters)	(6 digits)	(3 digits)	(2 digits)	(5 digits)	(16 digits)
0100	MH	001234	000	01	00560	0100MH0012340000100560
0100	MH	001234	001	01	00561	0100MH0012340010100561
0100	MH	001234	002	01	00562	0100MH0012340020100562

Exceptions to this scheme include the MARDI EDL sequence which uses 000000000. Images without ground-assigned Product Identifiers use 999999999. For ground test images that were not commanded through a flight system, this number is sequential only.

In addition, PRE_ATLO (which includes the camera development phase (DEV_), stand-alone (instrument) thermal vacuum testing (TVC_), stand-alone (instrument) calibration (CAL_), and delivery (DEL_)), ATLO, and Cruise data sets have a similarly structured PICNO with some minor differences. For further information and examples, see Appendix F: Image ID (PICNO) naming scheme for Cruise data for Mastcam, MAHLI, and MARDI and Appendix G: Image ID (PICNO) naming scheme for PRE_ATLO and ATLO data for MAHLI only.

3.5 Summary of Data Products

This section provides a brief summary of the data types delivered to the NASA Planetary Data System (PDS). Much of the remainder of this document describes these products in detail.

3.5.1 PDS EDR

The PDS agreed to accept MMM camera data in their original compressed format. Software is provided to decompress the data, and the process of extracting the original data from the downlink format is described. As noted in the following major section, there are 21 data types that can be wrapped into the original data format that are transferred from the cameras. Some of these are compressed without loss, some are transferred in lossy format, some are full-scale and others subscale (the only subscaling is by a factor of 8, used to produce thumbnail images). Each EDR data file includes the original camera data as formatted by the camera and the camera mini-header generated by the camera, prepended to the raw data. The camera mini-header can easily be stripped off the data file, but information is provided in this SIS to permit it to be decoded. The header information is provided as a standalone ASCII label file in compliant PDS format as described in Section 3.2.

3.5.2 PDS RDR

The PDS also requested RDR products in image format. These are generated from validated data and are processed in the following ways:

- decompressed and radiometrically calibrated (16-bits per band),
- decompressed, radiometrically calibrated, and color corrected and contrast enhanced (8-bits per band),
- decompressed, radiometrically calibrated, and geometrically linearized (16-bits per band),
- decompressed, radiometrically calibrated, color corrected and contast enhanced, and geometrically linearized (8-bits per band).

Radiometric calibration can include processing, either in the frequency domain (for JPEG products) or in the spatial domain (for data either transmitted losslessly and all data after decompression) as follows: 8-to-12-bit expansion, dark correction, shutter smear adjustment, bad pixel adjustment, flat fielding, and color correction (Section 5.1.2.12). Geometric linearization is the process of correcting for the optical distortion of the lens by spatial resampling. Linearization is the prerequisite for performing geometric processing for mosaicing or stereo-processing, which are not delivered as archive products. The header information is provided as a standalone ASCII label file in compliant PDS format as described in Section 3.2.

4. PRODUCT SPECIFICATION

The MMM instrument EDRs and RDRs described in this document are generated by Malin Space Science Systems.

The EDRs consist of unprocessed experiment data stored in original binary format. Data archived with the PDS are the fundamental telemetry data from the instrument. The EDRs are generated from “raw” uncalibrated data within an automated pipeline process managed by MSSS.

4.1 Processing Flow

Prior to entering the MSSS data processing pipeline, the effort begins with reconstruction of the packetized telemetry data resident on the Telemetry Data Subsystem (TDS), by the Mission data Processing and Control Subsystem (MPCS) into a binary “.dat” data product and associated “.emd” Earth metadata file. The data product and metadata are written by MPCS to the Operations Data Store (ODS) and messages are generated on a Java Message Server (JMS) bus. By MSL Project design, the as-received MMM instrument data are then retrieved from the ODS by a process managed by MIPL under OPGS, and placed in the File Exchange Interface (FEI) directory system. Upon FEI notification, the MMM data are transferred to MSSS by FEI subscription, where they are ingested by the MMM data pipeline. The data flow is illustrated in Figure 4.1-1.

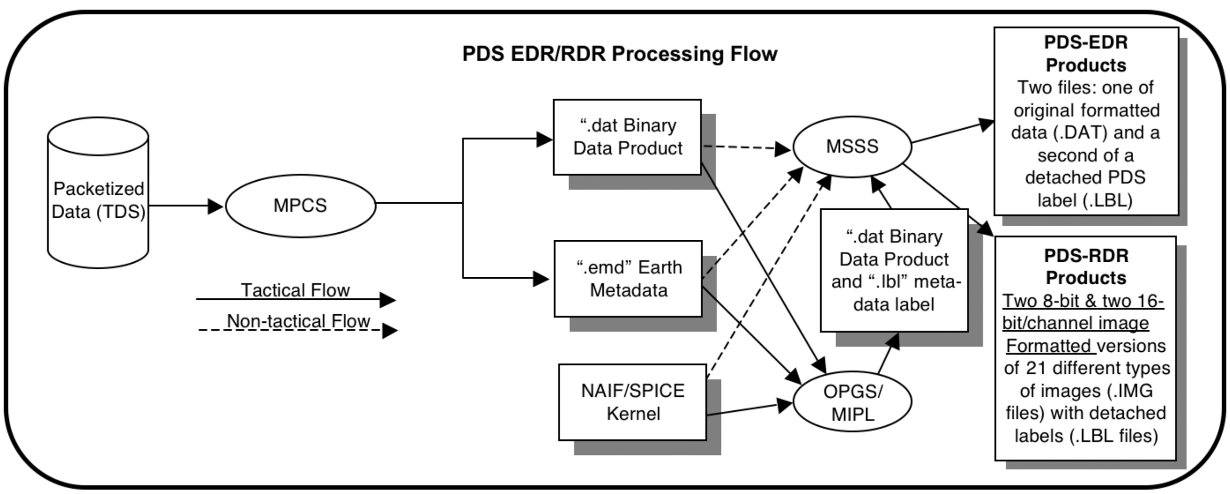


Figure 4.1-1: PDS EDR/RDR Data Flow where “Tactical Flow” is processing preformed in ‘near real-time’ in support of tactical mission operations, and the “Non-Tactical Flow” is processing performed on longer timescales.

The PDS EDR consists of data in the form received from the instrument. Although there is only one EDR file type, there are 3 encoding forms these data can take within the raw .dat file: raw, losslessly compressed, and JPEG compressed, and their sizes and bit depth vary as a function of type and original image size. These file formats can be expanded using software provided by MSSS to the PDS into 21 different spatial-domain image types, described in Section 4.4.2.

4.2 Product Validation

Validation of the PDS EDRs and RDRs falls into two primary categories: automated and manual. Automated validation is performed on every product. Manual validation is only performed on a sub-set.

Automated validation is performed as a part of the archiving process simultaneously with the archive volume validation. Validation operations include:

1. validation of the PDS syntax of the label,

2. a check of the label values against the database and against the index tables included on the archive volume, and

3. checks for internal consistency of the label items.

The internal-consistency checks include such things as verifying that the product creation date is later than the Earth received time, and comparing the geometry pointing information with the specified target. If problems are discovered and/or new possibilities identified for automated verification, they will be added to the validation procedure.

Manual validation of the images is performed by MMM team members both as spot-checking of data throughout the duration of the mission, and comprehensive validation of a sub-set of the data (for example, a few Sol's worth of data). Validation in this case includes, but is not limited to:

1. inspection of the image or other data object for errors (e.g., missing lines, corrupted image blocks, etc.) not specified in the label parameters,

2. verification that the target shown and the apparent geometry match that specified in the labels,

3. verification that the product is viewable using the specified software tools (see Section 5.2), and

4. a general check for any problems that might not have been anticipated in the automated validation procedure.

4.3 Product Structure

This section specifies the EDR and RDR structures, taking into account the concept of product labels and the product's binary content described previously in Sections 3.2 and 3.3, respectively. There are two types of products: a raw instrument EDR file with a detached PDS label, designated the PDS EDR, and an image-formatted RDR file with a detached PDS label, designated the PDS RDR.

4.3.1 MMM Camera Suite Products

The data records for all of the MMM products have the following structures:

PDS Archive EDR

1) A detached label of *validated* parameters in PDS (ASCII) format, in a separate file.
2) The original camera data as created by the instrument (may be in a variety of forms, described later in this section).

PDS Archive RDR

1) A detached label of *validated* parameters in PDS (ASCII) format, in a separate file.
2) An n by m array of binary image data with the origin at the upper left pixel in line (row) 1, sample (column) 1. The product forms for PDS RDRs are further described in Section 4.5.2. Note that some camera RDR products will be sub-framed so that the origin is not (1,1).

4.3.2 Data Packing

All MMM data products are transmitted from an MMM instrument to the rover RCE and then to the Ground Data System (GDS). Each step in this transfer adds one or more layers of metadata. The formats described below are for the instrument data packet only. This packet is identified as a "Science Data Frame" and is indicated in the .emd and .lbl label files by a byte offset into the corresponding .dat file. All indices below reference from this offset unless otherwise indicated. Images generated by Ground Support Equipment (GSE) during instrument testing and calibration are stored in .dat files without additional metadata. In this case, the byte offset to the Science Data Frame can be assumed to be 0. The Science Data Frame contains both a camera-generated "mini-header" and the science data themselves. These are both described below.

4.4 MMM Product Types and Format

The MMM products are formatted according to this SIS, following the general terms of labeling and bit ordering previously discussed in Sections 3.2 and 3.3, respectively. This section details the specifics of a variety of formats across all image files. The raw EDR format, and the 21 spatial-domain image formats that can be extracted therefrom, are listed in Table 4.4-1 and discussed subsequently in this section.

Not including sub-framing, the MMM cameras can acquire a variety of image data formats, and accomplish this by internal processing. The cameras always acquire raw 12-bit data, but only under very limited circumstances are these data downlinked to Earth. Normally, the 12-bit raw data will be converted from 12-to-8-bits through the use of a variety of companding (compress/expand) lookup tables; the most used table is a modified square-root encoding scheme that allocates additional values to low DNs. These companded 8-bit images can then be processed either immediately, and stored into each camera's 8-Gbyte buffer, or they can be stored unprocessed in the buffer, and then later processed in response to downlink commands. It is this flexibility that leads to the complexities of the raw data format and its description.

In addition to the 12-to-8-bit companding, onboard processing includes the following capabilities: Bayer pattern interpolation, lossless compression (Huffman), JPEG compression, video processing, focus merging, and range mapping of focused merged products. (For more information on focus stack acquisition and merge products, see MASTCAM_MAHLI_FOCUS_MERGE_PRODUCTS.PDF in the {MSLMST_*, MSLMHL_*}/DOCUMENT/ directory.) Except for thumbnails (discussed next), the cameras do not support sub-sampling or resampling, but do support sub-framing prior to image acquisition (i.e., sub-frames are commanded at the outset, not extracted from acquired full-frames).

Thumbnails are generated by creating a scratch JPEG image and extracting the lowest-order coefficients of the discrete cosine transform 8x8 pixel compression block, or minimum compression unit (MCU), which is essentially the average of the 8x8 spatial domain MCU. These coefficients are then assembled in to an 1/8th sized image, and can then be JPEG compressed. The extraction of these coefficients is the only way MMM images can be sub-sampled.

4.4.1 MMM Camera Instrument Suite

In this SIS, we do not distinguish between the products contained within the raw camera data records and the image files produced by appropriate processing of these camera data records. For example, although a PDS EDR consists of a single format camera data record, that EDR can contain one of 21 different types of image file, including full-frame or thumbnail, single band (8 or 16-bits) or multiple band (8-bits per band), and in raw, lossless or JPEG compressed form. These forms are converted to image format for delivery to the PDS as EDRs without further processing. The RDRs are image-formatted files derived from the 21 types that the raw EDR can contain.

4.4.2 Data Record Content

Image formatted data constituting the EDRs and RDRs are derived from three forms of binary data acquired by the cameras (Image, Video, and Zstack). As noted in the definitions above, images may be generated by the sensor itself, or computed within the DEA; images computed onboard may be thumbnails, focus merged, or range mapped products.

Table 4.4-1 enumerates the product types that can be generated by the MMM instruments, and the types used as the source of the imaging or algorithm processes. The products are contained within the raw camera data record and produced in image format as PDS EDRs and RDRs**.**

Table 4.4-2 describes how these product types are created from the imaging commands or image processing algorithms.

Table 4.4-1 Product Types Generated by MMM Cameras

Type	Commanded	Product	Format
A	Image	Image	Raster 16 bit
B			Raster 8 bit
C			Lossless
D			JPEG gray
E			JPEG 422
F			JPEG 444
G		Thumbnail	Raster
H			JPEG gray
I			JPEG 444
J	Video	Image	Raster 8 bit
K			Lossless
L			JPEG gray
M			JPEG 422
N			JPEG 444
O		Thumbnail	Raster 8 bit
P			JPEG gray
Q			JPEG 444
R	ZStack	Focus Merge Image	JPEG 444
S		Range map Image	JPEG gray
T		Focus Merge Thumbnail	JPEG 444
U		Range Map Thumbnail	JPEG gray

Table 4.4-2 Product Type Source

			Image Product Transmission Formats						Thumbnail Transmission Formats		
			Bayer 16	Bayer 8	Lossless	JPEG gray	JPEG 422	JPEG 444	JPEG 444	JPEG gray	Raster
Instrument Storage or Generation Format	Image	Bayer 8		B	C	D	E	F	I	H	G
		Lossless			C				I	H	G
		JPEG gray				D				H	G
		JPEG 422					E		I		G
		JPEG 444						F	I		G
	Video	Bayer 8		J	K	L	M	N	Q	P	O
		Lossless			K					P	O
		JPEG gray				L				P	O
		JPEG 422					M		Q[1]		O
		JPEG 444						N	Q		O
	Merge	Focus Merge						R	T		
		Range Map				S				U	
	Calibration	Bayer 16	A								

- [1] JPEG 422 images compressed as JPEG 444 for thumbnails have the chrominance channels replicated.
- Both the Focus Merge and Range Map images are generated via instrument command and then transmitted in a JPEG compressed form.
- Video thumbnails are generated one per frame if commanded.
- Thumbnails for JPEG compressed GOP video yield a thumbnail for only the first image in the group.

4.4.3 MMM Mini-Header

The "mini-header" appears as the first 64 bytes of each transmitted raw data product, and the first 64 bytes of the PDS EDR. The mini-header does not appear in the image formatted products. This header provides enough information to decompress and use the data product. All image Science Data Frames generated by MMM instruments begin with the 64-byte MMM mini-header. Image data immediately follow this header.

Table 4.4-3 MMM Mini-header

Field	Word	Size (bits)	Description	Values
product_id	0	32	camera assigned product ID (CDPID)	1 to 60416
magic0	1	32	Bit pattern that helps to identify product boundaries	0xFF00F0CA
sclk	2	32	instrument SCLK value of start of this image acquisition	integer
cmd[0]	3	16	vflush	vertical register flush count
		4	undefined	
		4	CCD state	Table 4.4-4
		1	led 1	0 off, 1 on
		1	led 2	0 off, 1 on
		1	led 3	0 off, 1 on
		1	video exposure	0 off, 1 on
		1	clkdiv2	Table 4.4-4
		1	long integration mode	0 off, 1 on
		1	test mode	0 off, 1 on
		1	clkdiv1	Table 4.4-4
cmd[1]	4	8	commanded filter	0 to 7 – filter index
		24	exposure in ms * 10	0 to 8388 0xFFFFFF means to use the previous exposure time (per filter for Mastcam)
cmd[2]	5	8	sx ÷ 8	starting column for sub-frame
		8	sy ÷ 8	starting row for sub-frame
		8	width ÷ 8, if 0, width is 1648	if thumbnail, size of thumbnail ÷ 8, not original image
		8	height ÷ 8, if 0, height is 1200	if thumbnail, size of thumbnail ÷ 8, not original image

Image, Video cmd[3]	6	15	auto focus initial position	focus motor position 0x7fff means to use the current position minus (step size x number of steps)÷2
		10	auto focus step size	focus mechanism counts
		6	auto focus number of steps	integer
		1	auto focus zstack on/off	1 (on) means to store intermediate focus images as separate products
Image, Video cmd[4]	7	8	auto exposure target DN	DN as companding with linear8 mode
		8	auto exposure fraction	percentage of pixels allowed over maximum DN
		8	auto exposure early termination	"early termination percentage"
		8	auto exposure number of steps	maximum number of iterations
Zstack cmd[3]	6	32	starting CDPID for merge	1 to 60416
Zstack cmd[4]	7	8	stack depth (number of images to merge)	1 to 8
		22	undefined	
		1	image blending	0 off, 1 on
		1	intra-stack image registration	0 off, 1 on
cmd[5]	8	8	A	UNUSED
		8	B	UNUSED
		8	C – color mode	0 means grayscale JPEG 0 with compression quality=0 means lossless no compression 1 means JPEG 422 2 means JPEG 444 0xFF means Predictive lossless compression
		8	D – compression quality	JPEG quality 1 to 100
cmd[6]	9	8	E	UNUSED
		8	F	UNUSED
		8	G	UNUSED

		8	H – companding mode	Companding table 0 to 32 0xFF means 16 bit calibration mode
camera status	10	1	undefined	
		1	UV LED	0 off, 1 on
		1	Vis1 LED	0 off, 1 on
		1	Vis2 LED	0 off, 1 on
		1	undefined	
		1	hall sensor state for Mastcam filter	0 off, 1 on
		1	hall sensor state for MAHLI cover	0 off, 1 on
		1	hall sensor state for focus mechanism	0 off, 1 on
Serial No.		24	DEA serial number	integer
Mech(1)	11	32	focus motor position	integer
Mech(2)	12	16	unused (was zoom)	
Mech(3)		16	filter motor position	filter index * 294
DC offset	13	32	DC offset	integer
Init_Size	14	32	Initially-allocated size of data product (for compressed data, may not match actual size.)	bytes
magic(1)	15	32	Bit pattern that helps to identify product boundaries	0x1010CC28

Note: The purple and blue shading indicate that Words 6 and 7 are re-used depending on if it is an Image, Video, or Z-stack.

Table 4.4-4 Decoding CCD state and clkdiv1/2

		CCD State		
clkdiv1	clkdiv2	0x0	0xA	0xF
0	0	20 MHz	invalid	invalid
0	1	invalid	invalid	invalid
1	0	5 MHz	3.33 MHz	2.5 MHz
1	1	10 MHz	invalid	invalid

For thumbnail products, the mini-header is a copy of the original source product header, with the dimensions and compression adjusted appropriately. The high bit of the product ID is set only if the file is a thumbnail. (Note that for raw thumbnails the dimensions may not be encodable as multiples of 8, so the closest multiple of 8 is given as the dimension. For example, a 1200x1200 image's thumbnail is 150x150, but 150 is not a multiple of 8, since 150/8 is 18.75. Therefore, the thumbnail dimensions are truncated to the nearest integer value of 8; in the case of 150, that is 18). For thumbnails created from raw products, the Init_Size parameter in the thumbnail mini-header is the size (in bytes) of the intermediate JPEG image used to create the thumbnail.

4.4.4 Compression Parameter

The compression parameter (cmd[5] and cmd[6] in the Mini-Header) can be visualized as 8 bytes ABCDEFGH from MSB to LSB, with the bytes having the following meanings:

A, B, and EFG are unused and are commanded as zero.

If D is non-zero, then the image is JPEG-compressed by the quality factor D that ranges from 1 (lowest quality) to 100 (highest quality.) Quality is computed per the usage of the Independent JPEG Group's JPEG software library, version 6b. Quality 75 is said to be "usually nearly indistinguishable from the source image" in the ITU T.81 JPEG specification [Ref 11]. C is the color mode used for compression, where 0 is gray scale, 1 is 422 color subsampling mode, and 2 is 444 color mode (no subsampling.) Most broadband color images should use C=1. **If C is zero and D is 0xff, then lossless compression is used.**

H specifies the 12-to-8 bit companding table used. 0 is the default, nominally lossless, square-root table. Tables 1-16 encode the pixels linearly by dividing by N with saturation at 255; Tables 17-32 encode the pixels linearly without saturation (the low-order 8 bits are simply transmitted.) 0xff selects 16-bit calibration mode, which has restrictions on image dimension, may not be compressed, and is intended to be used extremely sparingly in flight. Other values are not yet defined.

Table 4.4-5 Compression Parameter

		Representation of Various Compression Parameters							
PICNO Type	**Image Type**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
A	Raster 16 bit Image	N/A	N/A	0	0	N/A	N/A	N/A	0xFF
B	Raster 8 bit Image	N/A	N/A	0	0	N/A	N/A	N/A	companding table
C	Losslessly Compressed 8 Bit Image	N/A	N/A	0	0xFF	N/A	N/A	N/A	companding table
D	JPEG Gray Image	N/A	N/A	0	JPEG quality	N/A	N/A	N/A	companding table

		Representation of Various Compression Parameters							
PICNO Type	**Image Type**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
E	JPEG 422 Image	N/A	N/A	1	JPEG quality	N/A	N/A	N/A	companding table
F	JPEG 444 Image	N/A	N/A	2	JPEG quality	N/A	N/A	N/A	companding table
G	Raster 8 bit Thumbnail	N/A	N/A	0	0	N/A	N/A	N/A	companding table
H	JPEG Gray Thumbnail	N/A	N/A	0	JPEG quality	N/A	N/A	N/A	companding table
I	JPEG 444 Thumbnail	N/A	N/A	2	JPEG quality	N/A	N/A	N/A	companding table
J	Raster 8 bit Video	N/A	N/A	0	0	N/A	N/A	N/A	companding table
K	Losslessly Compressed 8 Bit Video	N/A	N/A	0	0xFF	N/A	N/A	N/A	companding table
L	JPEG GrayVideo	N/A	N/A	0	JPEG quality	N/A	N/A	N/A	companding table
M	JPEG 422 Video	N/A	N/A	1	JPEG quality	N/A	N/A	N/A	companding table
N	JPEG 444 Video	N/A	N/A	2	JPEG quality	N/A	N/A	N/A	companding table
O	Raster 8 Bit Thumbnail	N/A	N/A	0	0	N/A	N/A	N/A	companding table
P	JPEG Gray Thumbnail	N/A	N/A	1	JPEG quality	N/A	N/A	N/A	companding table
Q	JPEG 444 Thumbnail	N/A	N/A	2	JPEG quality	N/A	N/A	N/A	companding table
R	JPEG 444 Focus Merge Image	N/A	N/A	2	JPEG quality	N/A	N/A	N/A	companding table
S	JPEG Gray Range Map Image	N/A	N/A	0	JPEG quality	N/A	N/A	N/A	companding table
T	JPEG 444 Focus Merge Thumbnail	N/A	N/A	2	JPEG quality	N/A	N/A	N/A	companding table

		Representation of Various Compression Parameters							
PICNO Type	Image Type	A	B	C	D	E	F	G	H
U	JPEG Gray Range map Thumbnail	N/A	N/A	0	JPEG quality	N/A	N/A	N/A	companding table

4.4.5 Image Format Descriptions

4.4.5.1 Raster 16 Bit Image

This type of image is acquired by the MMM instruments only into camera volatile memory (DRAM) and transmitted to the rover RCE non-volatile memory (NVM) for preparation for transmission to Earth. The acquisition parameters are defined in the image MMM mini-header.

Products begin with the 64 byte MMM image mini-header and then image data will follow, stored in row major, column minor order with 12 bit values stored in 16 bit pixels in big-endian form.

4.4.5.2 Raster 8 Bit Image

This type of image is acquired by the MMM instruments through their volatile memory (DRAM) and into their non-volatile memory (Camera Flash) and transmitted to the rover RCE NVM for preparation for transmission to Earth. The acquisition parameters are defined in the image MMM mini-header.

In the instrument, 12 bit sensor values are converted to 8 bits using the companding table code in compression parameter H and defined in Appendix B: MMM DECompanding Tables.

Products begin with the 64 byte MMM image mini-header and then image data follows, stored in row major, column minor order with 8 bit pixels.

4.4.5.3 Losslessly Compressed 8 Bit Image

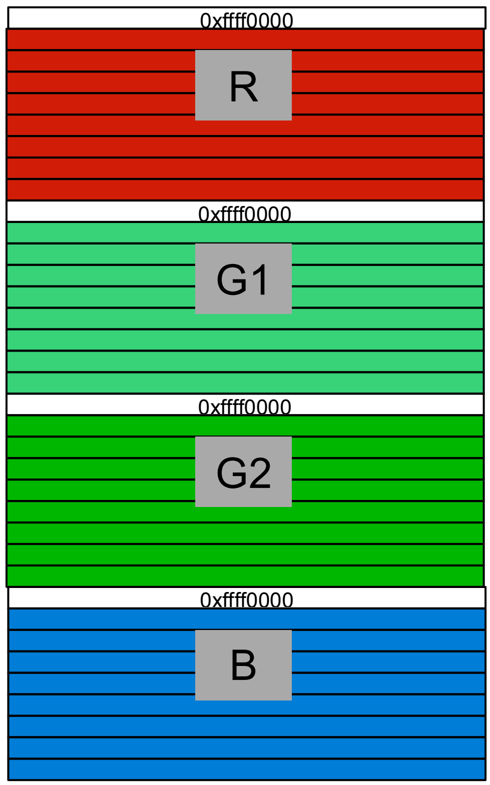
This type of image is acquired by the MMM instruments through their volatile memory (DRAM) and into NVM and transmitted to the rover RCE NVM for preparation for transmission to Earth. The acquisition parameters are defined in the image MMM mini-header.

In the instrument, 12 bit sensor values are converted to 8 bits using the companding table indicated.

Products begin with the 64 byte MMM image mini-header and then image data follows with sync codes stored in big-endian form. Compressed bits are stored and read from the least to most significant bit of each byte.

Image data are organized in segments of 8 line groups that are Huffman compressed. Decompression can be done using the tables and pseudo-code described in Appendix C: Huffman Tables. Additionally, the software described in Section 5.3 Software Distribution, can decompress and arrange this data in Bayer pattern form.

There is one line group for each Bayer filter color channel (R, G1, G2, and B) with each group preceded by the sync code, 0xffff0000. The sync code is not Huffman compressed. At the end of each segment, residual codes are padded to the right with zeros. The structure is outlined below showing the sync code and 8 image lines for each Bayer color filter.



This pattern repeats until all lines of the image are compressed. It is a requirement that the image height is divisible by 8 and therefore this format would be line multiples of 32.

Pixels are stored in row major, column minor order upon decompression. To assemble the image in sensor space, one line from each color filter group must be interleaved using the following Bayer filter pattern. This repeats for each corresponding line in a group.

R	G1	R	G1	R	G1	…
G2	B	G2	B	G2	B	…

4.4.5.4 **JPEG Images**

These types of images are acquired in one of two ways by the MMM instruments:

1. as raw data from the sensor through the DRAM to the NVM, and transmitted compressed to the rover RCE NVM with the JPEG compression parameter, or

2. with the JPEG compression parameters through the DRAM and stored in the NVM as compressed, then to the rover RCE NVM.

The acquisition parameters are defined in the image MMM mini-header, with the command compression type described in Table 4.4-5.

In the instrument, 12 bit sensor values are converted to 8 bits using the companding table code in compression parameter H and the table defined in Appendix B: MMM DECompanding Tables.

Image pixel values are converted to luminance and chrominance values using a 5x5 neighborhood convolution filter which accounts for the pixel position in the Bayer pattern (see Appendix D: Color Interpolation Kernels).

For the Mastcam spectral filters other than filter 0 (see Table 2.1-2), the unity filter (see Appendix D: Color Interpolation Kernels) is used and no Bayer color interpolation is performed.

These values are JPEG compressed according to the method described in Appendix E: JPEG Compression.

Products begin with the 64 byte MMM image mini-header and then JPEG compressed image data follows.

4.4.5.4.1 JPEG Gray Image

The JPEG compression parameters are set to JPEG Grayscale via parameter C in Table 4.4-5.

Image pixel values are converted to luminance values (see Appendix D: Color Interpolation Kernels).

4.4.5.4.2 JPEG 422 Image

The JPEG compression parameters are set to JPEG 422 via parameter C in Table 4.4-5. Chroma sub-sampling follows the JPEG convention.

4.4.5.4.3 JPEG 444 Image

The JPEG compression parameters are set to JPEG 444 via parameter C Table 4.4-5. No chroma sub-sampling occurs, in accordance with the JPEG convention.

4.4.5.5 **Image Thumbnail**

This type of image is generated and then transmitted to the rover RCE.

The acquisition parameters are defined in the image MMM mini-header, with the command compression type described in Table 4.4-5.

Parameter H is set by the source image companding table.

Products begin with the 64 byte MMM image mini-header and then image data follows, stored in row major, column minor order with 8 bit pixels.

4.4.5.5.1 Raster 8 Bit Thumbnail

If the original image is losslessly compressed, it is decompressed and the red Bayer color channel is extracted. This product is then compressed into an intermediate JPEG grayscale form with a quality that can be specified systemically (default value is quality 40). The DC luminance component from each 8x8 block of pixels is then used to form a new image with $1/64^{th}$ the number of pixels.

If the original image is Raster 8 Bit, then the product is compressed into an intermediate JPEG form with a quality that can be specified systemically (default value is quality 40). The DC luminance component from each 8x8 block of pixels is then used to form a new $1/64^{th}$ size image. Only the luminance channel is sampled.

If the original image is JPEG compressed, it is decompressed and the DC luminance component from each 8x8 block of pixels is used to form a new $1/64^{th}$ size image. This image is stored in raster form without any compression.

4.4.5.5.2 JPEG Gray Thumbnail

If the original image is losslessly compressed, then it is decompressed and the red Bayer color channel is extracted. The red channel is then compressed into an intermediate JPEG grayscale form with a quality that can be specified systemically (default value is quality 40). The DC luminance component from each 8x8 block of pixels is then used to form a new image with $1/64^{th}$ the number of pixels

If the original image is Raster 8 Bits, then it is compressed into an intermediate JPEG form with quality 40. The DC luminance component from each 8x8 block of pixels are then used to form a new image with $1/64^{th}$ the number of pixels.

If the original image is JPEG grey compressed, then the DC luminance component from each 8x8 block of pixels is used to form a new image with $1/64^{th}$ the number of pixels. This image is then further JPEG grayscale compressed using the parameters defined above and according to the method described in Appendix E: JPEG Compression.

4.4.5.5.3 JPEG 444 Thumbnail

If the original image is Raster 8 Bits, then it is compressed into an intermediate JPEG form with a quality that can be specified systemically (default value is quality 40). The DC luminance component from each 8x8 block of pixels is then used to form a new image with $1/64^{th}$ the number of pixels.

If the original image is JPEG (422 or 444 color sampled) compressed, then the DC luminance (Y) and chrominance (Cr,Cb) components from each 8x8 block of pixels are used to form a new image with $1/64^{th}$ the number of pixels. This image is then further JPEG 444 compressed using the parameters defined above and according to the method described in Appendix E: JPEG Compression.

4.4.5.6 **Video**

Raw and Lossless video frames are acquired and stored as separate products for each video frame.

Depending on how video frames are commanded, images may be transmitted as individual JPEG images or groups of images stored sequentially. There may be as many as 16 images in a group. Groups of JPEG images are called GOPs (Group Of Pictures). For videos with more than 16 images, video images may span multiple GOPs. The last GOP may contain less than 16 images.

Video images are acquired, processed, and compressed identically to images as in Section 4.4.5.4 JPEG Images. The JPEG images are stand-alone in that they can be decoded without any reference data and contain full JPEG headers and markers. For GOPs, the start of the next JPEG follows the end of the previous JPEG.

4.4.5.6.1 Raster 8 Bit Video Images

Raster video images are stored in the same fashion as single raster 8 bit images.

4.4.5.6.2 Losslessly Compressed 8 Bit Video Images

Losslessly compressed 8 bit video images are stored in the same fashion as 8 bit single images.

4.4.5.6.3 JPEG Gray Video

JPEG grayscale products contain a single mini-header, which is then followed by one or more JPEG grayscale images.

4.4.5.6.4 JPEG 422 Video

JPEG 422 products contain a single mini-header, which is then followed by one or more JPEG color 422 images.

4.4.5.6.5 JPEG 444 Video

JPEG 444 products contain a single mini-header, which is then followed by one or more JPEG color 444 images.

4.4.5.7 Video Thumbnails

Thumbnail generation is equivalent to the methods used for single image thumbnails as in Section 4.4.5.5 Image Thumbnail.

4.4.5.7.1 Raster 8 Bit Video Thumbnail

This product is created identically to the Raster 8 Bit Thumbnail. One thumbnail can be created for each Raster 8 Bit Video Image.

4.4.5.7.2 JPEG Gray Video Thumbnail

This product is created identically to the JPEG Gray Thumbnail.

For GOP video products, only the first JPEG in the group is used to create a thumbnail. Thus each GOP is represented by a single thumbnail (i.e., the other images in the GOP do not have thumbnails).

4.4.5.7.3 JPEG 444 Video Thumbnail

This product is created identically to the JPEG 444 Thumbnail.

For GOP video products, only the first JPEG in the group is used to create a thumbnail. Thus each GOP is represented by a single thumbnail (i.e., the other images in the GOP do not have thumbnails).

4.4.5.8 **ZStack**

This type of image is generated and then transmitted to the rover RCE.

The acquisition parameters are defined in the image MMM mini-header, with the command compression type described in Table 4.4-5.

Products begin with the 64 byte MMM image mini-header and then JPEG compressed image data will follows.

4.4.5.8.1 JPEG 444 Focus Merge Image

Parameter C is always 2, as only JPEG 444 compression is used for focus merges.

4.4.5.8.2 JPEG Gray Range Map Image

Compression parameter C is always 0, as only JPEG grayscale compression is supported for range maps.

The data values range from 0 to 255. These values are assigned on the basis of commanded stack depth. Table 4.4-6 shows the relationship between image commanded to participate in a focus merge and its corresponding grayscale data value (DN value) in a Range Map. Values between those in Table 4.4-6 are derived by linear interpolation during the focus merge process.

Table 4.4-6

Relation between commanded image participant in focus merge and Range Map data value (DN)							
Image Commanded to be Merged	**DN for 8-image merge**	**DN for 7-image merge**	**DN for 6-image merge**	**DN for 5-image merge**	**DN for 4-image merge**	**DN for 3-image merge**	**DN for 2-image merge**
1st	255	255	255	255	255	255	255
2nd	223	218	212	205	191	170	127
3rd	191	182	170	153	127	85	—
4th	159	145	127	102	63	—	—
5th	127	109	85	51	—	—	—
6th	95	72	42	—	—	—	—
7th	63	36	—	—	—	—	—
8th	31	—	—	—	—	—	—

The purpose of Table 4.4-6 is to provide the user with a means to relate the data values (0 to 255) in a Range Map product with the images that were commanded to be merged onboard the

MAHLI to produce that product. Take, for example, MAHLI image 0046MH0000120000100170S00. This is a Range Map product produced onboard the MAHLI on Sol 46. The RATIONALE_DESC describes this image as follows:

Rock - Jake_Matijevic 1 - stereo 1 - APXS standard documentation - working distance near 7 cm - stack acquired Sol 46 with MSL CAMERA_PRODUCT_IDs 133-140 - range map product

The RATIONALE_DESC tells the data user that image 0046MH0000120000100170S00 is the result of a command to merge eight images that were acquired on Sol 46 and have MSL:CAMERA_PRODUCT_IDs in the range 133 through 140. Table 4.4-7 shows the relation between these images and the data values in the Range Map:

Table 4.4-7

Eight Images Commanded to be Merged on Sol 46 to Produce Range Map 0046MH0000120000100170S00			
Sol Acquired	**MSL:CAMERA_PRODUCT_ID**	**Thumbnail Filename**	**Data Value (DN) from Table 4.4-5**
46	133	0046MH0001000030100133I01	255
46	134	0046MH0001000030100134I01	223
46	135	0046MH0001000030100135I01	191
46	136	0046MH0001000030100136I01	159
46	137	0046MH0001000030100137I01	127
46	138	0046MH0001000030100138I01	95
46	139	0046MH0001000030100139I01	63
46	140	0046MH0001000030100140I01	31

Once the relation between Range Map pixel data value (DN) and the 2 to 8 images commanded to be merged (in the example in Table 4.4-7, it was 8 images) is established, the user can relate these to lens focus mechanism motor count, INSTRUMENT_FOCUS_POSITION_CNT. Continuing with the example from MAHLI on produced on Sol 46, Table 4.4-8 shows the relation to INSTRUMENT_FOCUS_POSITION_CNT. Further, examination of the DN histogram of the Range Map image (Figure 4.4-1) tells the user exactly which of the images commanded to be merged were actually merged; those not merged were considered by the onboard focus merge software to be completely out of focus.

Table 4.4-8 and Figure 4.4-1 indicate that, for MAHLI range map product, 0046MH0000120000100170S0, only four of the eight images commanded to be merged were found to have picture elements in focus. For DN values of 95, 127, 159, or 191, the corresponding INSTRUMENT_FOCUS_POSITION_CNT is exactly as stated here. The histogram showed no DN values < 95 or > 191. All DN values in the intervals between 95, 127, 159, and 191 were linearly interpolated by the onboard focus merge software and their corresponding INSTRUMENT_FOCUS_POSITION_CNT positions can, likewise, be determined by linear interpolation.

Table 4.4-8

Relation of MAHLI Sol 46 Range Map Product (0046MH0000120000100170S00) to Focus Motor Count (INSTRUMENT_FOCUS_POSITION_CNT) and Identification of Which Images were Actually Merged.			
Thumbnail Filename from Table 4.4-7	**Data Value (DN) from** Table 4.4-6 **and** Table 4.4-7	**INSTRUMENT_FOCUS_ POSITION_CNT**	**Image Actually Merged? (from** Figure 4.4-1**)**
0046MH0000100030100133I01	255	13516	no
0046MH0000100030100134I01	223	13636	no
0046MH0000100030100135I01	191	13756	yes
0046MH0000100030100136I01	159	13876	yes
0046MH0000100030100137I01	127	13996	yes
0046MH0000100030100138I01	95	14116	yes
0046MH0000100030100139I01	63	14236	no
0046MH0000100030100140I01	31	14356	no

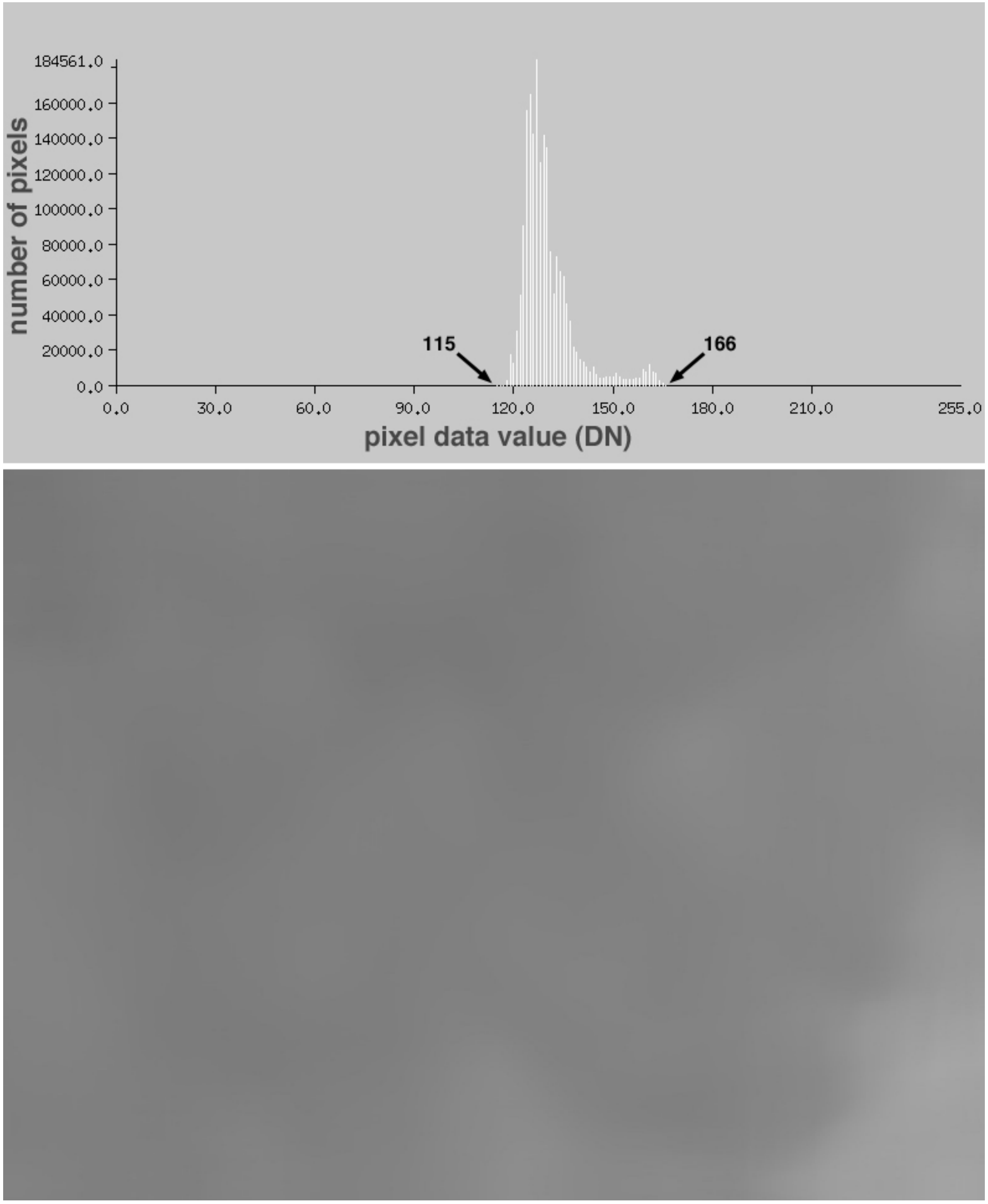


Figure 4.4-1: Example MAHLI Range Map product, image 0046MH0000120000100170S00, and its data value (DN) histogram. The largest DN value is 166, the smallest is 115, as indicated by the arrows on the histogram plot. The histogram was used to determine which of the eight images commanded to be merged to produce 0046MH0000120000100170S00 (and its corresponding Best Focus Image, 0046MH0000120000100169R00) were actually participants in the merge. The histogram indicates that the middle four of the eight images were merged (Table 4.4-8).

4.4.5.8.3 JPEG 444 Focus Merge Thumbnail

ZStack thumbnail generation is equivalent to the methods used for single image thumbnails as in Section 4.4.5.5 Image Thumbnail.

4.4.5.8.4 JPEG Gray Range Map Thumbnail

ZStack thumbnail generation is equivalent to the methods used for single image grayscale thumbnails as in Section 4.4.5.5 Image Thumbnail.

4.5 Image Formatted Products

There are 21 file types and 5 delivery products; a total of 105 types are possible with 12 exceptions. The total number of enumerated products is 93.

Table 4.5-1

	Product Type																				
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
XXXX	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
DRXX	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N
DRCX	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N
DRLX	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
DRCL	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N

Y - Product is created
Y - Product is reduced to 8 bits, color correction not applicable
N - Product is not created

Notes:

- Color corrected products are reduced from 16 bits to 8 bits.
- Range map products are always 8 bits.
- Range map products are not radiometrically corrected, linearized or color corrected.
- Focus merge products are not linearized.
- Science filters in either grayscale JPEG form or Raster 8 bit are single band.

4.5.1 PDS EDR

PDS EDRs have a detached label described in Section 3.2, with a data file having the ".DAT" extension. This file is the original data (possibly compressed). The MMM mini-header (Section 4.4.3) is prepended to this data. There is only one form of a PDS EDR file.

A PDS EDR can be distinguished with the Processing Code XXXX (characters 27-30) (Table 3.4-1).

Bit Depth (per band)	File Names
8 or 16	XXXX.LBL XXXX.DAT

4.5.2 PDS RDR

PDS RDRs have a detached label described in Section 3.2, separate from the binary image formatted data file described in Section 3.3. As noted in Section 3.5.2, there are four versions of PDS RDR data files. If the original data were compressed prior to transmission to Earth, they are always decompressed and radiometrically processed (Section 5.1). If the original data were in color form (YCbCr), they are written as three bands (red, green, and blue).

PDS RDRs designated with the Processing Codes DRCX or DRCL are reduced to 8 bits per color band. PDS RDRs can have one of four Processing Codes (characters 27-30) (Table 3.4-1) DRXX, DRCX, DRLX, DRCL (radiometric, radiometric color corrected, radiometric geometrically linearized, and radiometric, color corrected and geometrically linearized).

Decompressed	Radiometric Processing	Color Corrected	Linearized	Bit Depth (per band)	File Names
yes	yes			16	DRXX.LBL DRXX.IMG
yes	yes	yes		8	DRCX.LBL DRCX.IMG
yes	yes		yes	16	DRLX.LBL DRLX.IMG
yes	yes	yes	yes	8	DRCL.LBL DRCL.IMG

Note: color correction to grayscale images is not applicable. Instead, grayscale images are reduced to 8 bits using contrast enhancement.

The fundamental data forms are described in Section 4.4.

5. RDR PROCESSING AND APPLICABLE SOFTWARE

In this section, we describe the processing flow and software programs used within this process. RDRs are the result of processing applied to EDRs. The RDR process includes some ideas of how digressions from that flow may be forthcoming in future releases of MMM data and processes. Although MSSS is providing RDRs for the PDS delivery, MSSS encourages the user to perform their own RDR processing of the PDS EDRs.

5.1 RDR Processing

Figure 5.1-1 shows the spatial domain processing flow (using decompressed images as the input) and the alternative frequency domain flow (using the compressed data as input and performing calibration prior to decompression, by changing values in the JPEG DCT coefficients). As of the writing of this document, only the spatial domain flow is implemented. Section 5.1.2 describes that flow.

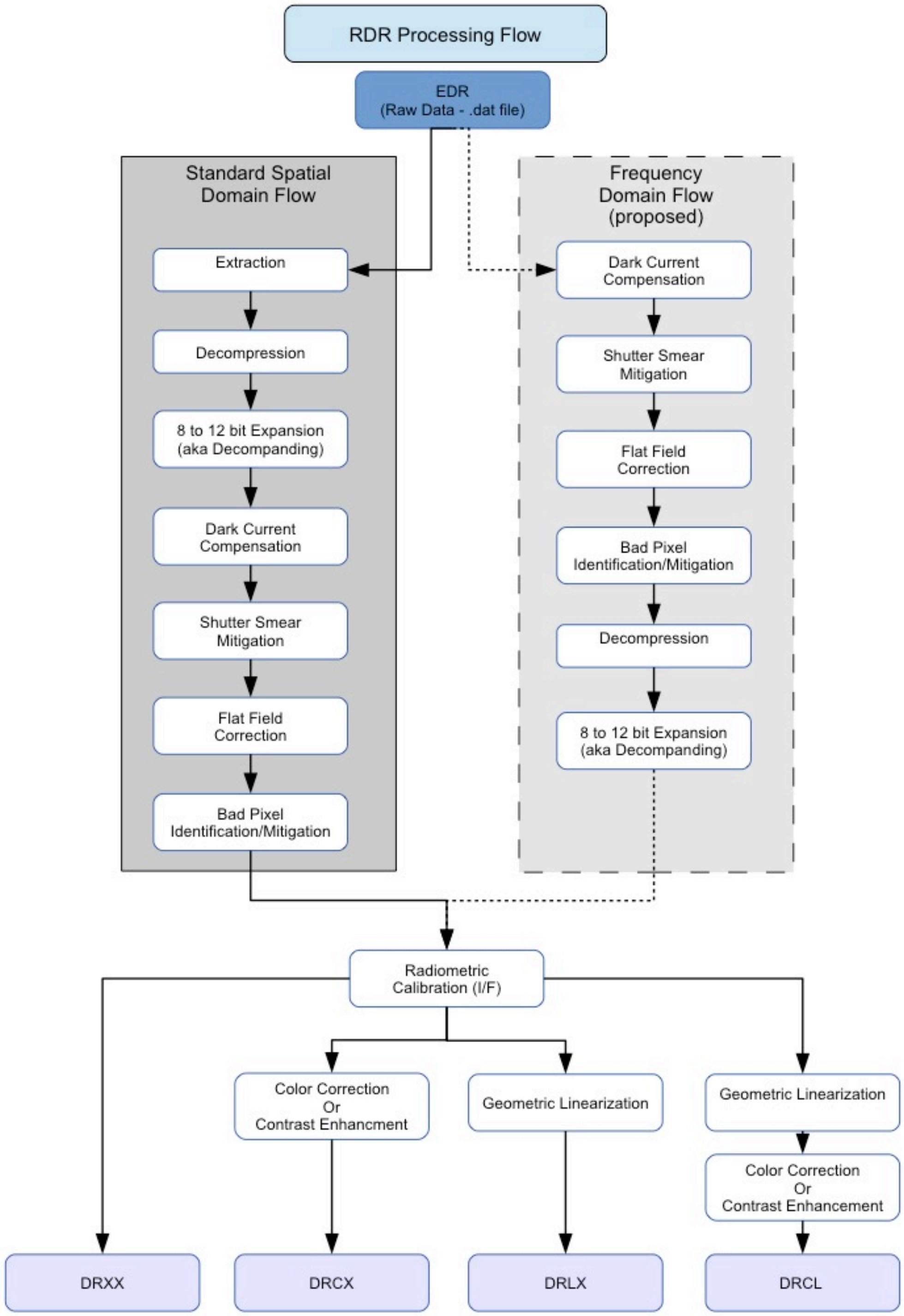


Figure 5.1-1: RDR processing flow with the resulting RDR products

5.1.1 Calibration Processing

RDRs delivered to the PDS have been processed using the methods described in the following Section 5.1.2. Data users can work with the .IMG formatted RDRs provided, or they can apply their own image processing software to the EDRs with data in their intrinsic form. An outline of the processing used to manipulate and process the EDRs into the delivered RDR form is described below. The user may apply these methods to produce an equivalent to the RDR provided to the MSL Project by the MMM team and archived by the PDS.

The MMM team uses its internal processing pipeline to provide the NASA PDS with RDRs.

5.1.2 RDR Processing Flow

5.1.2.1 **Extraction**

This stage of the processing uses the EDR (the .dat file) as the starting point to RDR processing. It therefore provides direct traceability of the RDR from the original raw data.

5.1.2.2 **Decompression**

If the images are compressed, then they are decompressed into spatial domain format. The YCrCb coefficients 8x8 frequency domain MCUs are transformed back into 8x8 spatial MCUs, and reordered into image arrays for each of the three output color bands (RGB). The image output is 8-bit grayscale for some of the products or 24-bit (3 band sequential channels) color products.

5.1.2.3 **Decompanding (8-to-12-bit expansion)**

This processing returns the data to their original 12-bit form, but there are potential losses owing to the nature of the encoding scheme. The most commonly used companding table is likely to be the square root encoding table, which maps several 12-bit values to the same 8-bit value. For example, original 12-bit values 31 and 32 are companded to 25, 338 through 344 are companded to 100, 773-785 are companded to 155, etc. Expanding these back to 12 bit potentially leads to DN contouring, though noise tends to mitigate this effect. (Indeed, square root encoding is commonly used because it preserves SNR.) We are contemplating using spatial continuity in images to develop an interpolation routine to use neighboring values to distribute the DN in a more realistic manner, although that is not part of the initial RDR release. The decompanding tables are included in this SIS as Appendix B: MMM DECompanding Tables and the files themselves can be found in the /CALIB/ directory. Functionally, decompanding applies the following equation:

$$DN_{16}(x,y) = LUT_n[DN_8(x,y)]$$

where x, y index the image array, DN_8 are the 8 bit array values, DN_{16} are the 16 bit decompanded values, and n is the decompanding Look-Up Table.

5.1.2.4 **Dark Current Compensation**

Dark current is the accumulation of charge within the detector from non-photoelectric phenomena, mostly thermally generated electrons. Under normal conditions, the MMM cameras generate only a small amount of dark current. A temperature-dependent model of dark current was generated during thermal vacuum testing, and this model can be applied routinely. A biased offset was implemented to provide room to accommodate variations in electronic behavior of the detector, and measurements of the dark current can be made by taking images at night, and using masked columns on the detector to extract dark current values. There are three ways to apply dark current compensation:

- dark column pixels, or
- temperature of the focal plane, or
- manually by using analogous measurements from related images

5.1.2.5 **Dark Columns**

A small number of sensors on the detector are masked. These pixels accumulate dark current in the same manner as photoactive pixels. An MMM imaging row contains 1608 photo-active pixels from the sensor. The format of an MMM image row is described in the table below.

Dark Pixels	Photo-active Pixels	Dark Pixels
1-23	24-1631	1632-1648

The contents of the first 24 columns are as follows (with one imaging pixel on the right in green):

<table>
<tr><td colspan="24">Pixels</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td></tr>
<tr><td colspan="2" rowspan="2"></td><td></td><td colspan="4">isolation</td><td colspan="16">dark pixels</td><td></td></tr>
<tr><td colspan="22">invalid ADC pipeline pixel from previous line</td></tr>
<tr><td colspan="24">dark pixels from the previous line</td></tr>
<tr><td colspan="8">JPEG MCU 0</td><td colspan="8">JPEG MCU 1</td><td colspan="8">JPEG MCU 2</td></tr>
</table>

Note that JPEG Minimum Coded Units (MCU) are blocks of 8x8 pixels. Each JPEG MCU above is shown in blue. For images compressed as JPEGs, the dark pixel in column 8 is compressed with non-dark pixels from MCU 0. For this reason, only dark columns 9 – 16 are used by MMM RDR processing.

Thumbnail processing takes into account the compression applied. Thumbnails effectively average all 8 of MCU 1 pixels into a single thumbnail pixel. Only the second thumbnail pixel is used for dark current processing.

For consistency, all images, even if not JPEG compressed, use the same group of 8. The average of these 8 pixels along the entire height of the image are used for dark current. The first two and last two lines on the sensor are not included.

Note: sub-framed images might not have dark columns if the first column is > 16. Functionally, the removal of dark current is as follows:

$DN_{dark\_removed}(x,y) = DN(x,y) – mean\_dark\_columns$

where x, y index the image array, DN are the 16 bit array values, and mean_dark_columns is the mean dark current measurement.

5.1.2.6 **Temperature**

Pre-flight calibration data measure charge accumulation as a function of temperature. This accumulation measured in DN/sec can be used with the image exposure time in the mini-header to determine the dark current.

A DC offset is removed from DN values during acquisition. The DC offset is in the MMM mini-header.

bias = exposure*DN/sec – DC offset
$DN_{dark\_removed}(x,y) = DN(x,y) – bias$

where x, y index the image array, DN are the 16 bit array values, and DC offset is the ADC offset as recorded in the MMM mini-header.

5.1.2.7 **Manual Approach**

A user-determined value may be supplied to the dark current processing. This can be used when dark current cannot be measured with temperature or dark columns. This value may be determined by

1) bias from an image close in time and from the same instrument

2) bias from an image close in time and from another MMM instrument

The bias is then removed from all DN values

$DN_{dark\_removed}(x,y) = DN(x,y) – bias$

where x, y index the image array, DN are the 16 bit array values, and bias is the value to remove.

5.1.2.8 **Shutter Smear Mitigation**

Cameras without physical shutters (that prevent light from shining on the photosensitive surface except for the exposure time) implement shuttering by shifting the accumulated photoelectrically generated charge to locations that are less but still somewhat light sensitive. As the charge is then read out, a small amount of light falls on the detector and is added in a sequential way to the image. This is called shutter smear. Under appropriate conditions (a static scene and one without a lot of structure), shutter smear can be mitigated by taking a part of the scene (usually one line at a time) and computing its fractional contribution to the next line, and doing this for the entire image. Shutter smear is most pronounced when the readout time is large relative to the exposure time. For most MMM exposures, this will not be the case, but for MARDI the short exposure time (≤ 1 ms) may lead to greater shutter smear. The scene itself can be used to determine the accumulated affect of shutter smear, and to subtract that accumulation from the final image. A complication in mitigating MMM shutter smear is that the sensitivity of each pixel in each line varies because of the effects of the Bayer Color Filter Array, imposing an additional pattern on the image.

Photon induced electrons are shifted off the CCD sensor, vertically, towards line 0. As electrons are shifted past pixels accumulating scene dependent charge, they pick up a portion of that charge. This charge is based on the clock readout rate, and shutter smear is a fraction of the readout rate and the exposure time. Since the smear is scene dependent, the assumption must be made that the scene does not vary during integration or readout time (since the assumption isn't always correct, shutter smear is only mitigated, not removed). A fraction of each line is added to an accumulator, which is subtracted from each line in the direction opposite the readout direction.

The smear factor is nominally the same for each instrument as they use the same type of sensor. The smear factor is dependent on exposure time and line readout rate.

$$S_{(x,y)} = DN_{(x)} * smf * t_{line\_read} / t_{exp}$$
$$DN_{desmeared(x,y)} = DN_{(x,y)} - S_{(x,y-1)}$$

Where smf is the smear factor, and $S_{(x,y)}$ is the accumulated smear at line y and column x. The accumulator is seeded with zero values for line y=0. Shutter smear is only subtracted for exposures less than 100ms.

Note: The value of the parameter “smf” in the formula is not given as it is still under development. This will be updated once we have smear factors or a smear factor function which properly mitigates smear induced artifacts.

5.1.2.9 **Flat Field Correction**

The brightness response recorded by the MMM detectors is not uniform as a function of position within the field of views. In particular, the Mastcams and MARDI have differing but roughly comparable non-uniformity in brightness. The Mastcam FOVs are vignetted at their corners by a filter wheel mask (the original design for the zoom lenses under-illuminated the field), and the Mastcams also display some structure under uniform illumination resulting from internal reflections. The MARDI is a wide-angle lens and the transmission of the light falls off radially from the optic axis. MAHLI’s response is more uniform. Laboratory measurements during calibration and expected sky calibrations (except for MARDI) provide measures of the non-uniformity of the cameras’ responses. These calibrations can be used to increase brightness in areas of lower response. Flat field reference images derived from calibration data can be used to adjust the brightnesses spatially within the images.

A flat field reference file is a matrix of fractional values with the same dimensions as a full-frame sensor image. If the image is a sensor subset, then the flat field reference file is subset accordingly.

For x,y inside the acquired image (sub-frames must be offset in the flat-field):

$$DN_{flat\_corrected(x,y)} = DN_{(x,y)}/flat_{(x,y)}$$

where x,y index the image array, DN are the 16 bit array values, and flat is the flat field specific to that image.

- RAW and lossless images can be flat fielded with high resolution fields encoded specific to each Bayer color filter array and pixel position.
- JPEG images have flat fields for either luminance, or red, green, and blue channels.

- Thumbnails use a subsampled flat field that is 1/64th of the original image size. Like JPEGs, there are flat fields for both luminance, or red, green, and blue channels.

MMM flat field reference files are stored as 1/flat so correction is multiplicative during processing. For instrument-specific flat fields, see the /CALIB/ directory.

5.1.2.10 Bad Pixel Mitigation

There are three sources of localized pixel response variations. First are non-uniformities in the sensitivity of the individual pixel photosites. These were mapped by the detector manufacturer (who charges more for blemish free detectors than for those with some blemishes) and during calibration. These are typically single pixels that are "hot" (more sensitive, and hence brighter) or "cold" (less sensitive, and darker than their neighbors). Our detectors did not have any column problems. The second source of localized pixel response variations is contamination on the detector or optics. Such contamination occults light, creating umbral or penumbral shadowing. These features can be a few pixels in size. The Mastcams and MARDI have very few of these and MAHLI has more; these were also mapped during calibration, and are monitored to make sure they do not migrate with time. The final source of non-uniform pixel response is radiation damage. The MSL spacecraft has two energetic particle sources: the Radioisotope Thermoelectric Generator (RTG) (a constant source of low flux neutrons), and the Dynamic Albedo of Neutrons (DAN) experiment that includes an active, pulsed neutron generator. Radiation-induced pixel responses can be both brighter and darker than their neighbors. Some of the problem pixels can self-heal, while others become long lived. Dark current images provide some insight into these. Depending on the severity of radiation induced problem pixels, separate bad pixel adjustment may be necessary to adjust the values for these locales.

The processing for images supplied to the PDS does not currently address bad pixels. This step serves as a placeholder should it become necessary to do this in future processing. At present the correction provided by the multiplicative flat field is deemed adequate. The default processing for images supplied to the PDS does not modify the DN values of bad pixels.

5.1.2.11 Radiometric Calibration

Radiometric calibration uses measured optical and optoelectronic properties to determine absolute and relative brightnesses from the camera images. For additional information on the Mastcam, MAHLI, and MAHLI camera calibration, see /CALIB/MSL_MMM_CAL.TXT.

5.1.2.12 Color Correction

Differences in filter and optics transmission and detector sensitivity as a function of wavelength cause color shifts in images unrelated to the actual color of the scene. For the color-corrected image products, we have applied empirically-derived color coefficients derived from imaging neutral gray targets under solar illumination in ground testing. The outcome for flight images is roughly what the planetary surface would look like if it were viewed by the human eye *in situ*. However, for quantitative color analysis, the radiometrically-corrected but not color-corrected products should be used.

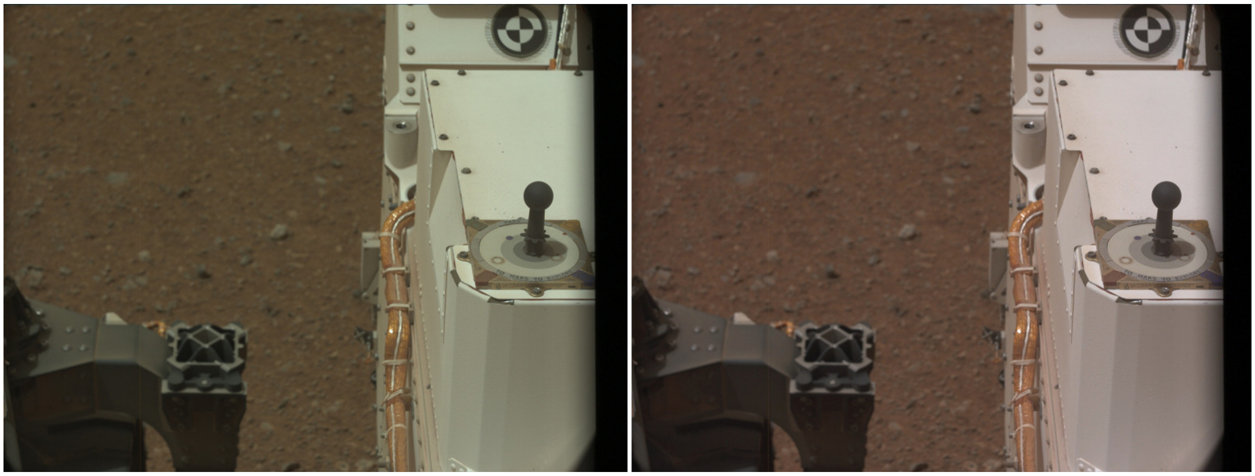


Figure 5.1-2: Use of color correction to create a cosmetic color balanced version of a raw EDR product. Note the slight greenish case of the raw image on the left.

5.1.2.13 Geometrically Corrected Images (Linearization)

A geometric camera model [Ref 13] is a set of equations that transforms a three-dimensional point in space to a two-dimensional position in an image (pixel location). It can also be inverted to transform a pixel in the image to a set of points in space that would map to that pixel (the imaging locus). The camera model contains the position and pointing vector for the camera and also models the lens distortion and interior geometry of the camera. There is a unique camera model associated with each image.

A linearized image has the distortion removed and is also corrected for the slight deviation of each pixel from square. This involves warping the image pixels to show how an ideal camera that has no distortion would image the scene. A simple pinhole camera model can then model the resulting image or equivalently a CAHV model [Ref 14] as explained below.

Lens Distortion

Radial distortion is modeled by adjusting the image point in the focal plane using a polynomial. The coordinate system is defined as *x* along the row direction, *y* along the column direction, and an imaged point (without distortion as (x, y)). Let the center of distortion be (x_0, y_0) which may be offset from the principal point, which is at *(0, 0).* If *r* is the radial distance (in millimeters) from the center of distortion to the image point, $r = \sqrt{(x - x_0)^2 + (y - y_0)^2}$, then the radial distortion of that point is

$$\Delta r = k_1 r^3 + k_2 r^5 + k_3 r^7$$

and

$$\Delta x = x \frac{\Delta r}{r}$$

$$\Delta y = y \frac{\Delta r}{r}.$$

The distortion is removed by inverting the nonlinear equation using an iterative procedure such as Newton's method. The distortion coefficients (k_1, k_2 and k_3) and the distortion center are determined during camera calibration.

Focal Plane to Pixel Transformation

The interior orientation part of the camera model models the relationship between the focal plane and the actual detector. Let *(i, j)* be the location of a pixel row and column and *(i_0, j_0)* be principal point of the camera. The mapping from the focal plane to the image is

$$i = i_0 + a_{11}x + a_{12}y$$

and

$$j = j_0 + a_{21}x + a_{22}y$$

where *(0, 0*) is the upper left corner of the upper left pixel. Since the focal length is confounded with the pixel pitch, we fix the value of $a_{21} = \frac{1}{pixel\_pitch}$ using the nominal value of the MMM camera's pixel pitch (7.4 microns). Moreover, in the absence of fiducial markers in the camera's focal plane, rotation of the detector is indistinguishable from rotation of the entire camera, so the value of a_{21} can be fixed at zero. The focal length, principal point and affine coefficients for relative scale and skew are determined during camera calibration. The actual image stored to memory may be a subframe of the physical detector as specified by an offset and image size.

Calibration

We calibrated the camera models during ATLO using calibration plates with markers at known positions on a grid. The camera model parameters were adjusted to remove the distortion using nonlinear optimization the root-mean-squared residual between the points projected through the camera model and the image points measured in the images. The following tables contains the calibrated coefficients for each of the MMM cameras.

Table 5.1-1: MMM Lens Distortion Calibrated Coefficients

Camera	x_0 (mm)	y_0 (mm)	k_1	k_2	k_3
Mastcam-34	-0.113876	0.152029	-1.118977e-04	-1.023513e-06	0.0
Mastcam-100	0.262451	-0.250667	1.513695e-04	0.0	0.0
MAHLI	0.0	0.0	9.045561e-05	0.0	0.0
MARDI	0.0	0.0	-3.589522e-03	1.828246e-05	-5.040188e-08

Table 5.1-2: MMM Interior Orientation Calibrated Coefficients

Camera	$i_0(pixels)$	$j_0(pixels)$	a_{11}	a_{12}	a_{21}	a_{22}
Mastcam-34	588.405	834.620	135.154157	-0.038589	0.0	135.135135
Mastcam-100	608.811	836.113	135.154157	-0.038589	0.0	135.135135
MAHLI	604.910	840.487	135.154157	-0.038589	0.0	135.135135
MARDI	588.381	819.047	135.154157	-0.038589	0.0	135.135135

The above coefficients may be modified over the course of the MSL mission. Specifically, the effects of temperature and focus motor count have not been taken into account.

Linearization procedure

First, we determine the size of the linearized image by projecting points along the edge (we use the four corners and four midpoints) onto the focal plane. The limits of the projection are used to set the subframe for the new image. A detector is defined having square pixels with the nominal pixel pitch and principal point as the original image. The value for each pixel in the linearized image is calculated by projecting the center of each pixel onto the focal plane, applying the radial distortion model, and transferring the position to a fractional pixel location in the original image. Bi-cubic interpolation is then used to calculate the actual value. Some of the pixels in the linearized image will project outside of the original image and must be given a missing data value. This value is defined by the MISSING_VALUE keyword in the label. An example of a linearize MARDI image is shown below.

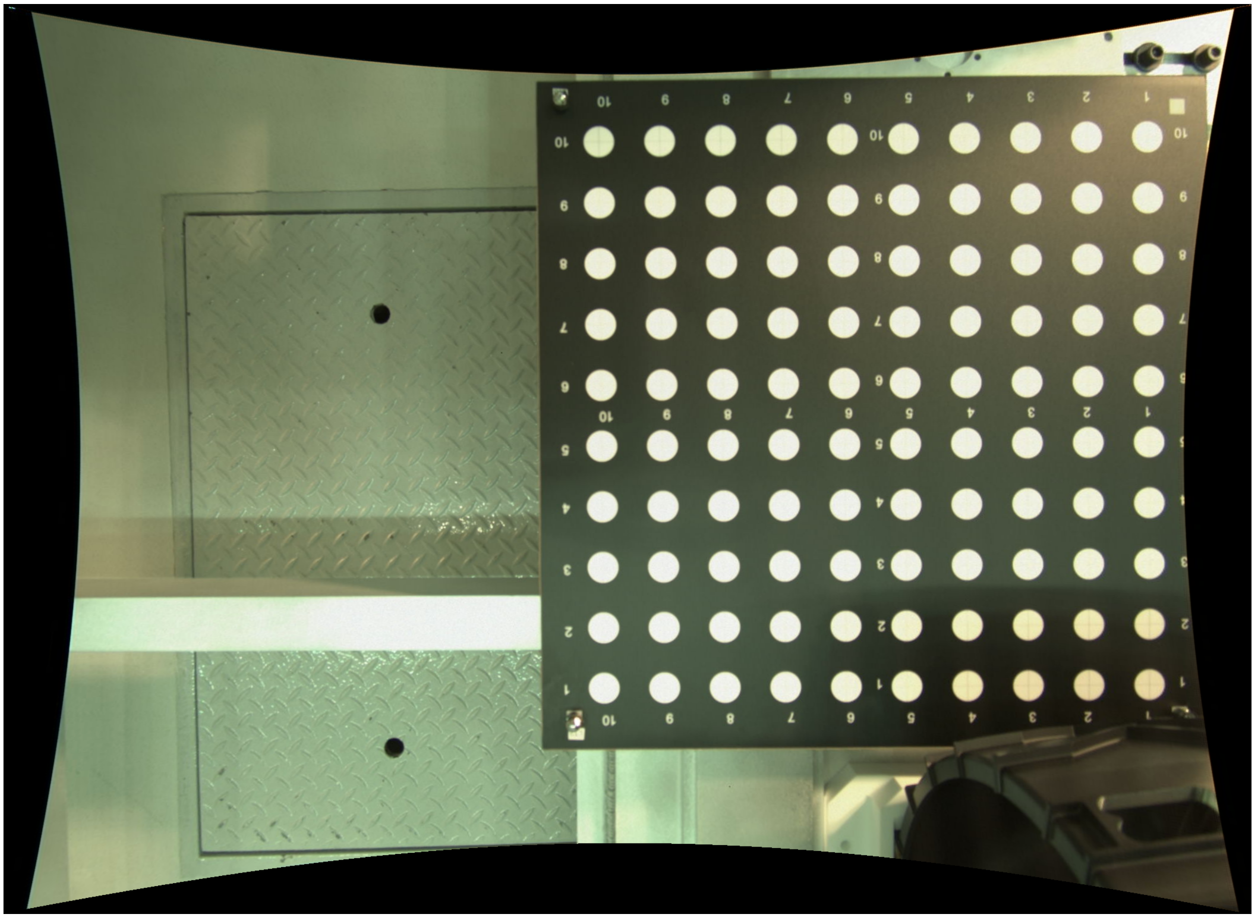


Figure 5.1-3: Linearized MARDI Calibration Image

The CAHV model

The linearized camera model is stored as a CAHV model in the PDS label (Ref [7]). The CAHV model can be losslessly constructed from the pinhole camera model. The CAHV model is parameterized using four vectors.

C -The 3D position of the entrance pupil
A -A unit vector normal to the image plane pointing outward (towards C)
H -A vector pointing roughly rightward in the image; it is a composite of the orientation of the detector rows, the horizontal scale, the horizontal center
V -A vector pointing roughly downward in the image; it is a composite of the orientation of the detector columns, the vertical scale, the vertical center, and A.

Note that in the CAHVOR model *(0, 0)* refers to the center of the upper left pixel.
If P is a point in the scene, then the corresponding image locations x and y can be computed as follows:

$$row = \frac{(P - C) \cdot H}{(P - C) \cdot A}$$

$$col = \frac{(P - C) \cdot V}{(P - C) \cdot A}$$

5.2 Applicable PDS Software Tools

PDS-labeled images and tables can be viewed with the program NASAView, developed by the PDS and available for a variety of computer platforms from the PDS web site http://pds.jpl.nasa.gov/tools/software_download.cfm. There is no charge for NASAView.

5.3 Software Distribution

The software provided to the PDS by MSSS for processing the MMM data is available to the community from the PDS in executable form for the following computer operating systems: Apple Macintosh OSX 10.7 and LINUX RedHat 5. It is PDS's responsibility to maintain the software and to upgrade it to other operating systems.

The distribution includes a single tool for reading, extracting, and decompressing MMM EDR products into an image .img viewable by NASAView. The tool, "dat2img", only works on XXXX.DAT files created by MMM instruments. As mentioned in Section 4.5.1, a MMM PDS EDR product consists of a detached label (.LBL) and a .DAT file.

5.3.1 Building dat2img

On a supported operating system (see above), untar MMM_DAT2IMG.TAR; this creates the dat2img source directory. Type "source build_all" in that directory which will then compile the dat2img binary. For further details, see MMM_DAT2IMG.TXT in the /SOFTWARE/DOC directory.

5.3.2 Running dat2img

The provided software decompresses the .DAT file into one or more .IMG formatted files.

The software does the following:

1. extracts the data contained in the mini-header
2. decompresses the image data (if compressed)
3. creates an image (.IMG) formatted file

Usage:

```
dat2img [-d ] input.DAT [output_dir]
```

Use -d option for detached label file (default is attached label)
Default output file is input_nn.IMG in the current directory

Example: ./dat2img -d 0000MD9999000032E1_XXXX.DAT out_dir

Output: out_dir/0000MD9999000032E1_XXXX_00.LBL
out_dir/0000MD9999000032E1_XXXX_00.IMG

Images are single band 8 bit, 3 band 8 bit RGB, or single band 16 bit images depending on the EDR contents. The labels for sequential GOP images are identical except for name.

The expected output will be

filename_00.LBL
filename_00.IMG

Note: Video GOP products output 1 to 16 individual image (.IMG) files with paired detached label (.LBL) files. For GOP video products the output is

filename_00.LBL
filename_00.IMG
filename_01.LBL
filename_02.IMG
…
filename_15.LBL
filename_15.IMG

APPENDICES

APPENDIX A: MMM KEYWORDS, DEFINTIONS, VALID VALUES AND ENTRIES, AND SAMPLE LABEL PRODUCTS

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
PDS_VERSION_ID		Specifies the version number of the PDS standards document that is valid when a data product label is created. Values for the PDS_version_id are formed by appending the integer for the latest version number to the letters 'PDS'.	PDS3, N/A, NULL, UNK	PDS3, N/A, NULL, UNK	PDS3, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
FILE_NAME	COMPRESSED_FILE	Specifies an image and typically consists of a sequence of characters representing 1) a routinely occurring measure, such as revolution number, 2) a letter identifying the spacecraft, target, or camera, and 3) a representation of a count within the measure, such as picture number within a given revolution. Extension is .DAT.	string (see section 3.4 of this document), N/A, NULL, UNK	string (see section 3.4 of this document), N/A, NULL, UNK	string (see section 3.4 of this document), N/A, NULL, UNK
RECORD_TYPE	COMPRESSED_FILE	Specifies the record format of a file.	UNDEFINED, FIXED_LENGTH, N/A, NULL, UNK	UNDEFINED, FIXED_LENGTH, N/A, NULL, UNK	UNDEFINED, FIXED_LENGTH, N/A, NULL, UNK
FILE_RECORDS	COMPRESSED_FILE	Specifies the number of physical file records, including both label records and data records.	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK
ENCODING_TYPE	COMPRESSED_FILE	Indicates the type of compression or encryption used for data storage.	MSLMMM-COMPRESSED, MSLMMM-DECOMPRESSED, N/A, NULL, UNK	MSLMMM-COMPRESSED, MSLMMM-DECOMPRESSED, N/A, NULL, UNK	MSLMMM-COMPRESSED, MSLMMM-DECOMPRESSED, N/A, NULL, UNK
INTERCHANGE_FORMAT	COMPRESSED_FILE	Represents the manner in which data items are stored.	BINARY, ASCII, N/A, NULL, UNK	BINARY, ASCII, N/A, NULL, UNK	BINARY, ASCII, N/A, NULL, UNK
UNCOMPRESSED_FILE_NAME	COMPRESSED_FILE	Provides the location independent name of a file. UNCOMPRESSED_FILE_NAME is the output file name from dat2img. Extension is .IMG.	string (see section 3.4 of this document), N/A, NULL, UNK	string (see section 3.4 of this document), N/A, NULL, UNK	string (see section 3.4 of this document), N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
REQUIRED_STORAGE_BYTES	COMPRESSED_FILE	Provides the number of bytes required to store an uncompressed file. This value may be an approximation and is used to ensure enough disk space is available for the resultant file.	Integer, N/A, NULL, UNK	Integer, N/A, NULL, UNK	Integer, N/A, NULL, UNK
^MINIHEADER_TABLE	COMPRESSED_FILE	Identifies and defines the attributes of commonly used header data structures for non-PDS formats.	EDR only: string array [2], N/A, NULL, UNK	EDR only: string array [2], N/A, NULL, UNK	EDR only: string array [2], N/A, NULL, UNK
FILE_NAME	UNCOMPRESSED_FILE	Specifies an image and typically consists of a sequence of characters representing 1) a routinely occurring measure, such as revolution number, 2) a letter identifying the spacecraft, target, or camera, and 3) a representation of a count within the measure, such as picture number within a given revolution. FILE_NAME is the output file name from dat2img. Extension is .IMG.	string (see section 3.4 of this document), N/A, NULL, UNK	string (see section 3.4 of this document), N/A, NULL, UNK	string (see section 3.4 of this document), N/A, NULL, UNK
RECORD_TYPE	UNCOMPRESSED_FILE	Specifies the record format of a file.	FIXED_LENGTH, N/A, NULL, UNK	FIXED_LENGTH, N/A, NULL, UNK	FIXED_LENGTH, N/A, NULL, UNK
FILE_RECORDS	UNCOMPRESSED_FILE	Specifies the number of physical file records, including both label records and data records.	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
RECORD_BYTES	UNCOMPRESSED_FILE	Specifies the number of bytes in a physical file record, including record terminators and separators.	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK
LINES	UNCOMPRESSED_FILE & IMAGE	Specifies the total number of data instances along the vertical axis of an image.	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK
LINE_SAMPLES	UNCOMPRESSED_FILE & IMAGE	Specifies the total number of data instances along the horizontal axis of an image.	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK
SAMPLE_TYPE	UNCOMPRESSED_FILE & IMAGE	Indicates the data storage representation of sample value.	string, CHARACTER, LSB_INTEGER, LSB_UNSIGNED_INTEGER, MSB_INTEGER, MSB_UNSIGNED_INTEGER, UNSIGNED_INTEGER, N/A, NULL, UNK	string, CHARACTER, LSB_INTEGER, LSB_UNSIGNED_INTEGER, MSB_INTEGER, MSB_UNSIGNED_INTEGER, UNSIGNED_INTEGER, N/A, NULL, UNK	string, CHARACTER, LSB_INTEGER, LSB_UNSIGNED_INTEGER, MSB_INTEGER, MSB_UNSIGNED_INTEGER, UNSIGNED_INTEGER, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
SAMPLE_BITS	UNCOMPRESSED_FILE & IMAGE	Indicates the stored number of bits, or units of binary information, contained in a LINE_SAMPLE value.	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK
BANDS	UNCOMPRESSED_FILE & IMAGE	Indicates the number of bands in an image or other object.	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK
FIRST_LINE	UNCOMPRESSED_FILE & IMAGE	Specifies the line within a source image that corresponds to the first line in a sub-image.	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK
FIRST_LINE_SAMPLE	UNCOMPRESSED_FILE & IMAGE	Specifies the sample within a source image that corresponds to the first sample in a sub-image.	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK
MSL:ACTIVE_FLIGHT_STRING_ID		Indicates which flight computer "string" (separate sets of electronics) was active when this product was acquired.	A, B, N/A, NULL, UNK	A, B, N/A, NULL, UNK	A, B, N/A, NULL, UNK
DATA_SET_ID		Specifies a unique alphanumeric identifier for a data set or a data product. The DATA_SET_ID value for a given data set or product is constructed according to flight project naming conventions. In most cases the DATA_SET_ID is an abbreviation of the DATA_SET_NAME. In the PDS, the values for DATA_SET_ID are constructed according to standards outlined in the Standards Reference.	MSL-M-MASTCAM-2-EDR-IMG-V1.0 MSL-M-MASTCAM-2-EDR-VID-V1.0 MSL-M-MASTCAM-2-EDR-Z-V1.0 MSL-M-MASTCAM-4-RDR-IMG-V1.0 MSL-M-MASTCAM-4-RDR-VID-V1.0 MSL-M-MASTCAM-4-RDR-Z-V1.0, N/A, NULL, UNK	MSL-M-MAHLI-2-EDR-IMG-V1.0 MSL-M-MAHLI-2-EDR-VID-V1.0 MSL-M-MAHLI-2-EDR-Z-V1.0 MSL-M-MAHLI-4-RDR-IMG-V1.0 MSL-M-MAHLI-4-RDR-VID-V1.0 MSL-M-MAHLI-4-RDR-Z-V1.0, N/A, NULL, UNK	MSL-M-MARDI-2-EDR-IMG-V1.0 MSL-M-MARDI-2-EDR-VID-V1.0 MSL-M-MARDI-4-RDR-IMG-V1.0 MSL-M-MARDI-4-RDR-VID-V1.0, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
DATA_SET_NAME		Specifies the full name given to a data set or a data product. The DATA_SET_NAME typically identifies the instrument that acquired the data, the target of that instrument, and the processing level of the data. In the PDS, values for DATA_SET_NAME are constructed according to standards outlined in the Standards Reference.	MSL MARS MAST CAMERA 2 EDR IMAGE V1.0 MSL MARS MAST CAMERA 2 EDR VIDEO V1.0 MSL MARS MAST CAMERA 2 EDR ZSTACK V1.0 MSL MARS MAST CAMERA 4 RDR IMAGE V1.0 MSL MARS MAST CAMERA 4 RDR VIDEO V1.0 MSL MARS MAST CAMERA 4 RDR ZSTACK V1.0, N/A, NULL, UNK	MSL MARS HAND LENS IMAGER 2 EDR IMAGE V1.0 MSL MARS HAND LENS IMAGER 2 EDR VIDEO V1.0 MSL MARS HAND LENS IMAGER 2 EDR ZSTACK V1.0 MSL MARS HAND LENS IMAGER 4 RDR IMAGE V1.0 MSL MARS HAND LENS IMAGER 4 RDR VIDEO V1.0 MSL MARS HAND LENS IMAGER 4 RDR ZSTACK V1.0, N/A, NULL, UNK	MSL MARS DESCENT IMAGER 2 EDR IMAGE V1.0 MSL MARS DESCENT IMAGER 2 EDR VIDEO V1.0 MSL MARS DESCENT IMAGER 4 RDR IMAGE V1.0 MSL MARS DESCENT IMAGER 4 RDR VIDEO V1.0, N/A, NULL, UNK
COMMAND_SEQUENCE_NUMBER		Specifies a numeric identifier for a sequence of commands sent to a spacecraft or instrument.	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK
GEOMETRY_PROJECTION_TYPE		Specifies the state of the pixels in an image before a re- projection has been applied. Describes if or how the pixels have been reprojected. RAW indicates reprojection has not been done; the pixels are as they came from the camera.	RAW, LINEARIZED, N/A, NULL, UNK	RAW, LINEARIZED, N/A, NULL, UNK	RAW, LINEARIZED, N/A, NULL, UNK
IMAGE_ID		Specifies an image and typically consists of a sequence of characters representing 1) a routinely occurring measure, such as revolution number, 2) a letter identifying the spacecraft, target, or camera, and 3) a representation of a count within the measure, such as picture number within a given revolution.	string (see section 3.4 of this document), N/A, NULL, UNK	string (see section 3.4 of this document), N/A, NULL, UNK	string (see section 3.4 of this document), N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
IMAGE_TYPE		Specifies the type of image acquired. This may be used to describe characteristics that differentiate one group of images from another such as the nature of the data in the image file, the purpose for which the image was acquired, or the way in which it was acquired where REGULAR is any image or sub-framed image product and THUMBNAIL is any image sub-sampled and transmitted as a thumbnail.	REGULAR, THUMBNAIL, N/A, NULL, UNK	REGULAR, THUMBNAIL, N/A, NULL, UNK	REGULAR, THUMBNAIL, N/A, NULL, UNK
MSL:IMAGE_ACQUIRE_MODE		This keyword describes the mode of image acquisition. Valid values are defined as: a) "NONE" - No image acquired b) "SERNO" - No image acquired, camera serial number returned only c) "IMAGE" - The image was acquired	IMAGE, SERNO, NONE, N/A, NULL, UNK	IMAGE, SERNO, NONE, N/A, NULL, UNK	IMAGE, SERNO, NONE, N/A, NULL, UNK
INSTRUMENT_HOST_ID		Specifies a unique identifier for the host where an instrument is located. This host can be either a spacecraft or an earth base (e.g., and observatory or laboratory on the earth). Thus, INSTRUMENT_HOST_ID can contain values which are either SPACECRAFT_ID values or EARTH_BASE_ID values.	MSL, N/A, NULL, UNK	MSL, N/A, NULL, UNK	MSL, N/A, NULL, UNK
INSTRUMENT_HOST_NAME		Specifies the full name of the host on which an instrument is based. This host can be either a spacecraft or an earth base. Thus, the INSTRUMENT_HOST_NAME element can contain values which are either SPACECRAFT_NAME values or EARTH_BASE_NAME values.	MARS SCIENCE LABORATORY, N/A, NULL, UNK	MARS SCIENCE LABORATORY, N/A, NULL, UNK	MARS SCIENCE LABORATORY, N/A, NULL, UNK
INSTRUMENT_ID		Specifies an abbreviated name or acronym which identifies an instrument.	MAST_LEFT, MAST_RIGHT, N/A, NULL, UNK	MAHLI, N/A, NULL, UNK	MARDI, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
INSTRUMENT_NAME		Specifies the full name of an instrument.	MAST CAMERA LEFT, MAST CAMERA RIGHT, N/A, NULL, UNK	MARS HAND LENS IMAGER CAMERA, N/A, NULL, UNK	MARS DESCENT IMAGER CAMERA, N/A, NULL, UNK
INSTRUMENT_SERIAL_NUMBER		Specifies the manufacturer's serial number assigned to an instrument. This number may be used to uniquely identify a particular instrument for tracing its components or determining its calibration history, for example. MARDI Engineering Model = 0 or 1002 (Note: 1002 was used for some imaging since the Mastcam Right Engineering Model DEA was used with the MARDI imaging head for some tests.) Mastcam Left Engineering Model = 1001; Mastcam Right Engineering Model = 1002; MAHLI Life Test Unit = 1003; MARDI Flight Model = 3001; MAHLI Flight Model = 3002; Mastcam Left Flight Model = 3003; Mastcam Right Flight Model = 3004	0, 1001, 1002, 3003, 3004, N/A, NULL, UNK	0, 1003, 3002, N/A, NULL, UNK	0, 1002, 3001, N/A, NULL, UNK
FLIGHT_SOFTWARE_VERSION_ID		Identifies the version of the active instrument flight software used to acquire the image. The Flight Software version is an opaque token – there is no arithmetic value associated with the token.	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK
INSTRUMENT_TYPE		Specifies the type of an instrument.	IMAGING CAMERA, N/A, NULL, UNK	IMAGING CAMERA, N/A, NULL, UNK	IMAGING CAMERA, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
INSTRUMENT_VERSION_ID		Specifies the model of an instrument used to obtain data. For example, this keyword can be used to distinguish between an engineering model of a camera used to acquire test data, and a flight model of a camera used to acquire science data during a mission. Identifiers for use in MSL are: “EM” - Engineering Model (serial number < 3000) and “FM” - Flight Model (serial number >= 3000), and "LTU" - Life Test Unit.	EM, FM, N/A, NULL, UNK	EM, FM, LTU, N/A, NULL, UNK	EM, FM, N/A, NULL, UNK
MSL:LOCAL_MEAN_SOLAR_TIME		Specifies the Local Mean Solar Time, or LMST, at the time of image acquisition (see IMAGE_TIME). It is one of two types of solar time used to express the time of day at a point on the surface of a planetary body.	Sol-xxxxxM<hh>:<mm>:<ss>.<fff>, N/A, NULL, UNK	Sol-xxxxxM<hh>:<mm>:<ss>.<fff>, N/A, NULL, UNK	Sol-xxxxxM<hh>:<mm>:<ss>.<fff>, N/A, NULL, UNK
LOCAL_TRUE_SOLAR_TIME		Specifies the local true solar time, or LTST, at the time of image acquisition (see IMAGE_TIME). It is one of two types of solar time used to express the time of day at a point on the surface of a planetary body. LTST is measured relative to the true position of the Sun as seen from a point on the planet's surface.	<hh>:<mm>:<ss>, N/A, NULL, UNK	<hh>:<mm>:<ss>, N/A, NULL, UNK	<hh>:<mm>:<ss>, N/A, NULL, UNK
MISSION_NAME		Specifies a major planetary mission or project. A given planetary mission may be associated with one or more spacecraft.	MARS SCIENCE LABORATORY, N/A, NULL, UNK	MARS SCIENCE LABORATORY, N/A, NULL, UNK	MARS SCIENCE LABORATORY, N/A, NULL, UNK
MISSION_PHASE_NAME		Specifies the commonly-used identifier of a mission phase.	"DEVELOPMENT", "LAUNCH", "CRUISE AND APPROACH", "ENTRY, DESCENT, AND LANDING", "PRIMARY SURFACE MISSION", "EXTENDED SURFACE MISSION", N/A, NULL, UNK	"DEVELOPMENT", "LAUNCH", "CRUISE AND APPROACH", "ENTRY, DESCENT, AND LANDING", "PRIMARY SURFACE MISSION", "EXTENDED SURFACE MISSION", N/A, NULL, UNK	"DEVELOPMENT", "LAUNCH", "CRUISE AND APPROACH", "ENTRY, DESCENT, AND LANDING", "PRIMARY SURFACE MISSION", "EXTENDED SURFACE MISSION", N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
OBSERVATION_ID		Specifies a unique identifier for a scientific observation within a data set. It is set via the data product context ID - which doesn't necessarily map to a specific object - it's just used to group various instrument data sets together via a common keyword.	NULL or character string, N/A, NULL, UNK	NULL or character string, N/A, NULL, UNK	NULL or character string, N/A, NULL, UNK
PLANET_DAY_NUMBER		Specifies the number of solar days elapsed since a reference day (e.g., the day on which a landing vehicle set down) for local mean solar time (LMST). Days are measured in rotations of the planet in question from midnight to midnight. For MSL, the reference day is “0”, as Landing day is Sol 0. If before Landing day (CRUISE), then value will be less than or equal to “0”. SURFACE is defined as 0 onwards.	integer, -n to n, N/A, NULL, UNK	integer, -n to n, N/A, NULL, UNK	integer, -n to n, N/A, NULL, UNK
INSTITUTION_NAME		The INSTITUTION_NAME element identifies a university, research center, or NASA center.	MALIN SPACE SCIENCE SYSTEMS, N/A, NULL, UNK	MALIN SPACE SCIENCE SYSTEMS, N/A, NULL, UNK	MALIN SPACE SCIENCE SYSTEMS, N/A, NULL, UNK
PRODUCT_CREATION_TIME		Specifies the UTC system format (ISO 8601) for the time when the archive product was created/processed.	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK
PRODUCT_VERSION_ID		Specifies the version of an individual product within a data set. PRODUCT_VERSION_ID is intended for use within AMMOS to identify separate iterations of a given product, which will also have a unique FILE_NAME. For MSL, this is a Version field that begins with “V” followed by a decimal number denoting the product’s iteration (i.e., version). Example: “V2.0”	V<float>, N/A, NULL, UNK	V<float>, N/A, NULL, UNK	V<float>, N/A, NULL, UNK
PRODUCT_ID		Specifies a permanent, unique identifier assigned to a data product by its producer.	string, see section 3.4 of this document, N/A, NULL, UNK	string, see section 3.4 of this document, N/A, NULL, UNK	string, see section 3.4 of this document, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
SOURCE_PRODUCT_ID		Identifies a product used as input to create a new product. The n/a source_product_id may be based on a file name. Pre-launch data format is a string. Cruise and surface data format is sclk = spacecraft clock time subsclk = spacecraft sub-clock time v = version	McamLThumbnail_sclk-subsclk-v, McamLImage_sclk-subsclk-v, McamLVideo_sclk-subsclk-v, McamLZstack_sclk-subsclk-v, McamLRangemap_sclk-subsclk-v, McamLRecoveredThumbnail_sclk-subsclk-v, McamLRecoveredProduct_sclk-subsclk-v,McamLUtilTest_sclk-subsclk-v, McamRThumbnail_sclk-subsclk-v, McamRImage_sclk-subsclk-v, McamRVideo_sclk-subsclk-v, McamRZstack_sclk-subsclk-v, McamRRangemap_sclk-subsclk-v, McamRRecoveredThumbnail_sclk-subsclk-v, McamRRecoveredProduct_sclk-subsclk-v, McamRUtilTest_sclk-subsclk-v, string, N/A, NULL, UNK	MhliThumbnail_sclk-subsclk-v, MhliImage_sclk-subsclk-v, MhliVideo_sclk-subsclk-v, MhliZstack_sclk-subsclk-v, MhliRangemap_sclk-subsclk-v, MhliRecoveredThumbnail_sclk-subsclk-v, MhliRecoveredProduct_sclk-subsclk-v, MhliUtilTest_sclk-subsclk-v, string, N/A, NULL, UNK	MrdiThumbnail_sclk-subsclk-v, MrdiImage_sclk-subsclk-v, MrdiVideo_sclk-subsclk-v, MrdiRecoveredThumbnail_sclk-subsclk-v, MrdiRecoveredProduct_sclk-subsclk-v, MrdiUtilTest_sclk-subsclk-v, string, N/A, NULL, UNK
MSL:INPUT_PRODUCT_ID		Specifies the product(s) directly used as input to create this product. It may contain either the PRODUCT_ID or the filename of the input products.	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK
MSL:CALIBRATION_FILE_NAME		Specifies the name of the calibration or test file assigned during testing and may also indicate the calibration method.	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
RELEASE_ID		Specifies the unique identifier associated with the release to the public of all or part of a data set. The release number is associated with the data set, not the mission. When a data set is released incrementally, such as every three months during a mission, the RELEASE_ID is updated each time part of the data set is released. The first release of a data set in the mission should have a value of "0001".	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK
MSL:REQUEST_ID		Specifies the ground-assigned Request ID associated with the data product.	integer, N/A. NULL, UNK	integer, N/A. NULL, UNK	integer, N/A. NULL, UNK
MSL:CAMERA_PRODUCT_ID		Specifies a numeric identifier generated by the instrument during image acquisition. This is the CDPID field in IMAGE_ID as defined in Table 3.4-1.	integer value, 1 to 60416, N/A, NULL, UNK	integer value, 1 to 60416, N/A, NULL, UNK	integer value, 1 to 60416, N/A, NULL, UNK
MSL:CAMERA_PRODUCT_ID_ COUNT		Specifies the number of times a specific MSL:CAMERA_PRODUCT_ID has been used. This is the CDPID COUNTER in the IMAGE_ID as defined in Table 3.4-1. Note: for pre-landing data, this value = 0.	integer value starting at 0, N/A, NULL, UNK	integer value starting at 0, N/A, NULL, UNK	integer value starting at 0, N/A, NULL, UNK
ROVER_MOTION_COUNTER_ NAME		Specifies an array of values that provides the formal names identifying each integer in ROVER_MOTION_COUNTER.	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
ROVER_MOTION_COUNTER		Specifies a set of integers which describe a (potentially) unique location (position/orientation) for a rover. Each time something happens that moves, or could potentially move, the rover, a new motion counter value is created. This includes intentional motion due to drive commands, as well as potential motion due to other articulating devices, such as arms or antennae. For MSL, the motion counter consists of ten values. In order, they are “Site”, “Drive”, “Pose”, “Arm”, “CHIMRA”, “Drill”, “RSM”, “HGA”, “DRT”, and “IC".	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK
SEQUENCE_ID		Specifies the spacecraft sequence associated with the given product. Format is cameraxxxx, where camera = mcam, mhli, or mrdi, and xxxxx is a numeric string .	aut_04096, mcamxxxxx, N/A, NULL, UNK	aut_04096, mhlixxxxx, N/A, NULL, UNK	aut_04096, mrdixxxxx, N/A, NULL, UNK
SEQUENCE_VERSION_ID		Specifies the version identifier for a particular observation sequence used during planning or data processing.	0 to 4095, N/A, NULL, UNK	0 to 4095, N/A, NULL, UNK	0 to 4095, N/A, NULL, UNK
SOLAR_LONGITUDE		Specifies the value L , the angle between the body_Sun line at the time of interest and the body_Sun line at the vernal equinox. This provides a measure of season on a target body, with values of 0 to 90 degrees representing northern spring, 90 to 180 degrees representing northern summer, 180 to 270 degrees representing northern autumn and 270 to 360 degrees representing northern winter.	float, 000.000 to 360.000, N/A, NULL, UNK	float, 000.000 to 360.000, N/A, NULL, UNK	float, 000.000 to 360.000, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
SPACECRAFT_CLOCK_CNT_PARTITION		Specifies the clock partition active for the SPACECRAFT_CLOCK_START_COUNT and SPACECRAFT_CLOCK_STOP_COUNT elements.	1, N/A, NULL, UNK	1, N/A, NULL, UNK	1, N/A, NULL, UNK
SPACECRAFT_CLOCK_START_COUNT		Specifies the value of the spacecraft clock at the time imaging begins. It may precede MSL:INSTRUMENT_CLOCK_START_COUNT if the command send time is known. If known, then it will be the time autofocus and/or autoexposure begin. Format is “sssssssss.mmmm”, stored as a floating point number where, “sssssssss” = seconds converted from clock’s coarse counter “mmmm”= milliseconds converted from clock’s fine counter.	sssssssss.mmmm, N/A, NULL, UNK	sssssssss.mmmm, N/A, NULL, UNK	sssssssss.mmmm, N/A, NULL, UNK
SPACECRAFT_CLOCK_STOP_COUNT		Specifies the value of the spacecraft clock at the end of imaging (usually IMAGE_TIME + exposure). Format is “sssssssss.mmmm”, stored as a floating point number where, “sssssssss” = seconds converted from clock’s coarse counter “mmmm”= milliseconds converted from clock’s fine counter.	sssssssss.mmmm, N/A, NULL, UNK	sssssssss.mmmm, N/A, NULL, UNK	sssssssss.mmmm, N/A, NULL, UNK
IMAGE_TIME		Specifies the start time of image acquisition. IMAGE_TIME is the value returned from SPICE suburoutines based on MSL:INSTRUMENT_CLOCK_START_COUNT in UTC system format (ISO 8601).	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
START_TIME		Specifies the date and time of SPACECRAFT_CLOCK_START_COUNT in UTC system format (ISO 8601). For MSL, the time period of interest is returned from SPICE suburoutines and based on the beginning of data acquisition.	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK
STOP_TIME		Specifies the date and time of SPACECRAFT_CLOCK_STOP_COUNT in UTC system format (ISO 8601).	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>[.<fff>], N/A, NULL, UNK
TARGET_NAME		Specifies a target. The target may be a planet, satellite, ring, region, feature, asteroid or comet.	CALIBRATION, CHECKOUT, COMET, DARK, DEIMOS, EARTH, JUPITER, MARS, NON SCIENCE, PHOBOS, SKY, STAR, N/A, NULL, UNK	CALIBRATION, CHECKOUT, COMET, DARK, DEIMOS, EARTH, JUPITER, MARS, NON SCIENCE, PHOBOS, SKY, STAR, N/A, NULL, UNK	CALIBRATION, CHECKOUT, COMET, DARK, DEIMOS, EARTH, JUPITER, MARS, NON SCIENCE, PHOBOS, SKY, STAR, N/A, NULL, UNK
TARGET_TYPE		Specifies the type of a named target.	CALIBRATION, COMET, DUST, PLANET, REFERENCE, SATELLITE, STAR, SUN, N/A, NULL, UNK	CALIBRATION, COMET, DUST, PLANET, REFERENCE, SATELLITE, STAR, SUN, N/A, NULL, UNK	CALIBRATION, COMET, DUST, PLANET, REFERENCE, SATELLITE, STAR, SUN, N/A, NULL, UNK
APPLICATION_PROCESS_ID		Specifies the name associated with the source or process which created the data.This includes Image, Rangemap, Recovered Product, Recovered Thumbnail, Thumbnail, Video, and Zstack	McamL = 406, 407, 408, 409, 411, 412, 413, 414 McamR = 419, 420, 421, 422, 424, 425, 426, 427, N/A, NULL, UNK	441, 443, 444, 445, 447, 448, 449, 450, N/A, NULL, UNK	462, 464, 465, 466, 468, 469, 470, 471, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
APPLICATION_PROCESS_NAME		Specifies the name associated with the source or process which created the data. For MSL, only APID Names uniquely identify Data Product types across all FSW versions.	McamLThumbnail, McamLImage, McamLVideo, McamLZstack, McamLRangemap, McamLRecoveredThumbnail, McamLRecoveredProduct, McamLUtilTest, McamRThumbnail, McamRImage, McamRVideo, McamRZstack, McamRRangemap, McamRRecoveredThumbnail, McamRRecoveredProduct, McamRUtilTest N/A, NULL, UNK	MhliThumbnail, MhliImage, MhliVideo, MhliZstack, MhliRangemap, MhliRecoveredThumbnail, MhliRecoveredProduct, MhliUtilTest, N/A, NULL, UNK	MrdiThumbnail, MrdiImage, MrdiVideo, MrdiRecoveredThumbnail, MrdiRecoveredProduct, MrdiUtilTest, N/A, NULL, UNK
EARTH_RECEIVED_START_TIME		Specifies the beginning time at which telemetry was received during a time period of interest. This should be represented in UTC system format (ISO 8601).	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>, N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss> , N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>, N/A, NULL, UNK
SPICE_FILE_NAME		Specifies the names of the SPICE files used in processing the data.	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK
TELEMETRY_PROVIDER_ID		Specifies the provider and version of the telemetry data used in the generation of this data.	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK
MSL:TELEMETRY_SOURCE_HOST_NAME		Specifies the name of the host venue that provides the telemetry source used in creation of this data set.	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
TELEMETRY_SOURCE_NAME		Specifies the name of the telemetry source used in creation of this data set. Format is sclk = spacecraft clock time subsclk = spacecraft sub-clock time v = version	McamLThumbnail_sclk-subsclk-v, McamLImage_sclk-subsclk-v, McamLVideo_sclk-subsclk-v, McamLZstack_sclk-subsclk-v, McamLRangemap_sclk-subsclk-v, McamLRecoveredThumbnail_sclk-subsclk-v, McamLRecoveredProduct_sclk-subsclk-v, McamLUtilTest_sclk-subsclk-v, McamRThumbnail_sclk-subsclk-v, McamRImage_sclk-subsclk-v, McamRVideo_sclk-subsclk-v, McamRZstack_sclk-subsclk-v, McamRRangemap_sclk-subsclk-v, McamRRecoveredThumbnail_sclk-subsclk-v, McamRRecoveredProduct_sclk-subsclk-v, McamRUtilTest_sclk-subsclk-v, N/A, NULL, UNK	MhliThumbnail_sclk-subsclk-v, MhliImage_sclk-subsclk-v, MhliVideo_sclk-subsclk-v, MhliZstack_sclk-subsclk-v, MhliRangemap_sclk-subsclk-v, MhliRecoveredThumbnail_sclk-subsclk-v, MhliRecoveredProduct_sclk-subsclk-v, MhliUtilTest_sclk-subsclk-v, N/A, NULL, UNK	MrdiThumbnail_sclk-subsclk-v, MrdiImage_sclk-subsclk-v, MrdiVideo_sclk-subsclk-v, MrdiRecoveredThumbnail_sclk-subsclk-v, MrdiRecoveredProduct_sclk-subsclk-v, MrdiUtilTest_sclk-subsclk-v, N/A, NULL, UNK
TELEMETRY_SOURCE_TYPE		Classifies of the source of the telemetry used in creating this data set.	DATA PRODUCT, N/A, NULL, UNK	DATA PRODUCT, N/A, NULL, UNK	DATA PRODUCT, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MSL:COMMUNICATION_SESSION_ID		Active Communication Session ID at time of MPDU (Metadata Protocol Data Unit) creation. For context, the MPDU is the first PDU (Protocol Data Unit) produced for a data product, and contains general and MSL specific “metadata”. It is wholly contained in a single packet.	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK
MSL:PRODUCT_COMPLETION_STATUS		Specifies the completion status of a product, specifying for example, if all portions have been downlinked and received correctly, if it is a partial product, or if it contains transmission errors. The specific valid values may be mission-dependent. For MSL, the valid values indicate whether it was a complete or partial product as it came out of MPCS, and whether the checksum passed, failed, or was missing.	“PARTIAL”, “PARTIAL_CHECKSUM_FAIL”, “COMPLETE_CHECKSUM_PASS”, “COMPLETE_NO_CHECKSUM”, “COMPLETE_CHECKSUM_FAIL”, N/A, NULL, UNK	“PARTIAL”, “PARTIAL_CHECKSUM_FAIL”, “COMPLETE_CHECKSUM_PASS”, “COMPLETE_NO_CHECKSUM”, “COMPLETE_CHECKSUM_FAIL”, N/A, NULL, UNK	“PARTIAL”, “PARTIAL_CHECKSUM_FAIL”, “COMPLETE_CHECKSUM_PASS”, “COMPLETE_NO_CHECKSUM”, “COMPLETE_CHECKSUM_FAIL”, N/A, NULL, UNK
MSL:SEQUENCE_EXECUTION_COUNT		Specifies how many times this sequence has executed since the last reset of the flight computer. For MSL, this means RCE (Rover Compute Element) start-up.	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK
MSL:TELEMETRY_SOURCE_START_TIME		Specifies the creation time of the source product from which this product was derived in UTC system format (ISO 8601). It is the same as TELEMETRY_SOURCE_SCLK_START converted to Spacecraft Event Time (SCET).	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>, N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>, N/A, NULL, UNK	<YYYY>-<MM>-<DD>T<hh>:<mm>:<ss>, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MSL:TELEMETRY_SOURCE_SCLK_START		Specifies the value of the spacecraft clock (in seconds) at the creation time of the source product from which this product was derived. For MSL, it refers to the creation time (DVT) of the onboard DPO and comes from the secondary packet header. Note that this is the SCLK used by Data Management operationally to identify data products.	1/sssssssss-mmmmm, N/A, NULL, UNK	1/sssssssss-mmmmm, N/A, NULL, UNK	1/sssssssss-mmmmm, N/A, NULL, UNK
SOFTWARE_NAME	PDS_HISTORY_PARMS	Specifies the name of data processing software such as a program or a program library.	MMMEDRGEN, MMMRDRGEN, other, N/A, NULL, UNK	MMMEDRGEN, MMMRDRGEN, other, N/A, NULL, UNK	MMMEDRGEN, MMMRDRGEN, other, N/A, NULL, UNK
SOFTWARE_VERSION_ID	PDS_HISTORY_PARMS	Specifies the version (development level) of a program or a program library.	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK
PROCESSING_HISTORY_TEXT	PDS_HISTORY_PARMS	Specifies an entry for each processing step and program used in generating a particular data file.	EDRs: "CODMAC LEVEL 1 to LEVEL 2 CONVERSION VIA MSSS MMMEDRGEN" RDRs: "CODMAC LEVEL 1 to LEVEL 4 CONVERSION VIA MSSS MMMRDRGEN", N/A, NULL, UNK	EDRs: "CODMAC LEVEL 1 to LEVEL 2 CONVERSION VIA MSSS MMMEDRGEN" RDRs: "CODMAC LEVEL 1 to LEVEL 4 CONVERSION VIA MSSS MMMRDRGEN", N/A, NULL, UNK	EDRs: "CODMAC LEVEL 1 to LEVEL 2 CONVERSION VIA MSSS MMMEDRGEN" RDRs: "CODMAC LEVEL 1 to LEVEL 4 CONVERSION VIA MSSS MMMRDRGEN", N/A, NULL, UNK
^MODEL_DESC	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies a textual description of a model (or a pointer to a file containing the description). This is not intended to be a brief summary, but rather a detailed description of the model; at minimum, it should include a reference to a detailed description of the model in published literature.	GEOMETRIC_CM.TXT, N/A, NULL, UNK	GEOMETRIC_CM.TXT, N/A, NULL, UNK	GEOMETRIC_CM.TXT, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
FILTER_NAME	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies the commonly-used name of the instrument filter through which an image or measurement was acquired or which is associated with a given instrument mode.	MASTCAM_L0_CLEAR, MASTCAM_L1_525NM, MASTCAM_L2_440NM, MASTCAM_L3_750NM, MASTCAM_L4_675NM, MASTCAM_L5_865NM, MASTCAM_L6_1035NM, MASTCAM_L7_880NM_ND5, MASTCAM_R0_CLEAR, MASTCAM_R1_525NM, MASTCAM_R2_440NM, MASTCAM_R3_800NM, MASTCAM_R4_905NM, MASTCAM_R5_935NM, MASTCAM_R6_1035NM, MASTCAM_R7_440NM_ND5, N/A, NULL, UNK	N/A, NULL, UNK	N/A, NULL, UNK
MODEL_TYPE	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies an identifier for the type or kind of model. The value should be one of a well defined set, providing an application program with sufficient information to know how to handle the rest of the parameters within the model. (CAHVORE is the only one that uses model component vectors 1-9.)	NONE, CAHV, CAHVOR, CAHVORE, N/A, NULL, UNK	NONE, CAHV, CAHVOR, CAHVORE, N/A, NULL, UNK	NONE, CAHV, CAHVOR, CAHVORE, N/A, NULL, UNK
MODEL_COMPONENT_ID	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies a sequence of identifiers (usually 1 character), where each identifier corresponds to a model component vector. It is used in conjunction with the MODEL_COMPONENT_n elements, where “n” is a number. The first id in the sequence corresponds to MODEL_COMPONENT_1, the second corresponds to MODEL_COMPONENT_2, etc.	NONE, ("C","A","H","V"), ("C","A","H","V","O","R"), ("C","A","H","V","O","R","E","T","P"), N/A, NULL, UNK	NONE, ("C","A","H","V"), ("C","A","H","V","O","R"), ("C","A","H","V","O","R","E","T","P"), N/A, NULL, UNK	NONE, ("C","A","H","V"), ("C","A","H","V","O","R"), ("C","A","H","V","O","R","E","T","P"), N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MODEL_COMPONENT_NAME	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies a sequence of names, where each name identifies its corresponding model component vector.	NONE, (“CENTER”, “AXIS”, “HORIZONTAL”, “VERTICAL”), (“CENTER”, “AXIS”, “HORIZONTAL”, “VERTICAL”, “OPTICAL”, “RADIAL”), (“CENTER”, “AXIS”, “HORIZONTAL”, “VERTICAL”, “OPTICAL”, “RADIAL”, “ENTRANCE”, “MTYPE”, “MPARM”), N/A, NULL, UNK	NONE, (“CENTER”, “AXIS”, “HORIZONTAL”, “VERTICAL”), (“CENTER”, “AXIS”, “HORIZONTAL”, “VERTICAL”, “OPTICAL”, “RADIAL”), (“CENTER”, “AXIS”, “HORIZONTAL”, “VERTICAL”, “OPTICAL”, “RADIAL”, “ENTRANCE”, “MTYPE”, “MPARM”), N/A, NULL, UNK	NONE, (“CENTER”, “AXIS”, “HORIZONTAL”, “VERTICAL”), (“CENTER”, “AXIS”, “HORIZONTAL”, “VERTICAL”, “OPTICAL”, “RADIAL”), (“CENTER”, “AXIS”, “HORIZONTAL”, “VERTICAL”, “OPTICAL”, “RADIAL”, “ENTRANCE”, “MTYPE”, “MPARM”), N/A, NULL, UNK
MODEL_COMPONENT_1	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies a set of values representing the first component of a model. The significance (or meaning) of this array of values is indicated by the first value of the MODEL_COMPONENT_ID and/or MODEL_COMPONENT_NAME elements. The interpretation of the values themselves depends on the model but they commonly represent a vector, a set of polynomial coefficients, or a simple numeric parameter. For example, for a geometric camera model with a value of “CAHV” for MODEL_TYPE, the first value of the MODEL_COMPONENT_NAME data element is CENTER, meaning that the MODEL_COMPONENT_1 is a focal center vector. The three items in this vector provide X, Y, and Z coordinates of the focal point of the camera.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK
MODEL_COMPONENT_2	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies the value of the component of the MODEL_COMPONENT_ID for the second element.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MODEL_COMPONENT_3	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies the value of the component of the MODEL_COMPONENT_ID for the third element.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK
MODEL_COMPONENT_4	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies the value of the component of the MODEL_COMPONENT_ID for the fourth element.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK
MODEL_COMPONENT_5	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies the value of the component of the MODEL_COMPONENT_ID for the fifth element.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK
MODEL_COMPONENT_6	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies the value of the component of the MODEL_COMPONENT_ID for the sixth element.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK
REFERENCE_COORD_SYSTEM_NAME	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies the full name of the reference coordinate system (CS) for the group in which the keyword occurs. All vectors and positions relating to 3-D space within the enclosing group are expressed using this reference coordinate system. For MSL, EDRs use a standard, predefined frame name for each occurrence. However, RDRs can use any value available in COORDINATE_SYSTEM_NAME. Despite that, only a few frame names are commonly used. “SITE_FRAME” is used for most SITE, ROVER, and LOCAL_LEVEL CS definitions, as well as for XYZ data and many mosaics. “ROVER_NAV_FRAME” is used for most other CS definitions, surface normals, camera models, and some mosaics. “LOCAL_LEVEL_FRAME” is used for some mosaics.	SITE_FRAME, ROVER_NAV_FRAME, N/A, NULL, UNK	SITE_FRAME, ROVER_NAV_FRAME, N/A, NULL, UNK	SITE_FRAME, ROVER_NAV_FRAME, N/A, NULL, UNK
COORDINATE_SYSTEM_INDEX_NAME	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies an array of the formal names identifying each integer specified in COORDINATE_SYSTEM_INDEX.	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL,	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL,	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL,

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
			UNK	UNK	UNK
REFERENCE_COORD_SYSTEM_INDEX	GEOMETRIC_CAMERA_MODEL_PARMS	Specifies which instance of the coordinate system named by REFERENCE_COORD_SYSTEM_NAME is the reference coordinate system for the group in which the keyword occurs. This index is a set of integers which serve to identify coordinate system instances in a mission-specific manner. For MSL, these indices are based on the ROVER_MOTION_COUNTER and are in the same order as specified by ROVER_MOTION_COUNTER_NAME, “Site”, “Drive”, “Pose”, “Arm”, “CHIMRA”, “Drill”, “RSM”, “HGA”, “DRT”, and “IC”.	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK
MSL:SOLUTION_ID	ROVER_COORDINATE_SYSTEM_PARMS	Specifies the unique identifier for the solution set to which the values in the group belong. For MSL, when in a COORDINATE_SYSTEM group, the SOLUTION_ID specifies the ID of the coordinate system being defined in that group.	TELEMETRY, N/A, NULL, UNK	TELEMETRY, N/A, NULL, UNK	TELEMETRY, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
COORDINATE_SYSTEM_NAME	ROVER_COORDINATE_SYSTEM_PARMS	Specifies the full name of the coordinate system to which the state vectors are referenced. When in a COORDINATE_SYSTEM group, this keyword provides the full name of the coordinate system being defined by the group.	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK
COORDINATE_SYSTEM_INDEX_NAME	ROVER_COORDINATE_SYSTEM_PARMS	Specifies an array of the formal names identifying each integer specified in COORDINATE_SYSTEM_INDEX.	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK
COORDINATE_SYSTEM_INDEX	ROVER_COORDINATE_SYSTEM_PARMS	Specifies an integer array used to record and track the movement of a rover or lander during surface operations where “Site”, “Drive”, “Pose”, “Arm”, “CHIMRA”, “Drill”, “RSM”, “HGA”, “DRT”, and “IC”.	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK
ORIGIN_OFFSET_VECTOR	ROVER_COORDINATE_SYSTEM_PARMS	Specifies the offset from the reference coordinate system's origin to the origin of the coordinate system being defined by the enclosing COORDINATE_SYSTEM_STATE group. In other words, it is the location of the current system's origin as measured in the reference system.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
ORIGIN_ROTATION_QUATERNION	ROVER_COORDINATE_SYSTEM_PARMS	Specifies an array of four values that specifies the rotation of the coordinate system being defined by the enclosing COORDINATE_SYSTEM_STATE group, relative to the reference system. Note that quaternions have different component order conventions between flight and ground software. They are received in the order "(v1, v2, v3, s)". However, the ground order convention is "(s, v1, v2, v3)", and all values are converted to the ground order before being stored in the label.	float array [4], N/A, NULL, UNK	float array [4], N/A, NULL, UNK	float array [4], N/A, NULL, UNK
POSITIVE_AZIMUTH_DIRECTION	ROVER_COORDINATE_SYSTEM_PARMS	Specifies the direction in which azimuth is measured in positive degrees for an observer on the surface of a body. The azimuth is measured with respect to the elevational reference plane. A value of CLOCKWISE indicates that Azimuth is measured positively Clockwise, and COUNTERCLOCKWISE indicates that Azimuth increases positively Counter-clockwise. For the MSL operational coordinate frames, which follow the Mars Pathfinder convention, increasing azimuth moves in a clockwise ("CLOCKWISE") direction as viewed from above.	CLOCKWISE, N/A, NULL, UNK	CLOCKWISE, N/A, NULL, UNK	CLOCKWISE, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
POSITIVE_ELEVATION_DIRECTION	ROVER_COORDINATE_SYSTEM_PARMS	Specifies the direction in which elevation is measured in positive degrees for an observer on the surface of a body. The elevation is measured with respect to the azimuthal reference plane. A value of UP or ZENITH indicates that elevation is measured positively upwards, i.e., the zenith point would be at +90 degrees and the nadir point at -90 degrees. DOWN or NADIR indicates that the elevation is measured positively downwards; the zenith point would be at -90 degrees and the nadir point at +90 degrees.	UP, N/A, NULL, UNK	UP, N/A, NULL, UNK	UP, N/A, NULL, UNK
QUATERNION_MEASUREMENT_METHOD	ROVER_COORDINATE_SYSTEM_PARMS	Specifies the quality of the rover orientation estimate.	UNKNOWN, TILT_ONLY, FINE, N/A, NULL, UNK	UNKNOWN, TILT_ONLY, FINE, N/A, NULL, UNK	UNKNOWN, TILT_ONLY, FINE, N/A, NULL, UNK
REFERENCE_COORD_SYSTEM_NAME	ROVER_COORDINATE_SYSTEM_PARMS	Specifies which instance of the coordinate system named by REFERENCE_COORD_SYSTEM_NAME is the reference coordinate system for the group in which the keyword occurs. This index is a set of integers which serve to identify coordinate system instances in a mission-specific manner. For MSL, these indices are based on the ROVER_MOTION_COUNTER and are in the same order as specified by ROVER_MOTION_COUNTER_NAME.	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK
MSL:SOLUTION_ID	RSM_COORDINATE_SYSTEM_PARMS	Specifies the unique identifier for the solution set to which the values in the group belong. For MSL, when in a COORDINATE_SYSTEM group, the SOLUTION_ID specifies the ID of the coordinate system being defined in that group.	TELEMETRY, N/A, NULL, UNK	TELEMETRY, N/A, NULL, UNK	TELEMETRY, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
COORDINATE_SYSTEM_NAME	RSM_COORDINATE_SYSTEM_PARMS	Specifies the full name of the coordinate system to which the state vectors are referenced. When in a COORDINATE_SYSTEM group, this keyword provides the full name of the coordinate system being defined by the group.	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK
COORDINATE_SYSTEM_INDEX_NAME	RSM_COORDINATE_SYSTEM_PARMS	Specifies an array of the formal names identifying each integer specified in COORDINATE_SYSTEM_INDEX.	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK
COORDINATE_SYSTEM_INDEX	RSM_COORDINATE_SYSTEM_PARMS	Specifies an integer array used to record and track the movement of a rover or lander during surface operations where “Site”, “Drive”, “Pose”, “Arm”, “CHIMRA”, “Drill”, “RSM”, “HGA", “DRT”, and “IC”.	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK
ORIGIN_OFFSET_VECTOR	RSM_COORDINATE_SYSTEM_PARMS	Specifies the offset from the reference coordinate system's origin to the origin of the coordinate system being defined by the enclosing COORDINATE_SYSTEM_STATE group. In other words, it is the location of the current system's origin as measured in the reference system.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
ORIGIN_ROTATION_QUATERNION	RSM_COORDINATE_SYSTEM_PARMS	Specifies an array of four values that specifies the rotation of the coordinate system being defined by the enclosing COORDINATE_SYSTEM_STATE group, relative to the reference system. Note that quaternions have different component order conventions between flight and ground software. They are received in the order "(v1, v2, v3, s)". However, the ground order convention is "(s, v1, v2, v3)", and all values are converted to the ground order before being stored in the label.	float array [4], N/A, NULL, UNK	float array [4], N/A, NULL, UNK	float array [4], N/A, NULL, UNK
POSITIVE_AZIMUTH_DIRECTION	RSM_COORDINATE_SYSTEM_PARMS	Specifies the direction in which azimuth is measured in positive degrees for an observer on the surface of a body. The azimuth is measured with respect to the elevational reference plane. A value of CLOCKWISE indicates that Azimuth is measured positively Clockwise, and COUNTERCLOCKWISE indicates that Azimuth increases positively Counter-clockwise. For the MSL operational coordinate frames, which follow the Mars Pathfinder convention, increasing azimuth moves in a clockwise ("CLOCKWISE") direction as viewed from above.	CLOCKWISE, N/A, NULL, UNK	CLOCKWISE, N/A, NULL, UNK	CLOCKWISE, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
POSITIVE_ELEVATION_DIRECTION	RSM_COORDINATE_SYSTEM_PARMS	Specifies the direction in which elevation is measured in positive degrees for an observer on the surface of a body. The elevation is measured with respect to the azimuthal reference plane. A value of UP or ZENITH indicates that elevation is measured positively upwards, i.e., the zenith point would be at +90 degrees and the nadir point at -90 degrees. DOWN or NADIR indicates that the elevation is measured positively downwards; the zenith point would be at -90 degrees and the nadir point at +90 degrees.	UP, N/A, NULL, UNK	UP, N/A, NULL, UNK	UP, N/A, NULL, UNK
REFERENCE_COORD_SYSTEM_NAME	RSM_COORDINATE_SYSTEM_PARMS	Specifies which instance of the coordinate system named by REFERENCE_COORD_SYSTEM_NAME is the reference coordinate system for the group in which the keyword occurs. This index is a set of integers which serve to identify coordinate system instances in a mission-specific manner. For MSL, these indices are based on the ROVER_MOTION_COUNTER and are in the same order as specified by ROVER_MOTION_COUNTER_NAME.	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK
MSL:SOLUTION_ID	ARM_COORDINATE_SYSTEM_PARMS	Specifies the unique identifier for the solution set to which the values in the group belong. For MSL, when in a COORDINATE_SYSTEM group, the SOLUTION_ID specifies the ID of the coordinate system being defined in that group.	TELEMETRY, N/A, NULL, UNK	TELEMETRY, N/A, NULL, UNK	TELEMETRY, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
COORDINATE_SYSTEM_NAME	ARM_COORDINATE_SYSTEM_PARMS	Specifies the full name of the coordinate system to which the state vectors are referenced. When in a COORDINATE_SYSTEM group, this keyword provides the full name of the coordinate system being defined by the group.	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK
COORDINATE_SYSTEM_INDEX_NAME	ARM_COORDINATE_SYSTEM_PARMS	Specifies an array of the formal names identifying each integer specified in COORDINATE_SYSTEM_INDEX.	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK	("SITE", “DRIVE”, “POSE”, “ARM”, “CHIMRA”, “DRILL”, “RSM”, “HGA”, “DRT”, “IC”), N/A, NULL, UNK
COORDINATE_SYSTEM_INDEX	ARM_COORDINATE_SYSTEM_PARMS	Specifies an integer array used to record and track the movement of a rover or lander during surface operations where “Site", “Drive”, “Pose”, “Arm”, “CHIMRA”, “Drill”, “RSM”, “HGA”, “DRT”, and “IC”.	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK	integer array [10], N/A, NULL, UNK
ORIGIN_OFFSET_VECTOR	ARM_COORDINATE_SYSTEM_PARMS	Specifies the offset from the reference coordinate system's origin to the origin of the coordinate system being defined by the enclosing COORDINATE_SYSTEM_STATE group. In other words, it is the location of the current system's origin as measured in the reference system.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
ORIGIN_ROTATION_QUATERNION	ARM_COORDINATE_SYSTEM_PARMS	Specifies an array of four values that specifies the rotation of the coordinate system being defined by the enclosing COORDINATE_SYSTEM_STATE group, relative to the reference system. Note that quaternions have different component order conventions between flight and ground software. They are received in the order "(v1, v2, v3, s)". However, the ground order convention is "(s, v1, v2, v3)", and all values are converted to the ground order before being stored in the label.	float array [4], N/A, NULL, UNK	float array [4], N/A, NULL, UNK	float array [4], N/A, NULL, UNK
POSITIVE_AZIMUTH_DIRECTION	ARM_COORDINATE_SYSTEM_PARMS	Specifies the direction in which azimuth is measured in positive degrees for an observer on the surface of a body. The azimuth is measured with respect to the elevational reference plane. A value of CLOCKWISE indicates that Azimuth is measured positively Clockwise, and COUNTERCLOCKWISE indicates that Azimuth increases positively Counter-clockwise. For the MSL operational coordinate frames, which follow the Mars Pathfinder convention, increasing azimuth moves in a clockwise ("CLOCKWISE") direction as viewed from above.	CLOCKWISE, N/A, NULL, UNK	CLOCKWISE, N/A, NULL, UNK	CLOCKWISE, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
POSITIVE_ELEVATION_DIRECTION	ARM_COORDINATE_SYSTEM_PARMS	Specifies the direction in which elevation is measured in positive degrees for an observer on the surface of a body. The elevation is measured with respect to the azimuthal reference plane. A value of UP or ZENITH indicates that elevation is measured positively upwards, i.e., the zenith point would be at +90 degrees and the nadir point at -90 degrees. DOWN or NADIR indicates that the elevation is measured positively downwards; the zenith point would be at -90 degrees and the nadir point at +90 degrees.	UP, N/A, NULL, UNK	UP, N/A, NULL, UNK	UP, N/A, NULL, UNK
REFERENCE_COORD_SYSTEM_NAME	ARM_COORDINATE_SYSTEM_PARMS	Specifies which instance of the coordinate system named by REFERENCE_COORD_SYSTEM_NAME is the reference coordinate system for the group in which the keyword occurs. This index is a set of integers which serve to identify coordinate system instances in a mission-specific manner. For MSL, these indices are based on the ROVER_MOTION_COUNTER and are in the same order as specified by ROVER_MOTION_COUNTER_NAME.	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK
ARTICULATION_DEVICE_ID	RSM_ARTICULATION_STATE_PARMS	Specifies the unique abbreviated identification of an articulation device. An articulation device is anything that can move independently of the spacecraft to which it is attached, (e.g., mast heads, wheel bogies, arms, etc.).	RSM, N/A, NULL, UNK	RSM, N/A, NULL, UNK	RSM, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
ARTICULATION_DEVICE_NAME	RSM_ARTICULATION_STATE_PARMS	Specifies the common name of an articulation device. An articulation device is anything that can move independently of the spacecraft to which it is attached, (e.g. mast heads, wheel bogies, arms, etc.)	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK
ARTICULATION_DEVICE_ANGLE_NAME	RSM_ARTICULATION_STATE_PARMS	Specifies the formal name which identifies each of the values used in ARTICULATION_DEVICE_ANGLE.	(AZIMUTH-MEASURED, ELEVATION-MEASURED, AZIMUTH-REQUESTED, ELEVATION-REQUESTED, AZIMUTH-INITIAL, ELEVATION-INITIAL, AZIMUTH-FINAL, ELEVATION-FINAL), N/A, NULL, UNK	(AZIMUTH-MEASURED, ELEVATION-MEASURED, AZIMUTH-REQUESTED, ELEVATION-REQUESTED, AZIMUTH-INITIAL, ELEVATION-INITIAL, AZIMUTH-FINAL, ELEVATION-FINAL), N/A, NULL, UNK	(AZIMUTH-MEASURED, ELEVATION-MEASURED, AZIMUTH-REQUESTED, ELEVATION-REQUESTED, AZIMUTH-INITIAL, ELEVATION-INITIAL, AZIMUTH-FINAL, ELEVATION-FINAL), N/A, NULL, UNK
ARTICULATION_DEVICE_ANGLE	RSM_ARTICULATION_STATE_PARMS	Specifies the value of an angle, in radians, between two parts or segments of an articulated device.	float array [8] <rad>, N/A, NULL, UNK	float array [8] <rad>, N/A, NULL, UNK	float array [8] <rad>, N/A, NULL, UNK
ARTICULATION_DEVICE_MODE	RSM_ARTICULATION_STATE_PARMS	Specifies the deployment state (i.e., physical configuration) of an articulation device at the time of data acquisition. This includes the mode of the last move of the Arm.	STOWED, DEPLOYED, N/A, NULL, UNK	STOWED, DEPLOYED, N/A, NULL, UNK	STOWED, DEPLOYED, N/A, NULL, UNK
ARTICULATION_DEVICE_ID	ARM_ARTICULATION_STATE_PARMS	Specifies the unique abbreviated identification of an articulation device. An articulation device is anything that can move independently of the spacecraft to which it is attached, (e.g., mast heads, wheel bogies, arms, etc.).	ARM, N/A, NULL, UNK	ARM, N/A, NULL, UNK	ARM, N/A, NULL, UNK
ARTICULATION_DEVICE_NAME	ARM_ARTICULATION_STATE_PARMS	Specifies the common name of an articulation device. An articulation device is anything that can move independently of the spacecraft to which it is attached, (e.g. mast heads, wheel bogies, arms, etc.)	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
ARTICULATION_DEVICE_ANGLE_NAME	ARM_ARTICULATION_STATE_PARMS	Specifies the formal name which identifies each of the values used in ARTICULATION_DEVICE_ANGLE.	(JOINT 1 AZIMUTH-ENCODER, JOINT 2 ELEVATION-ENCODER, JOINT 3 ELBOW-ENCODER, JOINT 4 WRIST-ENCODER, JOINT 5 TURRET-ENCODER, JOINT 1 AZIMUTH-RESOLVER, JOINT 2 ELEVATION-RESOLVER, JOINT 3 ELBOW-RESOLVER, JOINT 4 WRIST-RESOLVER, JOINT 5 TURRET-RESOLVER), N/A, NULL, UNK	(JOINT 1 AZIMUTH-ENCODER, JOINT 2 ELEVATION-ENCODER, JOINT 3 ELBOW-ENCODER, JOINT 4 WRIST-ENCODER, JOINT 5 TURRET-ENCODER, JOINT 1 AZIMUTH-RESOLVER, JOINT 2 ELEVATION-RESOLVER, JOINT 3 ELBOW-RESOLVER, JOINT 4 WRIST-RESOLVER, JOINT 5 TURRET-RESOLVER), N/A, NULL, UNK	(JOINT 1 AZIMUTH-ENCODER, JOINT 2 ELEVATION-ENCODER, JOINT 3 ELBOW-ENCODER, JOINT 4 WRIST-ENCODER, JOINT 5 TURRET-ENCODER, JOINT 1 AZIMUTH-RESOLVER, JOINT 2 ELEVATION-RESOLVER, JOINT 3 ELBOW-RESOLVER, JOINT 4 WRIST-RESOLVER, JOINT 5 TURRET-RESOLVER), N/A, NULL, UNK
ARTICULATION_DEVICE_ANGLE	ARM_ARTICULATION_STATE_PARMS	Specifies the value of an angle between two parts or segments of an articulated device.	float array [10] <rad>, N/A, NULL, UNK	float array [10] <rad>, N/A, NULL, UNK	float array [10] <rad>, N/A, NULL, UNK
ARTICULATION_DEVICE_MODE	ARM_ARTICULATION_STATE_PARMS	Specifies the deployment state (i.e., physical configuration) of an articulation device at the time of data acquisition. This includes the mode of the last move of the Arm.	FREE SPACE, GUARDED, RETRACTING, PRELOAD, N/A, NULL, UNK	FREE SPACE, GUARDED, RETRACTING, PRELOAD, N/A, NULL, UNK	FREE SPACE, GUARDED, RETRACTING, PRELOAD, N/A, NULL, UNK
ARTICULATION_DEVICE_TEMP_NAME	ARM_ARTICULATION_STATE_PARMS	Specifies the array of formal names identifying each of the values used in ARTICULATION_DEVICE_TEMP.	(AZIMUTH JOINT, ELEVATION JOINT, ELBOW JOINT, WRIST JOINT, TURRET JOINT), N/A, NULL, UNK	(AZIMUTH JOINT, ELEVATION JOINT, ELBOW JOINT, WRIST JOINT, TURRET JOINT), N/A, NULL, UNK	(AZIMUTH JOINT, ELEVATION JOINT, ELBOW JOINT, WRIST JOINT, TURRET JOINT), N/A, NULL, UNK
ARTICULATION_DEVICE_TEMP	ARM_ARTICULATION_STATE_PARMS	Specifies the temperature, in degrees Celsius, of an articulated device or some part of an articulated device.	float array [5] <degC>, N/A, NULL, UNK	float array [5] <degC>, N/A, NULL, UNK	float array [5] <degC>, N/A, NULL, UNK
CONTACT_SENSOR_STATE_NAME	ARM_ARTICULATION_STATE_PARMS	Specifies the possible value that can be contained in the CONTACT_SENSOR_STATE array.	(MAHLI SWITCH 1, MAHLI SWITCH 2, DRT SWITCH 1, DRT SWITCH 2, APXS DOOR SWITCH, APXS CONTACT SWITCH), N/A, NULL, UNK	(MAHLI SWITCH 1, MAHLI SWITCH 2, DRT SWITCH 1, DRT SWITCH 2, APXS DOOR SWITCH, APXS CONTACT SWITCH), N/A, NULL, UNK	(MAHLI SWITCH 1, MAHLI SWITCH 2, DRT SWITCH 1, DRT SWITCH 2, APXS DOOR SWITCH, APXS CONTACT SWITCH), N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
CONTACT_SENSOR_STATE	ARM_ARTICULATION_STATE_PARMS	Specifies an array of identifiers for the state of an instrument or an instrument host's contact sensors at a specified time.	CONTACT, NO CONTACT, CLOSED, N/A, NULL, UNK	CONTACT, NO CONTACT, CLOSED, N/A, NULL, UNK	CONTACT, NO CONTACT, CLOSED, N/A, NULL, UNK
ARTICULATION_DEV_VECTOR	ARM_ARTICULATION_STATE_PARMS	Specifies the direction and magnitude of an external force acting on the articulation device, in the rover's coordinate system, at the time the pose was computed. Valid values are between -1.0 to 1.0.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK
ARTICULATION_DEV_VECTOR_NAME	ARM_ARTICULATION_STATE_PARMS	Specifies the formal name of the vector type acting on the articulation device.	GRAVITY, N/A, NULL, UNK	GRAVITY, N/A, NULL, UNK	GRAVITY, N/A, NULL, UNK
ARTICULATION_DEV_INSTRUMENT_ID	ARM_ARTICULATION_STATE_PARMS	Specifies an abbreviated name or acronym which identifies the instrument mounted on the articulation device.	TURRET, DRILL, DRT, MAHLI, APXS, PORTIONER TUBE, SCOOP TIP, SCOOP TCP, N/A, NULL, UNK	TURRET, DRILL, DRT, MAHLI, APXS, PORTIONER TUBE, SCOOP TIP, SCOOP TCP, N/A, NULL, UNK	TURRET, DRILL, DRT, MAHLI, APXS, PORTIONER TUBE, SCOOP TIP, SCOOP TCP, N/A, NULL, UNK
ARTICULATION_DEVICE_ID	CHASSIS_ARTICULATION_STATE_PARMS	Specifies the unique abbreviated identification of an articulation device. An articulation device is anything that can move independently of the spacecraft to which it is attached, (e.g., mast heads, wheel bogies, arms, etc.).	CHASSIS, N/A, NULL, UNK	CHASSIS, N/A, NULL, UNK	CHASSIS, N/A, NULL, UNK
ARTICULATION_DEVICE_NAME	CHASSIS_ARTICULATION_STATE_PARMS	Specifies the common name of an articulation device. An articulation device is anything that can move independently of the spacecraft to which it is attached, (e.g. mast heads, wheel bogies, arms, etc.)	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK
ARTICULATION_DEVICE_ANGLE_NAME	CHASSIS_ARTICULATION_STATE_PARMS	Specifies the formal name which identifies each of the values used in ARTICULATION_DEVICE_ANGLE.	(LEFT FRONT WHEEL, RIGHT FRONT WHEEL, LEFT REAR WHEEL, RIGHT REAR WHEEL, LEFT BOGIE, RIGHT BOGIE, LEFT DIFFERENTIAL, RIGHT DIFFERENTIAL), N/A, NULL, UNK	(LEFT FRONT WHEEL, RIGHT FRONT WHEEL, LEFT REAR WHEEL, RIGHT REAR WHEEL, LEFT BOGIE, RIGHT BOGIE, LEFT DIFFERENTIAL, RIGHT DIFFERENTIAL), N/A, NULL, UNK	(LEFT FRONT WHEEL, RIGHT FRONT WHEEL, LEFT REAR WHEEL, RIGHT REAR WHEEL, LEFT BOGIE, RIGHT BOGIE, LEFT DIFFERENTIAL, RIGHT DIFFERENTIAL), N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
ARTICULATION_DEVICE_ANGLE	CHASSIS_ARTICULATION_STATE_PARMS	Specifies the value of an angle between two parts or segments of an articulated device.	float array [8] <rad>, N/A, NULL, UNK	float array [8] <rad>, N/A, NULL, UNK	float array [8] <rad>, N/A, NULL, UNK
ARTICULATION_DEVICE_MODE	CHASSIS_ARTICULATION_STATE_PARMS	Specifies the deployment state (i.e., physical configuration) of an articulation device at the time of data acquisition. This includes the mode of the last move of the Arm.	STOWED, DEPLOYED, N/A, NULL, UNK	STOWED, DEPLOYED, N/A, NULL, UNK	STOWED, DEPLOYED, N/A, NULL, UNK
ARTICULATION_DEVICE_ID	HGA_ARTICULATION_STATE_PARMS	Specifies the unique abbreviated identification of an articulation device. An articulation device is anything that can move independently of the spacecraft to which it is attached, (e.g., mast heads, wheel bogies, arms, etc.).	HGA, N/A, NULL, UNK	HGA, N/A, NULL, UNK	HGA, N/A, NULL, UNK
ARTICULATION_DEVICE_NAME	HGA_ARTICULATION_STATE_PARMS	Specifies the common name of an articulation device. An articulation device is anything that can move independently of the spacecraft to which it is attached, (e.g. mast heads, wheel bogies, arms, etc.)	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK	MOBILITY CHASSIS, HIGH GAIN ANTENNA, REMOTE SENSING MAST, SAMPLE ARM, N/A, NULL, UNK
ARTICULATION_DEVICE_ANGLE_NAME	HGA_ARTICULATION_STATE_PARMS	Specifies the formal name which identifies each of the values used in ARTICULATION_DEVICE_ANGLE.	(AZIMUTH, ELEVATION), N/A, NULL, UNK	(AZIMUTH, ELEVATION), N/A, NULL, UNK	(AZIMUTH, ELEVATION), N/A, NULL, UNK
ARTICULATION_DEVICE_ANGLE	HGA_ARTICULATION_STATE_PARMS	Specifies the value of an angle, in radians, between two parts or segments of an articulated device.	float array [2] <rad>, N/A, NULL, UNK	float array [2] <rad>, N/A, NULL, UNK	float array [2] <rad>, N/A, NULL, UNK
ARTICULATION_DEVICE_MODE	HGA_ARTICULATION_STATE_PARMS	Specifies the deployment state (i.e., physical configuration) of an articulation device at the time of data acquisition. This includes the mode of the last move of the Arm.	STOWED, DEPLOYED, N/A, NULL, UNK	STOWED, DEPLOYED, N/A, NULL, UNK	STOWED, DEPLOYED, N/A, NULL, UNK
COORDINATE_SYSTEM_NAME	SITE_COORDINATE_SYSTEM_PARMS	Specifies the full name of the coordinate system to which the state vectors are referenced. When in a COORDINATE_SYSTEM group, this keyword provides the full name of the coordinate system being defined by the group.	SITE_FRAME, N/A, NULL, UNK	SITE_FRAME, N/A, NULL, UNK	SITE_FRAME, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
COORDINATE_SYSTEM_INDEX_NAME	SITE_COORDINATE_SYSTEM_PARMS	Specifies an array of the formal names identifying each integer specified in COORDINATE_SYSTEM_INDEX.	SITE, N/A, NULL, UNK	SITE, N/A, NULL, UNK	SITE, N/A, NULL, UNK
COORDINATE_SYSTEM_INDEX	SITE_COORDINATE_SYSTEM_PARMS	Specifies an integer array used to record and track the movement of a rover or lander during surface operations where "Site", "Drive", "Pose", "Arm", "CHIMRA", "Drill", "RSM", "HGA", "DRT", and "IC".	integer array [1], N/A, NULL, UNK	integer array [1], N/A, NULL, UNK	integer array [1], N/A, NULL, UNK
ORIGIN_OFFSET_VECTOR	SITE_COORDINATE_SYSTEM_PARMS	Specifies the offset from the reference coordinate system's origin to the origin of the coordinate system being defined by the enclosing COORDINATE_SYSTEM_STATE group. In other words, it is the location of the current system's origin as measured in the reference system.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK
ORIGIN_ROTATION_QUATERNION	SITE_COORDINATE_SYSTEM_PARMS	Specifies an array of four values that specifies the rotation of the coordinate system being defined by the enclosing COORDINATE_SYSTEM_STATE group, relative to the reference system. Note that quaternions have different component order conventions between flight and ground software. They are received in the order "(v1, v2, v3, s)". However, the ground order convention is "(s, v1, v2, v3)", and all values are converted to the ground order before being stored in the label.	float array [4], N/A, NULL, UNK	float array [4], N/A, NULL, UNK	float array [4], N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
POSITIVE_AZIMUTH_DIRECTION	SITE_COORDINATE_SYSTEM_PARMS	Specifies the direction in which azimuth is measured in positive degrees for an observer on the surface of a body. The azimuth is measured with respect to the elevational reference plane. A value of CLOCKWISE indicates that Azimuth is measured positively Clockwise, and COUNTERCLOCKWISE indicates that Azimuth increases positively Counter-clockwise. For the MSL operational coordinate frames, which follow the Mars Pathfinder convention, increasing azimuth moves in a clockwise ("CLOCKWISE") direction as viewed from above.	CLOCKWISE, N/A, NULL, UNK	CLOCKWISE, N/A, NULL, UNK	CLOCKWISE, N/A, NULL, UNK
POSITIVE_ELEVATION_DIRECTION	SITE_COORDINATE_SYSTEM_PARMS	Specifies the direction in which elevation is measured in positive degrees for an observer on the surface of a body. The elevation is measured with respect to the azimuthal reference plane. A value of UP or ZENITH indicates that elevation is measured positively upwards, i.e., the zenith point would be at +90 degrees and the nadir point at -90 degrees. DOWN or NADIR indicates that the elevation is measured positively downwards; the zenith point would be at -90 degrees and the nadir point at +90 degrees.	UP, N/A, NULL, UNK	UP, N/A, NULL, UNK	UP, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
REFERENCE_COORD_SYSTEM_NAME	SITE_COORDINATE_SYSTEM_PARMS	Specifies which instance of the coordinate system named by REFERENCE_COORD_SYSTEM_NAME is the reference coordinate system for the group in which the keyword occurs. This index is a set of integers which serve to identify coordinate system instances in a mission-specific manner. For MSL, these indices are based on the ROVER_MOTION_COUNTER and are in the same order as specified by ROVER_MOTION_COUNTER_NAME.	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK	ROVER_NAV_FRAME, SITE_FRAME, LOCAL_LEVEL_FRAME, ROVER_MECH_FRAME, RSM_HEAD_FRAME, ARM_TURRET_FRAME, ARM_DRILL_FRAME, ARM_DRT_FRAME, ARM_MAHLI_FRAME, ARM_APXS_FRAME, ARM_PORTION_FRAME, ARM_SCOOP_TIP_FRAME, ARM_SCOOP_TCP_FRAME, N/A, NULL, UNK
COMMAND_INSTRUMENT_ID	OBSERVATION_REQUEST_PARMS	Specifies an abbreviated name or acronym which identifies the instrument that was commanded.	MAST_LEFT, MAST_RIGHT, N/A, NULL, UNK	MAHLI, N/A, NULL, UNK	MARDI, N/A, NULL, UNK
RATIONALE_DESC	OBSERVATION_REQUEST_PARMS	Describes the rationale for performing a particular observation.	string, N/A, NULL, UNK	string, N/A, NULL, UNK	string, N/A, NULL, UNK
FIRST_LINE	IMAGE_REQUEST_PARMS	Specifies the line within a source image that corresponds to the first line in a sub-image.	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK
FIRST_LINE_SAMPLE	IMAGE_REQUEST_PARMS	Specifies the sample within a source image that corresponds to the first sample in a sub-image.	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK
LINES	IMAGE_REQUEST_PARMS	Specifies the total number of data instances along the vertical axis of an image.	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK
LINE_SAMPLES	IMAGE_REQUEST_PARMS	Specifies the total number of data instances along the horizontal axis of an image.	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK	positive integer, N/A, NULL, UNK
EXPOSURE_TYPE	IMAGE_REQUEST_PARMS	Specifies the exposure mode requested for image acquisition.	AUTO, MANUAL, N/A, NULL, UNK	AUTO, MANUAL, N/A, NULL, UNK	AUTO, MANUAL, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
EXPOSURE_DURATION	IMAGE_REQUEST_PARMS	Specifies the value of the time between the opening and closing of an instrument aperture (such as a camera shutter). For MSL, there are no mechanical shutters. Instead, an "electronic shutter" concept was adopted whereby the detectors accumulate charge for EXPOSURE_DURATION amount of time and then that charge is flushed to a masked frame transfer area for readout and digitization. In milliseconds.	float, 0.0 to 838.8 seconds in increments of 0.1 milliseconds, N/A, NULL, UNK	float, 0.0 to 838.8 seconds in increments of 0.1 milliseconds, N/A, NULL, UNK	float, 0 .0 to 838.8 seconds in increments of 0.1 milliseconds, N/A, NULL, UNK
INST_CMPRS_MODE	IMAGE_REQUEST_PARMS	Specifies the method used for on-board compression of data, 1 = PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, 2 = RAW RASTER, and 3 = JPEG DISCRETE COSINE TRANSFORM (DCT)	1,2,3, N/A, NULL, UNK	1,2,3, N/A, NULL, UNK	1,2,3, N/A, NULL, UNK
INST_CMPRS_NAME	IMAGE_REQUEST_PARMS	Specifies the method used for on-board compression used for data storage and transmission. For the MSL mission, a value of 0 indicates some form of lossless (or no) compression, while non-zero values indicate modes the lossy compressors may use where 1 = PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, 2 = RAW RASTER, and 3 = JPEG DISCRETE COSINE TRANSFORM (DCT)	PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, RAW RASTER, JPEG DISCRETE COSINE TRANSFORM (DCT); HUFFMAN/QUALITY, N/A, NULL, UNK	PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, RAW RASTER, JPEG DISCRETE COSINE TRANSFORM (DCT); HUFFMAN/QUALITY, N/A, NULL, UNK	PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, RAW RASTER, JPEG DISCRETE COSINE TRANSFORM (DCT); HUFFMAN/QUALITY, N/A, NULL, UNK
INST_CMPRS_QUALITY	IMAGE_REQUEST_PARMS	Specifies a JPEG specific variable which identifies the resultant or targeted image quality index for on-board data compression where JPEG = 1-100 and N/A = other	integer, 0 to 101, N/A, NULL, UNK	integer, 0 to 101, N/A, NULL, UNK	integer, 0 to 101, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
AUTO_EXPOSURE_DATA_CUT	IMAGE_REQUEST_PARMS	Specifies the DN value which a specified fraction of pixels is permitted to exceed. The fraction is specified using the keyword AUTO_EXPOSURE_PIXEL_FRACTION.	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK	integer, 0 to n, N/A, NULL, UNK
AUTO_EXPOSURE_PERCENT	IMAGE_REQUEST_PARMS	Specifies the auto-exposure early-termination percent. If the calculated exposure time has written this value, then terminate auto exposure early.	integer, 000 to 100, N/A, NULL, UNK	integer, 000 to 100, N/A, NULL, UNK	integer, 000 to 100, N/A, NULL, UNK
AUTO_EXPOSURE_PIXEL_FRACTION	IMAGE_REQUEST_PARMS	Specifies the percentage of pixels whose targeted value is higher than the AUTO_EXPOSURE_DATA_CUT keyword.	integer, 000 to 100, N/A, NULL, UNK	integer, 000 to 100, N/A, NULL, UNK	integer, 000 to 100, N/A, NULL, UNK
MAX_AUTO_EXPOS_ITERATION_COUNT	IMAGE_REQUEST_PARMS	Specifies the maximum number of exposure iterations the instrument will perform in order to obtain the requested exposure when operating in an autonomous mode.	integer, 0 to 10, N/A, NULL, UNK	integer, 0 to 10, N/A, NULL, UNK	integer, 0 to 10, N/A, NULL, UNK
MSL:AUTO_FOCUS_ZSTACK_FLAG	IMAGE_REQUEST_PARMS	Indicates whether or not Zstack image products were created during the auto focus imaging step. TRUE if Zstack is enabled.	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK	N/A, NULL, UNK
MSL:INSTRUMENT_FOCUS_POSITION_CNT	IMAGE_REQUEST_PARMS	Specifies the position in motor counts of the focus motor on a camera. When in a request group, this specifies the initial focus position used by the autofocus algorithm. When in INSTRUMENT_STATE, it specifies the actual focus position used for the image.	integer, 0 to 5000, N/A, NULL, UNK	integer, 0 to 16200, N/A, NULL, UNK	N/A, NULL, UNK
MSL:INSTRUMENT_FOCUS_STEP_SIZE	IMAGE_REQUEST_PARMS	For MMM cameras on MSL, specifies the size in motor counts of each (or the initial) step taken by the focus adjustment mechanism in an autofocus algorithm.	integer, 0 to 1023, N/A, NULL, UNK	integer, 0 to 1023, N/A, NULL, UNK	N/A, NULL, UNK
MSL:INSTRUMENT_FOCUS_STEPS	IMAGE_REQUEST_PARMS	For MMM cameras on MSL, specifies the number of steps (images) to be taken by an autofocus algorithm.	integer, 0 to 63, N/A, NULL, UNK	integer, 0 to 63, N/A, NULL, UNK	N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
FILTER_NAME	IMAGE_REQUEST_PARMS	Specifies the commonly used name of the requested filter through which an image or measurement should be acquired.	MASTCAM_L0_CLEAR, MASTCAM_L1_525NM, MASTCAM_L2_440NM, MASTCAM_L3_750NM, MASTCAM_L4_675NM, MASTCAM_L5_865NM, MASTCAM_L6_1035NM, MASTCAM_L7_880NM_ND5, MASTCAM_R0_CLEAR, MASTCAM_R1_525NM, MASTCAM_R2_440NM, MASTCAM_R3_800NM, MASTCAM_R4_905NM, MASTCAM_R5_935NM, MASTCAM_R6_1035NM, MASTCAM_R7_440NM_ND5, N/A, NULL, UNK	N/A, NULL, UNK	N/A, NULL, UNK
FILTER_NUMBER	IMAGE_REQUEST_PARMS	Specifies the requested number of an instrument filter through which an image should be acquired.	integer, 0 to 7, N/A, NULL, UNK	N/A, NULL, UNK	N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MSL:INVERSE_LUT_FILE_NAME	IMAGE_REQUEST_PARMS	Specifies the name of the inverse-lookup-table file used in generating the RDR.	MMM_LUT0, MMM_LUT1, MMM_LUT2, MMM_LUT3, MMM_LUT4, MMM_LUT5, MMM_LUT6, MMM_LUT7, MMM_LUT8, MMM_LUT9, MMM_LUT10, MMM_LUT11, MMM_LUT12, MMM_LUT13, MMM_LUT14, MMM_LUT15, MMM_LUT16, MMM_LUT17, MMM_LUT18, MMM_LUT19, MMM_LUT20, MMM_LUT21, MMM_LUT22, MMM_LUT23, MMM_LUT24, MMM_LUT25, MMM_LUT26, MMM_LUT27, MMM_LUT28, MMM_LUT29, MMM_LUT30, MMM_LUT31, N/A, NULL, UNK	MMM_LUT0, MMM_LUT1, MMM_LUT2, MMM_LUT3, MMM_LUT4, MMM_LUT5, MMM_LUT6, MMM_LUT7, MMM_LUT8, MMM_LUT9, MMM_LUT10, MMM_LUT11, MMM_LUT12, MMM_LUT13, MMM_LUT14, MMM_LUT15, MMM_LUT16, MMM_LUT17, MMM_LUT18, MMM_LUT19, MMM_LUT20, MMM_LUT21, MMM_LUT22, MMM_LUT23, MMM_LUT24, MMM_LUT25, MMM_LUT26, MMM_LUT27, MMM_LUT28, MMM_LUT29, MMM_LUT30, MMM_LUT31, N/A, NULL, UNK	MMM_LUT0, MMM_LUT1, MMM_LUT2, MMM_LUT3, MMM_LUT4, MMM_LUT5, MMM_LUT6, MMM_LUT7, MMM_LUT8, MMM_LUT9, MMM_LUT10, MMM_LUT11, MMM_LUT12, MMM_LUT13, MMM_LUT14, MMM_LUT15, MMM_LUT16, MMM_LUT17, MMM_LUT18, MMM_LUT19, MMM_LUT20, MMM_LUT21, MMM_LUT22, MMM_LUT23, MMM_LUT24, MMM_LUT25, MMM_LUT26, MMM_LUT27, MMM_LUT28, MMM_LUT29, MMM_LUT30, MMM_LUT31, N/A, NULL, UNK
FLAT_FIELD_CORRECTION_FLAG	IMAGE_REQUEST_PARMS	Specifies whether or not a flat field correction was applied to an image.	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
GROUP_APPLICABILITY_FLAG	VIDEO_REQUEST_PARMS	Specifies whether a group of keywords are valid values. It is present in a Group only when information is received from telemetry. For MSL, when in a REQUEST_PARMS group, it specifies whether or not the activity represented by the group was commanded. If TRUE, the rest of the contents of the group specify the commanded arguments or parameters for that activity.	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK
MSL:COMMANDED_VIDEO_FRAMES	VIDEO_REQUEST_PARMS	Indicates the number of video image frames commanded.	integer 0 to n, N/A, NULL, UNK	integer 0 to n, N/A, NULL, UNK	integer 0 to n, N/A, NULL, UNK
INTERFRAME_DELAY	VIDEO_REQUEST_PARMS	Provides the time between successive frames of an image in milliseconds.	integer 0 to 65535, N/A, NULL, UNK	integer 0 to 65535, N/A, NULL, UNK	integer 0 to 65535, N/A, NULL, UNK
GROUP_APPLICABILITY_FLAG	ZSTACK_REQUEST_PARMS	Specifies whether a group of keywords are valid values. It is present in a Group only when information is received from telemetry. For MSL, when in a REQUEST_PARMS group, it specifies whether or not the activity represented by the group was commanded. If TRUE, the rest of the contents of the group specify the commanded arguments or parameters for that activity.	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK	N/A, NULL, UNK
MSL:ZSTACK_IMAGE_DEPTH	ZSTACK_REQUEST_PARMS	Indicates the number of images used in ZStack focus merge or range map products.	integer, 0 to 8, N/A, NULL, UNK	integer, 0 to 8, N/A, NULL, UNK	N/A, NULL, UNK
MSL:IMAGE_BLENDING_FLAG	ZSTACK_REQUEST_PARMS	Indicates whether intra-stack image blending has been performed during the focus merge operation. FALSE means images were merged without blending.	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK	N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MSL:IMAGE_REGISTRATION_FLAG	ZSTACK_REQUEST_PARMS	Indicates whether intra-stack image registration has been performed during the focus merge operation. TRUE indicates that intra-stack image registration has been performed during the focus merge operation. FALSE indicates that images have been merged without translation.	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK	N/A, NULL, UNK
HORIZONTAL_FOV	INSTRUMENT_STATE_PARMS	Specifies the angular measure of the horizontal field of view of an imaged scene in degrees.	float <deg>, N/A, NULL, UNK	float <deg>, N/A, NULL, UNK	float <deg>, N/A, NULL, UNK
VERTICAL_FOV	INSTRUMENT_STATE_PARMS	Specifies the angular measure of the vertical field of view of an imaged scene in degrees.	float <deg>, N/A, NULL, UNK	float <deg>, N/A, NULL, UNK	float <deg>, N/A, NULL, UNK
DETECTOR_FIRST_LINE	INSTRUMENT_STATE_PARMS	Specifies the starting row from the hardware, such as a charge-coupled device (CCD), that contains data.	1, N/A, NULL, UNK	1, N/A, NULL, UNK	1, N/A, NULL, UNK
DETECTOR_LINES	INSTRUMENT_STATE_PARMS	Specifies the number of rows extracted from the hardware, such as a charge-coupled device (CCD), that contain data.	1200, N/A, NULL, UNK	1200, N/A, NULL, UNK	1200, N/A, NULL, UNK
MSL:DETECTOR_SAMPLES	INSTRUMENT_STATE_PARMS	Indicates the number of columns extracted from the hardware, such as a charge-coupled device (CCD), that contain data.	1648, N/A, NULL, UNK	1648, N/A, NULL, UNK	1648, N/A, NULL, UNK
DETECTOR_TO_IMAGE_ROTATION	INSTRUMENT_STATE_PARMS	Specifies the clockwise rotation, in degrees, that was applied to an image along its optical path through an instrument, from detector to final image orientation.	0.0, N/A, NULL, UNK	0.0, N/A, NULL, UNK	0.0, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
EXPOSURE_DURATION	INSTRUMENT_STATE_PARMS	Specifies the value of the time, in milliseconds, between the opening and closing of an instrument aperture (such as a camera shutter). For MSL, there are no mechanical shutters. Instead, an "electronic shutter" concept was adopted whereby the detectors accumulate charge for EXPOSURE_DURATION amount of time and then that charge is flushed to a masked frame transfer area for readout and digitization.	float, 0 .0 to 838.8 seconds in increments of 0.1 milliseconds <ms>, N/A, NULL, UNK	float, 0 .0 to 838.8 seconds in increments of 0.1 milliseconds <ms>, N/A, NULL, UNK	float, 0 .0 to 838.8 seconds in increments of 0.1 milliseconds <ms>, N/A, NULL, UNK
FILTER_NAME	INSTRUMENT_STATE_PARMS	Specifies the commonly used name of the filter through which an image or measurement was acquired.	MASTCAM_L0_CLEAR, MASTCAM_L1_525NM, MASTCAM_L2_440NM, MASTCAM_L3_750NM, MASTCAM_L4_675NM, MASTCAM_L5_865NM, MASTCAM_L6_1035NM, MASTCAM_L7_880NM_ND5, MASTCAM_R0_CLEAR, MASTCAM_R1_525NM, MASTCAM_R2_440NM, MASTCAM_R3_800NM, MASTCAM_R4_905NM, MASTCAM_R5_935NM, MASTCAM_R6_1035NM, MASTCAM_R7_440NM_ND5 <nm>, N/A, NULL, UNK	N/A, NULL, UNK	N/A, NULL, UNK
FILTER_NUMBER	INSTRUMENT_STATE_PARMS	Specifies the number of an instrument filter through which an image was acquired.	integer, 0 to 7, N/A, NULL, UNK	N/A, NULL, UNK	N/A, NULL, UNK
CENTER_FILTER_WAVELENGTH	INSTRUMENT_STATE_PARMS	Provides the mid_point wavelength value between the minimum and maximum instrument filter wavelength values (in nm)	Mastcam Left: 590, 525, 440, 750, 675, 865, 1035, 880 <nm> Mastcam Right: 575, 525, 440, 800, 905, 935, 1035, 440 <nm>, N/A, NULL, UNK	N/A, NULL, UNK	N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
FLAT_FIELD_CORRECTION_FLAG	INSTRUMENT_STATE_PARMS	Specifies whether or not a flat field correction was applied to an image.	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK
MSL:INSTRUMENT_CLOCK_START_COUNT	INSTRUMENT_STATE_PARMS	Specifies the SCLK for the start of image acquisition. SCLK is internal to the MMM instruments, but is set from the RCE SCLK. This time is after autofocus, autoexposure, and optical filter movement if performed.	sssssssss.mmmm, N/A, NULL, UNK	sssssssss.mmmm, N/A, NULL, UNK	sssssssss.mmmm, N/A, NULL, UNK
MSL:SENSOR_READOUT_RATE	INSTRUMENT_STATE_PARMS	Specifies the clock rate, in MHz, at which dn values are read from the imaging sensor. Values may be one of: 2.5, 3.33, 5, 10, or 20 MHz.	2.5, 3.33, 5, 10, 20 <MHz>, N/A, NULL, UNK	2.5, 3.33, 5, 10, 20 <MHz>, N/A, NULL, UNK	2.5, 3.33, 5, 10, 20 <MHz>, N/A, NULL, UNK
INSTRUMENT_TEMPERATURE_NAME	INSTRUMENT_STATE_PARMS	Specifies an array of the formal names identifying each of the values used in INSTRUMENT_TEMPERATURE.	(DEA_TEMP, FPA_TEMP, OPTICS_TEMP, ELECTRONICS, ELECTRONICS_A, ELECTRONICS_B), N/A, NULL, UNK	(DEA_TEMP, FPA_TEMP, OPTICS_TEMP, ELECTRONICS, ELECTRONICS_A, ELECTRONICS_B), N/A, NULL, UNK	(DEA_TEMP, FPA_TEMP, OPTICS_TEMP, ELECTRONICS, ELECTRONICS_A, ELECTRONICS_B), N/A, NULL, UNK
INSTRUMENT_TEMPERATURE	INSTRUMENT_STATE_PARMS	Specifies the temperature, in degrees Celsius, of an instrument or some part of an instrument. Note that this may be an array of multiple values for temperatures on different parts of the instrument.	float array [6] <degC>, N/A, NULL,UNK	float array [6] <degC>, N/A, NULL, UNK	float array [6] <degC>, N/A, NULL, UNK
MSL:INSTRUMENT_TEMPERATURE_STATUS	INSTRUMENT_STATE_PARMS	Value from RCE indicating validity or status of the temperature reading.	float array [6] <degC>, N/A, NULL, UNK	float array [6] <degC>, N/A, NULL, UNK	float array [6] <degC>, N/A, NULL, UNK
SAMPLE_BIT_METHOD	INSTRUMENT_STATE_PARMS	Specifies the method in which bit scaling is performed. For MSL, the bit scaling is a 12-bit to 8-bit scaling and can be performed onboard via hardware and/or software , or on the ground in an inverse operation.	HARDWARE, N/A, NULL, UNK	HARDWARE, N/A, NULL, UNK	HARDWARE, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
SAMPLE_BIT_MODE_ID	INSTRUMENT_STATE_PARMS	Specifies the type of pixel scaling performed. For MSL, pixel scaling is accomplished by using onboard lookup tables or by shifting a specified bit into the most significant bit.	MMM_LUT0, MMM_LUT1, MMM_LUT2, MMM_LUT3, MMM_LUT4, MMM_LUT5, MMM_LUT6, MMM_LUT7, MMM_LUT8, MMM_LUT9, MMM_LUT10, MMM_LUT11, MMM_LUT12, MMM_LUT13, MMM_LUT14, MMM_LUT15, MMM_LUT16, MMM_LUT17, MMM_LUT18, MMM_LUT19, MMM_LUT20, MMM_LUT21, MMM_LUT22, MMM_LUT23, MMM_LUT24, MMM_LUT25, MMM_LUT26, MMM_LUT27, MMM_LUT28, MMM_LUT29, MMM_LUT30, MMM_LUT31, N/A, NULL, UNK	MMM_LUT0, MMM_LUT1, MMM_LUT2, MMM_LUT3, MMM_LUT4, MMM_LUT5, MMM_LUT6, MMM_LUT7, MMM_LUT8, MMM_LUT9, MMM_LUT10, MMM_LUT11, MMM_LUT12, MMM_LUT13, MMM_LUT14, MMM_LUT15, MMM_LUT16, MMM_LUT17, MMM_LUT18, MMM_LUT19, MMM_LUT20, MMM_LUT21, MMM_LUT22, MMM_LUT23, MMM_LUT24, MMM_LUT25, MMM_LUT26, MMM_LUT27, MMM_LUT28, MMM_LUT29, MMM_LUT30, MMM_LUT31, N/A, NULL, UNK	MMM_LUT0, MMM_LUT1, MMM_LUT2, MMM_LUT3, MMM_LUT4, MMM_LUT5, MMM_LUT6, MMM_LUT7, MMM_LUT8, MMM_LUT9, MMM_LUT10, MMM_LUT11, MMM_LUT12, MMM_LUT13, MMM_LUT14, MMM_LUT15, MMM_LUT16, MMM_LUT17, MMM_LUT18, MMM_LUT19, MMM_LUT20, MMM_LUT21, MMM_LUT22, MMM_LUT23, MMM_LUT24, MMM_LUT25, MMM_LUT26, MMM_LUT27, MMM_LUT28, MMM_LUT29, MMM_LUT30, MMM_LUT31, N/A, NULL, UNK
MSL:FOCUS_POSITION_COUNT	INSTRUMENT_STATE_PARMS	Indicates the position of the focus motor in motor steps. This value is only applicable to Mastcam and the MAHLI instruments.	integer, 0 to 5000, N/A, NULL, UNK	integer, 0 to 16200, N/A, NULL, UNK	N/A, NULL, UNK
MSL:FILTER_POSITION_COUNT	INSTRUMENT_STATE_PARMS	Indicates the position of the optical filter wheel in motor counts. Optical filters are 294 motor counts apart. This keyword is only applicable to the Mastcam instruments.	signed integer, N/A, NULL, UNK	N/A, NULL, UNK	N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MSL:COVER_HALL_SENSOR_FLAG	INSTRUMENT_STATE_PARMS	Indicates the status of the Hall sensor used for the MAHLI cover state. When used with the FOCUS_HALL_SENSOR value, the states are as follows: If cover=0 & focus=0, in launch lock state; if cover=1 & focus=0, in between launch lock and cover fully open; if cover=0 & focus=1, cover is fully open and at or beyond focus midrange; if cover=1 & focus=1, cover is fully open and focus midrange is not reached.	N/A, NULL, UNK	0, 1, N/A, NULL, UNK	N/A, NULL, UNK
MSL:FILTER_HALL_SENSOR_FLAG	INSTRUMENT_STATE_PARMS	Indicates the status of the Hall sensor used for the Mastcam filter wheels. A value of 1 indicates one of the magnets on the filter wheel are near the Hall sensor. A statechange generally indicates the wheel has moved to the next adjacent filter. This is not true for all filter positions.	0, 1, N/A, NULL, UNK	N/A, NULL, UNK	N/A, NULL, UNK
MSL:FOCUS_HALL_SENSOR_FLAG	INSTRUMENT_STATE_PARMS	Indicates the status of the Hall sensor used for the MAHLI or Mastcam focus mechanism. For MAHLI, refer to the description of COVER_HALL_SENSOR.	0, 1, N/A, NULL, UNK	0, 1, N/A, NULL, UNK	N/A, NULL, UNK
MSL:LED_STATE_NAME	INSTRUMENT_STATE_PARMS	Specifies the name of the LED state for MAHLI. There are three LED groups: two visible light groups and one UV group.	(VIS1, VIS2, UV), N/A, NULL, UNK	(VIS1, VIS2, UV), N/A, NULL, UNK	(VIS1, VIS2, UV), N/A, NULL, UNK
MSL:LED_STATE_FLAG	INSTRUMENT_STATE_PARMS	Specifies the state of the LED for MAHLI. LEDs states may be either ON or OFF. This keyword is not applicable for Mastcam and MARDI instruments.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK
DETECTOR_ERASE_COUNT	INSTRUMENT_STATE_PARMS	Specifies the number of times a detector has been flushed of data in raw counts. This reports the value of the camera head vertical register (vflush) parameter.	integer, 0 to 8191, N/A, NULL, UNK	integer, 0 to 8191, N/A, NULL, UNK	integer, 0 to 8191, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
INST_CMPRS_MODE	IMAGE_PARMS	Specifies the method used for on-board compression of data. For the MSL mission, a value of 0 indicates some form of lossless (or no) compression, while non-zero values indicate modes the lossy compressors may use where 1 = PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, 2 = RAW RASTER, and 3 = JPEG DISCRETE COSINE TRANSFORM (DCT)	1,2,3, N/A, NULL, UNK	1,2,3, N/A, NULL, UNK	1,2,3, N/A, NULL, UNK
INST_CMPRS_NAME	IMAGE_PARMS	Specifies the type of on-board compression used for data storage and transmission. For the MSL mission, a value of 0 indicates some form of lossless (or no) compression, while non-zero values indicate modes the lossy compressors may use where 1 = PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, 2 = RAW RASTER, and 3 = JPEG DISCRETE COSINE TRANSFORM (DCT)	PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, RAW RASTER, JPEG DISCRETE COSINE TRANSFORM (DCT); HUFFMAN/QUALITY, N/A, NULL, UNK	PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, RAW RASTER, JPEG DISCRETE COSINE TRANSFORM (DCT); HUFFMAN/QUALITY, N/A, NULL, UNK	PREDICTIVE LOSSLESS BAYER HUFFMAN ENCODING, RAW RASTER, JPEG DISCRETE COSINE TRANSFORM (DCT); HUFFMAN/QUALITY, N/A, NULL, UNK
INST_CMPRS_QUALITY	IMAGE_PARMS	Specifies a JPEG specific variable which identifies the resultant or targeted image quality index for on-board data compression where JPEG = 1-100 and N/A = other	integer, 0 to 101, N/A, NULL, UNK	integer, 0 to 101, N/A, NULL, UNK	integer, 0 to 101, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MSL:INVERSE_LUT_FILE_NAME	IMAGE_PARMS	Specifies the name of the inverse-lookup-table file used in generating the RDR.	MMM_LUT0, MMM_LUT1, MMM_LUT2, MMM_LUT3, MMM_LUT4, MMM_LUT5, MMM_LUT6, MMM_LUT7, MMM_LUT8, MMM_LUT9, MMM_LUT10, MMM_LUT11, MMM_LUT12, MMM_LUT13, MMM_LUT14, MMM_LUT15, MMM_LUT16, MMM_LUT17, MMM_LUT18, MMM_LUT19, MMM_LUT20, MMM_LUT21, MMM_LUT22, MMM_LUT23, MMM_LUT24, MMM_LUT25, MMM_LUT26, MMM_LUT27, MMM_LUT28, MMM_LUT29, MMM_LUT30, MMM_LUT31, N/A, NULL, UNK	MMM_LUT0, MMM_LUT1, MMM_LUT2, MMM_LUT3, MMM_LUT4, MMM_LUT5, MMM_LUT6, MMM_LUT7, MMM_LUT8, MMM_LUT9, MMM_LUT10, MMM_LUT11, MMM_LUT12, MMM_LUT13, MMM_LUT14, MMM_LUT15, MMM_LUT16, MMM_LUT17, MMM_LUT18, MMM_LUT19, MMM_LUT20, MMM_LUT21, MMM_LUT22, MMM_LUT23, MMM_LUT24, MMM_LUT25, MMM_LUT26, MMM_LUT27, MMM_LUT28, MMM_LUT29, MMM_LUT30, MMM_LUT31, N/A, NULL, UNK	MMM_LUT0, MMM_LUT1, MMM_LUT2, MMM_LUT3, MMM_LUT4, MMM_LUT5, MMM_LUT6, MMM_LUT7, MMM_LUT8, MMM_LUT9, MMM_LUT10, MMM_LUT11, MMM_LUT12, MMM_LUT13, MMM_LUT14, MMM_LUT15, MMM_LUT16, MMM_LUT17, MMM_LUT18, MMM_LUT19, MMM_LUT20, MMM_LUT21, MMM_LUT22, MMM_LUT23, MMM_LUT24, MMM_LUT25, MMM_LUT26, MMM_LUT27, MMM_LUT28, MMM_LUT29, MMM_LUT30, MMM_LUT31, N/A, NULL, UNK
PIXEL_AVERAGING_HEIGHT	IMAGE_PARMS	Specifies the vertical dimension, in pixels, of the area over which pixels were averaged prior to image compression.	1 for non-thumbnail, and 8 for thumbnail, N/A, NULL, UNK	1 for non-thumbnail, and 8 for thumbnail, N/A, NULL, UNK	1 for non-thumbnail, and 8 for thumbnail, N/A, NULL, UNK
PIXEL_AVERAGING_WIDTH	IMAGE_PARMS	Specifies the horizontal dimension, in pixels, of the area over which pixels were averaged prior to image compression.	1 for non-thumbnail, and 8 for thumbnail, N/A, NULL, UNK	1 for non-thumbnail, and 8 for thumbnail, N/A, NULL, UNK	1 for non-thumbnail, and 8 for thumbnail, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
GROUP_APPLICABILITY_FLAG	VIDEO_PARMS	Specifies whether a group of keywords are valid values. It is present in a Group only when information is received from telemetry. For MSL, when in a REQUEST_PARMS group, it specifies whether or not the activity represented by the group was commanded. If TRUE, the rest of the contents of the group specify the commanded arguments or parameters for that activity.	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK
MSL:GOP_FRAME_INDEX	VIDEO_PARMS	Specifies the frame index within the GOP. Frame indices may be 0 to 15. See note under MSL:GOP_TOTAL_FRAMES for GOP description. This value is only applicable to DAT files with GOP products.	0 to 15, N/A, NULL, UNK	0 to 15, N/A, NULL, UNK	0 to 15, N/A, NULL, UNK
MSL:GOP_TOTAL_FRAMES	VIDEO_PARMS	Indicates, for video products compressed into a group of images (Group Of Pictures or GOP), the number of JPEG images in a GOP. This is not the total number of images acquired from a video command. For that, see MSL:COMMANDED_VIDEO_FRAMES. Note: GOP (Group Of Pictures) products are video products packaged as a group of images. There may be up to 16 JPEG images in a GOP.	1 to 16, N/A, NULL, UNK	1 to 16, N/A, NULL, UNK	1 to 16, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MSL:GOP_OFFSET	VIDEO_PARMS	Provides an array of values of byte lengths for JPEG images that are stored sequentially in DAT files, starting with MSL:GOP_FRAME_INDEX 0. MSL:GOP_OFFSET 0 is the the first byte following the MMM mini-header in the DAT file. See note under MSL:GOP_TOTAL_FRAMES for GOP description. This value is only applicable to DAT files with GOP products.	Only set for compressed video products (see description of GOP in SIS). EDR only: positive integer; N/A, NULL, UNK	Only set for compressed video products (see description of GOP in SIS). EDR only: positive integer; N/A, NULL, UNK	Only set for compressed video products (see description of GOP in SIS). EDR only: positive integer; N/A, NULL, UNK
MSL:GOP_LENGTH	VIDEO_PARMS	Provides an array of JPEG sizes in bytes, for each image in a GOP, starting with MSL:GOP_FRAME_INDEX 0. See note under MSL:GOP_TOTAL_FRAMES for GOP description. This value is only applicable to DAT files with GOP products.	Only set for compressed video products (see description of GOP in SIS). EDR only: positive integer; N/A, NULL, UNK	Only set for compressed video products (see description of GOP in SIS). EDR only: positive integer; N/A, NULL, UNK	Only set for compressed video products (see description of GOP in SIS). EDR only: positive integer; N/A, NULL, UNK
MSL:INFINITY_CONSTANT	DERIVED_IMAGE_PARMS	The MSL:INFINITY_CONSTANT element supplies the numerical value used to represent a value of 'infinity'	Integer, N/A, NULL, UNK	Integer, N/A, NULL, UNK	Integer, N/A, NULL, UNK
MSL:COVER_STATE_FLAG	DERIVED_IMAGE_PARMS	Indicates the state of the MAHLI cover.	N/A, NULL, UNK	OPEN, CLOSED, N/A, NULL, UNK	N/A, NULL, UNK
MSL:MINIMUM_FOCUS_DISTANCE	DERIVED_IMAGE_PARMS	Specifies the estimated distance to the nearest pixel with less than 1 pixel of gaussian blur. A constant representing 'infinity' is a valid value (Please see MSL:INFINITY_CONSTANT). Units are mm for MAHLI and meters for Mastcam and MARDI. Values are based on instrument calibration and focus motor counts.	float <m>, N/A, NULL, UNK	float <m>, N/A, NULL, UNK	2, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
MSL:BEST_FOCUS_DISTANCE	DERIVED_IMAGE_PARMS	Specifies the estimated distance to best focus from the front of the instrument sapphire window. A constant representing 'infinity' is a valid value (Please see MSL:INFINITY_CONSTANT). Units are mm for MAHLI and meters for Mastcam and MARDI. Values are based on instrument calibration and focus motor counts.	integer, N/A, NULL, UNK	integer, N/A, NULL, UNK	N/A, NULL, UNK
MSL:MAXIMUM_FOCUS_DISTANCE	DERIVED_IMAGE_PARMS	Specifies the estimated distance to the FURTHEST pixel with less than 1 pixel of gaussian blur. A constant representing 'infinity' is a valid value (Please see MSL:INFINITY_CONSTANT). Units are mm for MAHLI and meters for Mastcam and MARDI. Values are based on instrument calibration and focus motor counts.	integer, N/A, NULL, UNK	integer, N/A, NULL, UNK	integer, N/A, NULL, UNK
MSL:FRAME_RATE	DERIVED_IMAGE_PARMS	Specifies the calculated frame rate, for video products, in frames per second.	float, 0 to n, N/A, NULL, UNK	float, 0 to n, N/A, NULL, UNK	float, 0 to n, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
FIXED_INSTRUMENT_AZIMUTH	DERIVED_IMAGE_PARMS	The FIXED_INSTRUMENT_AZIMUTH element provides one of two angular measurements for the pointing direction of an instrument, measured with respect to a coordinate frame co-linear with the surface fixed coordinate frame. The azimuth is measured positively in the clockwise direction (as viewed from above) with the meridian passing through the positive spin axis ('north pole') defining the zero reference. The angle is measured in the local gravity horizontal plane, i.e., a plane perpendicular to the local gravity vector. The FIXED_INSTRUMENT_AZIMUTH is derived from the instrument pointing and spacecraft orientation. It is co-linear with the surface fixed coordinate system, but the origin of the observation may not be coincident with the origin of the surface fixed frame. Note that the FIXED_INSTRUMENT_AZIMUTH describes the pointing direction of the instrument rather than the angular coordinates of the target of the observation. If there has been any significant change over time in the position of the observing instrument (ie., the origin of the coordinate frame in which this value is measured), this data element can not be used to uniquely describe the vector to a viewed object. See also FIXED_INSTRUMENT_ELEVATION.	float 0 to 360, N/A, NULL, UNK	float 0 to 360, N/A, NULL, UNK	float 0 to 360, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
FIXED_INSTRUMENT_ELEVATION	DERIVED_IMAGE_PARMS	The FIXED_INSTRUMENT_ELEVATION element provides one of two angular measurements of the pointing direction of an instrument, measured with respect to a coordinate frame co-linear with the surface fixed coordinate frame. The positive direction of the elevation is set by the POSITIVE_ELEVATION_DIRECTION data element. It is measured from the plane which is perpendicular to the local gravity vector and which intersects the elevation axis around which the instrument rotates. The FIXED_INSTRUMENT_ELEVATION is derived from the instrument pointing and spacecraft orientation. It is co-linear with the surface fixed coordinate system, but the origin of the observation may not be co- incident with the origin of the surface fixed frame. Note that the FIXED_INSTRUMENT_ELEVATION describes the pointing direction of the instrument rather than the angular coordinates of the target of the observation. If there has been any change over time in the position of the observing instrument (i.e., the origin of the coordinate frame in which this value is measured), this data element can not be used to uniquely describe the vector to a viewed object. Assuming a flat surface, and combined with the INSTRUMENT_ALTITUDE data element, it can be used to determine the position of an object; however, given realistic non-flat surfaces, observations from another point of origin are required to determine an object's distance.	float -90 to 90, N/A, NULL, UNK	float -90 to 90, N/A, NULL, UNK	float -90 to 90, N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
SOLAR_AZIMUTH	DERIVED_IMAGE_PARMS	The SOLAR_AZIMUTH element provides one of two angular measurements indicating the direction to the sun as measured from a specific point on the surface of a planet (e.g., from a lander or rover). The positive direction of the elevation is up. It is measured from the plane which intersects the surface point and is normal to the line passing between the surface point and the planet's center of mass.	float 0 to 360, N/A, NULL, UNK	float 0 to 360, N/A, NULL, UNK	float 0 to 360, N/A, NULL, UNK
SOLAR_ELEVATION	DERIVED_IMAGE_PARMS	The SOLAR_ELEVATION element provides one of two angular measurements indicating the direction to the sun as measured from a specific point on the surface of a planet (e.g., from a lander or rover). The azimuth is measured positively in the clockwise direction (as viewed from above) with the meridian passing through the positive spin axis of the planet (i.e., the north pole), defining the zero reference.	float -90 to 90, N/A, NULL, UNK	float -90 to 90, N/A, NULL, UNK	float -90 to 90, N/A, NULL, UNK
DARK_LEVEL_CORRECTION	PROCESSING_PARMS	Provides the DN value subtracted from every pixel in an image for purposes of radiometric calibration.	integer, N/A, NULL, UNK	integer, N/A, NULL, UNK	integer, N/A, NULL, UNK
SHUTTER_EFFECT_CORRECTION_FLAG	PROCESSING_PARMS	Specifies whether or not a shutter effect correction was applied to the image. The shutter effect correction involves the removal from the image of the shutter, or fixed-pattern.	N/A for EDR; N/A, TRUE or FALSE for RDRs, NULL, UNK	N/A for EDRs; N/A, TRUE or FALSE for RDRs, NULL, UNK	N/A for EDRs; N/A, TRUE, or FALSE for RDRs, NULL, UNK
RADIOMETRIC_CORRECTION_TYPE	PROCESSING_PARMS	Identifies the method used for radiometric correction.	MMMRAD1, N/A, NULL, UNK	MMMRAD1, N/A, NULL, UNK	MMMRAD1, N/A, NULL, UNK
RADIANCE_OFFSET	PROCESSING_PARMS	Specifies the constant value by which a stored radiance value is shifted or displaced.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK

			Valid Values & Entries for EDRs and RDRs		
Keyword	Object/Group	Definition	Mastcam L & R	MAHLI	MARDI
RADIANCE_SCALING_FACTOR	PROCESSING_PARMS	Specifies the constant value by which a stored radiance is multiplied.	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK	float array [3], N/A, NULL, UNK
FLAT_FIELD_CORRECTION_FLAG	PROCESSING_PARMS	Specifies whether or not a flat field correction was applied to an image.	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK	TRUE, FALSE, N/A, NULL, UNK

Example Mastcam Left (M34) Label Product, 0289ML0009620000106329M00_XXXX.LBL:

```
PDS_VERSION_ID                      = PDS3

/* Pointers to Data Objects */

OBJECT                        = COMPRESSED_FILE
  FILE_NAME                   = "0289ML0009620000106329M00_XXXX.DAT"
  RECORD_TYPE                 = UNDEFINED
  FILE_RECORDS                = "N/A"
  ENCODING_TYPE               = "MSLMMM-COMPRESSED"
  INTERCHANGE_FORMAT          = BINARY
  UNCOMPRESSED_FILE_NAME      = ( "0289ML0009620000106329M00_XXXX_00.IMG",
"0289ML0009620000106329M00_XXXX_01.IMG",
"0289ML0009620000106329M00_XXXX_02.IMG",
"0289ML0009620000106329M00_XXXX_03.IMG",
"0289ML0009620000106329M00_XXXX_04.IMG",
"0289ML0009620000106329M00_XXXX_05.IMG",
"0289ML0009620000106329M00_XXXX_06.IMG",
"0289ML0009620000106329M00_XXXX_07.IMG",
"0289ML0009620000106329M00_XXXX_08.IMG",
"0289ML0009620000106329M00_XXXX_09.IMG",
"0289ML0009620000106329M00_XXXX_10.IMG",
"0289ML0009620000106329M00_XXXX_11.IMG",
"0289ML0009620000106329M00_XXXX_12.IMG",
"0289ML0009620000106329M00_XXXX_13.IMG",
"0289ML0009620000106329M00_XXXX_14.IMG",
"0289ML0009620000106329M00_XXXX_15.IMG" )
  REQUIRED_STORAGE_BYTES      = "34880"
  ^MINIHEADER_TABLE           = ("0289ML0009620000106329M00_XXXX.DAT",
                                 1 <BYTES> )
  DESCRIPTION               = "The first 64 bytes of the data file
(described by the MINIHEADER_TABLE below) determine the interpretation
of the image in the rest of the file. In particular, if the columns
COLOR_MODE and INST_CMPRS_QUALITY are both 0, the image is a RAW RASTER;
otherwise, the image is a JPEG with a specified mode
(grayscale, 442 colors, or 444 colors) and quality 1 to 100,
or it is LOSSLESS."
END_OBJECT                    = COMPRESSED_FILE
```

```
OBJECT                         = UNCOMPRESSED_FILE
  /* DAT2IMG decompression software will generate the following */
  /* IMG files along with corresponding detached PDS labels     */
  FILE_NAME                    = ( "0289ML0009620000106329M00_XXXX_00.IMG",
"0289ML0009620000106329M00_XXXX_01.IMG",
"0289ML0009620000106329M00_XXXX_02.IMG",
"0289ML0009620000106329M00_XXXX_03.IMG",
"0289ML0009620000106329M00_XXXX_04.IMG",
"0289ML0009620000106329M00_XXXX_05.IMG",
"0289ML0009620000106329M00_XXXX_06.IMG",
"0289ML0009620000106329M00_XXXX_07.IMG",
"0289ML0009620000106329M00_XXXX_08.IMG",
"0289ML0009620000106329M00_XXXX_09.IMG",
"0289ML0009620000106329M00_XXXX_10.IMG",
"0289ML0009620000106329M00_XXXX_11.IMG",
"0289ML0009620000106329M00_XXXX_12.IMG",
"0289ML0009620000106329M00_XXXX_13.IMG",
"0289ML0009620000106329M00_XXXX_14.IMG",
"0289ML0009620000106329M00_XXXX_15.IMG" )
  RECORD_TYPE                  = FIXED_LENGTH
  FILE_RECORDS                 = 1344
  RECORD_BYTES                 = 64

  /* IMAGE DATA ELEMENTS */
  OBJECT                               = IMAGE
    LINES                              = 128
    LINE_SAMPLES                       = 224
    SAMPLE_TYPE                        = UNSIGNED_INTEGER
    SAMPLE_BITS                        = 8
    BANDS                              = 3
    FIRST_LINE                         = 1
    FIRST_LINE_SAMPLE                  = 721
  END_OBJECT                           = IMAGE

END_OBJECT                     = UNCOMPRESSED_FILE


/* Identification Data Elements */
```

```
MSL:ACTIVE_FLIGHT_STRING_ID          = "B"
DATA_SET_ID                          = "MSL-M-MASTCAM-2-EDR-VID-V1.0"
DATA_SET_NAME                        = "MSL MARS MAST CAMERA 2 EDR VIDEO V1.0"
COMMAND_SEQUENCE_NUMBER              = 0
GEOMETRY_PROJECTION_TYPE             = RAW
IMAGE_ID                             = "0289ML0009620000106329M00"
IMAGE_TYPE                           = REGULAR
MSL:IMAGE_ACQUIRE_MODE               = IMAGE
INSTRUMENT_HOST_ID                   = MSL
INSTRUMENT_HOST_NAME                 = "MARS SCIENCE LABORATORY"
INSTRUMENT_ID                        = MAST_LEFT
INSTRUMENT_NAME                      = "MAST CAMERA LEFT"
INSTRUMENT_SERIAL_NUMBER             = "3003"
FLIGHT_SOFTWARE_VERSION_ID           = "1105031458"
INSTRUMENT_TYPE                      = "IMAGING CAMERA"
INSTRUMENT_VERSION_ID                = FM
MSL:LOCAL_MEAN_SOLAR_TIME            = "Sol-00289M17:14:45.088"
LOCAL_TRUE_SOLAR_TIME                = "16:23:40"
MISSION_NAME                         = "MARS SCIENCE LABORATORY"
MISSION_PHASE_NAME                   = "PRIMARY SURFACE MISSION"
OBSERVATION_ID                       = "NULL"
PLANET_DAY_NUMBER                    = 0289
INSTITUTION_NAME                     = "MALIN SPACE SCIENCE SYSTEMS"
PRODUCT_CREATION_TIME                = 2013-11-09T00:49:39.354
PRODUCT_VERSION_ID                   = "V1.0"
PRODUCT_ID                           = "0289ML0009620000106329M00_XXXX"
SOURCE_PRODUCT_ID                    = "McamLVideo_0423166067-31182-1"
MSL:INPUT_PRODUCT_ID                 = "0289ML0009620000106329M00_DXXX"
MSL:CALIBRATION_FILE_NAME            = "N/A"
RELEASE_ID                           = "0004"
MSL:REQUEST_ID                       = "2000962000"
MSL:CAMERA_PRODUCT_ID                = "6329"
MSL:CAMERA_PRODUCT_ID_COUNT          = 1
ROVER_MOTION_COUNTER_NAME            = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
ROVER_MOTION_COUNTER                 = (6, 82,
                                        6, 1096,
```

```
                                    267, 176,
                                    972, 1110,
                                    0, 26 )
SEQUENCE_ID                       = "mcam00962"
SEQUENCE_VERSION_ID               = "0"
SOLAR_LONGITUDE                   = 327.206
SPACECRAFT_CLOCK_CNT_PARTITION    = 1
SPACECRAFT_CLOCK_START_COUNT      = "423166067.0000"
SPACECRAFT_CLOCK_STOP_COUNT       = "423166067.0100"
IMAGE_TIME                        = 2013-05-30T06:13:56.400
START_TIME                        = 2013-05-30T06:13:56.400
STOP_TIME                         = 2013-05-30T06:13:56.552
TARGET_NAME                       = "MARS"
TARGET_TYPE                       = "PLANET"

/* Telemetry Data Elements */

APPLICATION_PROCESS_ID            = 413
APPLICATION_PROCESS_NAME          = McamLVideo
EARTH_RECEIVED_START_TIME         = 2013-05-30T17:46:36
SPICE_FILE_NAME                   = "chronos.msl_gc120806_v3"
TELEMETRY_PROVIDER_ID             = "NULL"
MSL:TELEMETRY_SOURCE_HOST_NAME    = "NULL"
TELEMETRY_SOURCE_NAME             = "McamLVideo_0423166067-31182-1"
TELEMETRY_SOURCE_TYPE             = "DATA PRODUCT"
MSL:COMMUNICATION_SESSION_ID      = "32901"
MSL:PRODUCT_COMPLETION_STATUS     = COMPLETE_CHECKSUM_PASS
MSL:SEQUENCE_EXECUTION_COUNT      = 1
MSL:TELEMETRY_SOURCE_START_TIME   = 2013-05-30T06:13:57
MSL:TELEMETRY_SOURCE_SCLK_START   = "1/423166067-31182"


/* History Data Elements */

GROUP                             = PDS_HISTORY_PARMS
 SOFTWARE_NAME                     = MMMEDRGEN
 SOFTWARE_VERSION_ID               = "pds3.0"
 PROCESSING_HISTORY_TEXT           = "CODMAC LEVEL 1 to LEVEL 2
                                     CONVERSION VIA MSSS MMMEDRGEN"
END_GROUP                         = PDS_HISTORY_PARMS
```

```
/* Camera Model Data Elements */

GROUP                                  = GEOMETRIC_CAMERA_MODEL_PARMS
 ^MODEL_DESC                             = "GEOMETRIC_CM.TXT"
 FILTER_NAME                             = MASTCAM_L0_CLEAR
 MODEL_TYPE                              = "CAHVOR"
 MODEL_COMPONENT_ID                      = ("C", "A", "H", "V", "O", "R")
 MODEL_COMPONENT_NAME                    = ("CENTER", "AXIS", "HORIZONTAL",
                                           "VERTICAL", "OPTICAL", "RADIAL")
 MODEL_COMPONENT_1                       = ( 6.852712e-01, 5.138023e-01,
-1.978161e+00 )
 MODEL_COMPONENT_2                       = ( 5.264679e-01, -8.219916e-01,
2.171297e-01 )
 MODEL_COMPONENT_3                       = ( 3.968181e+03, 2.417095e+03,
3.176776e+01 )
 MODEL_COMPONENT_4                       = ( -2.351260e+02, 3.500144e+02,
4.664586e+03 )
 MODEL_COMPONENT_5                       = ( 5.282578e-01, -8.213505e-01,
2.152003e-01 )
 MODEL_COMPONENT_6                       = ( -1.510000e-04, -1.391890e-01,
-1.250336e+00 )
 REFERENCE_COORD_SYSTEM_NAME             = ROVER_NAV_FRAME
 COORDINATE_SYSTEM_INDEX_NAME            = ("SITE", "DRIVE", "POSE",
                                           "ARM", "CHIMRA", "DRILL",
                                           "RSM", "HGA",
                                           "DRT", "IC")
 REFERENCE_COORD_SYSTEM_INDEX            = (6, 82, 6,
                                           1096, 267, 176,
                                           972, 1110,
                                           0, 26 )
END_GROUP                              = GEOMETRIC_CAMERA_MODEL_PARMS


/* Coordinate System State: Rover */

GROUP                                  = ROVER_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                         = telemetry
 COORDINATE_SYSTEM_NAME                  = ROVER_NAV_FRAME
 COORDINATE_SYSTEM_INDEX_NAME            = ("SITE", "DRIVE", "POSE",
```

```
                                      "ARM", "CHIMRA", "DRILL",
                                      "RSM", "HGA",
                                      "DRT", "IC")
 COORDINATE_SYSTEM_INDEX            = (6, 82, 6,
                                      1096, 267, 176,
                                      972, 1110,
                                      0, 26 )
 ORIGIN_OFFSET_VECTOR               = (0.279950, -1.236299, -0.068265)
 ORIGIN_ROTATION_QUATERNION         = (0.1748126,
                                      0.0162626,
                                      0.0378810,
                                      -0.9837383)
 POSITIVE_AZIMUTH_DIRECTION         = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION       = UP
 QUATERNION_MEASUREMENT_METHOD      = TILT_ONLY
 REFERENCE_COORD_SYSTEM_NAME        = SITE_FRAME
END_GROUP                          = ROVER_COORDINATE_SYSTEM_PARMS


/* Coordinate System State: Remote Sensing Mast */

GROUP                              = RSM_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                    = telemetry
 COORDINATE_SYSTEM_NAME             = RSM_HEAD_FRAME
 COORDINATE_SYSTEM_INDEX_NAME       = ("SITE", "DRIVE", "POSE",
                                      "ARM", "CHIMRA", "DRILL",
                                      "RSM", "HGA",
                                      "DRT", "IC")
 COORDINATE_SYSTEM_INDEX            = (6, 82, 6,
                                      1096, 267, 176,
                                      972, 1110,
                                      0, 26 )
 ORIGIN_OFFSET_VECTOR               = (0.804427, 0.559542, -1.906076)
 ORIGIN_ROTATION_QUATERNION         = ( 0.8654016,
                                       -0.0529545,
                                       -0.0954168,
                                       -0.4890518)
 POSITIVE_AZIMUTH_DIRECTION         = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION       = UP
 REFERENCE_COORD_SYSTEM_NAME        = ROVER_NAV_FRAME
```

```
END_GROUP                          = RSM_COORDINATE_SYSTEM_PARMS

/* Coordinate System State: Robotic Arm */

GROUP                              = ARM_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                     = telemetry
 COORDINATE_SYSTEM_NAME              = ARM_DRILL_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
 COORDINATE_SYSTEM_INDEX             = (6, 82, 6,
                                        1096, 267, 176,
                                        972, 1110, 0, 26 )
 ORIGIN_OFFSET_VECTOR                = (1.000274, -0.061308, -0.854421)
 ORIGIN_ROTATION_QUATERNION          = ( 0.1171885,
                                         -0.5568511,
                                         -0.4604641,
                                         -0.6812903)
 POSITIVE_AZIMUTH_DIRECTION          = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION        = UP
 REFERENCE_COORD_SYSTEM_NAME         = ROVER_NAV_FRAME
END_GROUP                          = ARM_COORDINATE_SYSTEM_PARMS

/* Articulation Device State: Remote Sensing Mast */

GROUP                              = RSM_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID              = RSM
 ARTICULATION_DEVICE_NAME            = "REMOTE SENSING MAST"
 ARTICULATION_DEVICE_ANGLE_NAME      = ("AZIMUTH-MEASURED",
                                        "ELEVATION-MEASURED",
                                        "AZIMUTH-REQUESTED",
                                        "ELEVATION-REQUESTED",
                                        "AZIMUTH-INITIAL",
                                        "ELEVATION-INITIAL",
                                        "AZIMUTH-FINAL",
                                        "ELEVATION-FINAL")
 ARTICULATION_DEVICE_ANGLE           = ( 2.138695 <rad>, 1.369004 <rad>,
                                         2.141518 <rad>, 1.373124 <rad>,
                                         3.158974 <rad>, 0.750427 <rad>,
```

```
                                      2.141463 <rad>, 1.373079 <rad> )
 ARTICULATION_DEVICE_MODE            = DEPLOYED
END_GROUP                          = RSM_ARTICULATION_STATE_PARMS


/* Articulation Device State: Robotic Arm */

GROUP                              = ARM_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID              = ARM
 ARTICULATION_DEVICE_NAME            = "SAMPLE ARM"
 ARTICULATION_DEVICE_ANGLE_NAME      = ("JOINT 1 AZIMUTH-ENCODER",
                                        "JOINT 2 ELEVATION-ENCODER",
                                        "JOINT 3 ELBOW-ENCODER",
                                        "JOINT 4 WRIST-ENCODER",
                                        "JOINT 5 TURRET-ENCODER",
                                        "JOINT 1 AZIMUTH-RESOLVER",
                                        "JOINT 2 ELEVATION-RESOLVER",
                                        "JOINT 3 ELBOW-RESOLVER",
                                        "JOINT 4 WRIST-RESOLVER",
                                        "JOINT 5 TURRET-RESOLVER")
 ARTICULATION_DEVICE_ANGLE           = ( 0.519990 <rad>,
                                        -1.059992 <rad>,
                                        -0.799997 <rad>,
                                        0.250051 <rad>,
                                        4.600031 <rad>,
                                        0.517548 <rad>,
                                        -1.061398 <rad>,
                                        -0.806221 <rad>,
                                        0.245080 <rad>,
                                        4.598596 <rad> )
 ARTICULATION_DEVICE_MODE            = "FREE SPACE"
 ARTICULATION_DEVICE_TEMP_NAME       = ("AZIMUTH JOINT",
                                        "ELEVATION JOINT",
                                        "ELBOW JOINT",
                                        "WRIST JOINT",
                                        "TURRET JOINT")
 ARTICULATION_DEVICE_TEMP            = ( 2.8693 <degC>,
                                        0.1209 <degC>,
                                        -2.2257 <degC>,
                                        6.3346 <degC>,
```

```
                                          -0.4169 <degC> )
 CONTACT_SENSOR_STATE_NAME               = ( "MAHLI SWITCH 1", "MAHLI SWITCH 2",
                                            "DRT SWITCH 1", "DRT SWITCH 2",
                                            "DRILL SWITCH 1", "DRILL SWITCH 2",
                                            "APXS DOOR SWITCH", "APXS CONTACT
SWITCH" )
 CONTACT_SENSOR_STATE                    = ( "NO CONTACT","NO CONTACT","NO
CONTACT","NO CONTACT","NO CONTACT","NO CONTACT","NO CONTACT","CLOSED" )

 ARTICULATION_DEV_VECTOR                = ( -0.045240446925163276,
-0.06884415447711946, 0.99660110473632812)
 ARTICULATION_DEV_VECTOR_NAME            = "GRAVITY"
 ARTICULATION_DEV_INSTRUMENT_ID          = "APXS"
END_GROUP                              = ARM_ARTICULATION_STATE_PARMS

/* Articulation Device State: Mobility Chassis */

GROUP                                   = CHASSIS_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID                    = CHASSIS
 ARTICULATION_DEVICE_NAME                  = "MOBILITY CHASSIS"
 ARTICULATION_DEVICE_ANGLE_NAME            = ("LEFT FRONT WHEEL",
                                             "RIGHT FRONT WHEEL",
                                             "LEFT REAR WHEEL",
                                             "RIGHT REAR WHEEL",
                                             "LEFT BOGIE",
                                             "RIGHT BOGIE",
                                             "LEFT DIFFERENTIAL",
                                             "RIGHT DIFFERENTIAL")
 ARTICULATION_DEVICE_ANGLE                 = ( 0.000043 <rad>, -0.000000 <rad>,
-0.000043 <rad>, -0.000043 <rad>,
                                              0.069703 <rad>, 0.038476 <rad>,
                                              0.019094 <rad>, -0.020234 <rad> )
 ARTICULATION_DEVICE_MODE                  = DEPLOYED
END_GROUP                               = CHASSIS_ARTICULATION_STATE_PARMS


/* Articulation Device State: High Gain Antenna */

GROUP                                   = HGA_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID                    = HGA
```

```
 ARTICULATION_DEVICE_NAME            = "HIGH GAIN ANTENNA"
 ARTICULATION_DEVICE_ANGLE_NAME      = ("AZIMUTH", "ELEVATION")
 ARTICULATION_DEVICE_ANGLE           = ( 0.000000 <rad>, -0.784997 <rad> )
 ARTICULATION_DEVICE_MODE            = "DEPLOYED"
END_GROUP                          = HGA_ARTICULATION_STATE_PARMS


/* Coordinate System State: Site */

GROUP                              = SITE_COORDINATE_SYSTEM_PARMS
 COORDINATE_SYSTEM_NAME              = SITE_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE" )
 COORDINATE_SYSTEM_INDEX             = (6 )
 ORIGIN_OFFSET_VECTOR                = (32.373859, 46.404690, 1.506085 )
 ORIGIN_ROTATION_QUATERNION          = (1.0000000,
                                        0.0000000,
                                        0.0000000,
                                        0.0000000 )
 POSITIVE_AZIMUTH_DIRECTION          = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION        = UP
 REFERENCE_COORD_SYSTEM_NAME         = SITE_FRAME
END_GROUP                          = SITE_COORDINATE_SYSTEM_PARMS


/* Observation Request */

GROUP                              = OBSERVATION_REQUEST_PARMS
 COMMAND_INSTRUMENT_ID               = MAST_LEFT
 RATIONALE_DESC                      = "Surface Sampling System high frame
rate portion drop video"
END_GROUP                          = OBSERVATION_REQUEST_PARMS


/* Image Request */

GROUP                              = IMAGE_REQUEST_PARMS
 FIRST_LINE                          = 1
 FIRST_LINE_SAMPLE                   = 721
 LINES                               = 128
 LINE_SAMPLES                        = 224
```

```
 EXPOSURE_TYPE                          = MANUAL
 EXPOSURE_DURATION                      = 10.0 <ms>
 INST_CMPRS_MODE                        = 3
 INST_CMPRS_NAME                        = "JPEG DISCRETE COSINE TRANSFORM (DCT);
HUFFMAN/QUALITY"
 INST_CMPRS_QUALITY                     = "N/A"
 AUTO_EXPOSURE_DATA_CUT                 = "NULL"
 AUTO_EXPOSURE_PERCENT                  = 010
 AUTO_EXPOSURE_PIXEL_FRACTION           = 002
 MAX_AUTO_EXPOS_ITERATION_COUNT         = 8
 MSL:AUTO_FOCUS_ZSTACK_FLAG             = "NULL"
 MSL:INSTRUMENT_FOCUS_POSITION_CNT      = "NULL"
 MSL:INSTRUMENT_FOCUS_STEP_SIZE         = "NULL"
 MSL:INSTRUMENT_FOCUS_STEPS             = "NULL"
 FILTER_NAME                            = "MASTCAM_L0_CLEAR"
 FILTER_NUMBER                          = "0"
 MSL:INVERSE_LUT_FILE_NAME              = MMM_LUT0
 FLAT_FIELD_CORRECTION_FLAG             = FALSE
END_GROUP                             = IMAGE_REQUEST_PARMS


/* Video Request */

GROUP                                 = VIDEO_REQUEST_PARMS
 GROUP_APPLICABILITY_FLAG               = TRUE
 MSL:COMMANDED_VIDEO_FRAMES             = 1120
 INTERFRAME_DELAY                       = 0 <ms>
END_GROUP                             = VIDEO_REQUEST_PARMS

/* ZStack Request */

GROUP                                 = ZSTACK_REQUEST_PARMS
 GROUP_APPLICABILITY_FLAG               = FALSE
 MSL:ZSTACK_IMAGE_DEPTH                  = "N/A"
 MSL:IMAGE_BLENDING_FLAG                 = "N/A"
 MSL:IMAGE_REGISTRATION_FLAG             = "N/A"
END_GROUP                             = ZSTACK_REQUEST_PARMS


/* Instrument State Results */
```

```
GROUP                                = INSTRUMENT_STATE_PARMS
 HORIZONTAL_FOV                        = 2.7645
 VERTICAL_FOV                          = 1.5600
 DETECTOR_FIRST_LINE                   = 1
 DETECTOR_LINES                        = 1200
 MSL:DETECTOR_SAMPLES                  = 1648
 DETECTOR_TO_IMAGE_ROTATION            = 0.0
 EXPOSURE_DURATION                     = 10.0 <ms>
 FILTER_NAME                           = MASTCAM_L0_CLEAR
 FILTER_NUMBER                         = "0"
 CENTER_FILTER_WAVELENGTH              = 590 <nm>
 FLAT_FIELD_CORRECTION_FLAG            = FALSE
 MSL:INSTRUMENT_CLOCK_START_COUNT      = "423166067.0000"
 MSL:SENSOR_READOUT_RATE               = 20 <MHz>
 INSTRUMENT_TEMPERATURE_NAME           = ( "DEA_TEMP", "FPA_TEMP",
                                           "OPTICS_TEMP", "ELECTRONICS",
                                           "ELECTRONICS_A", "ELECTRONICS_B" )
 INSTRUMENT_TEMPERATURE                = ( 27.4667 <degC>,
                                           -10.7685 <degC>,
                                           -10.7999 <degC>,
                                           -11.1503 <degC>,
                                           "NULL",
                                           "NULL" )
 MSL:INSTRUMENT_TEMPERATURE_STATUS     = ( 0,
                                           0,
                                           0,
                                           0,
                                           "UNK",
                                           "UNK" )
 SAMPLE_BIT_METHOD                     = "HARDWARE"
 SAMPLE_BIT_MODE_ID                    = MMM_LUT0
 MSL:FOCUS_POSITION_COUNT              = 2010
 MSL:FILTER_POSITION_COUNT             = 0
 MSL:COVER_HALL_SENSOR_FLAG            = "N/A"
 MSL:FILTER_HALL_SENSOR_FLAG           = 0
 MSL:FOCUS_HALL_SENSOR_FLAG            = 1
 MSL:LED_STATE_NAME                    = ("VIS1", "VIS2", "UV")
 MSL:LED_STATE_FLAG                    = ( "N/A", "N/A", "N/A" )
 DETECTOR_ERASE_COUNT                  = 0
```

```
END_GROUP                          = INSTRUMENT_STATE_PARMS


/* Image Data Elements */

GROUP                              = IMAGE_PARMS
 INST_CMPRS_MODE                     = 3
 INST_CMPRS_NAME                     = "JPEG DISCRETE COSINE TRANSFORM (DCT);
HUFFMAN/QUALITY"
 INST_CMPRS_QUALITY                  = 85
 MSL:INVERSE_LUT_FILE_NAME           = MMM_LUT0
 PIXEL_AVERAGING_HEIGHT              = 1
 PIXEL_AVERAGING_WIDTH               = 1
END_GROUP                          = IMAGE_PARMS

/* Video Data Elements */

GROUP                              = VIDEO_PARMS
 GROUP_APPLICABILITY_FLAG            = TRUE
 MSL:GOP_FRAME_INDEX                 = 0
 MSL:GOP_TOTAL_FRAMES                = 16
 MSL:GOP_OFFSET                      = ( 64, 4096, 6144, 8192, 10240, 12288,
14336, 16384, 18432, 20480, 22528, 24576, 26624, 28672, 30720, 32768 )
 MSL:GOP_LENGTH                      = ( 1268, 1257, 1283, 1252, 1269, 1264,
1274, 1277, 1249, 1265, 1264, 1272, 1262, 1254, 1244, 1272 )
END_GROUP                          = VIDEO_PARMS


/* Derived Data Elements */

GROUP                              = DERIVED_IMAGE_PARMS
 MSL:INFINITY_CONSTANT               = 999999
 MSL:COVER_STATE_FLAG                = "N/A"
 MSL:MINIMUM_FOCUS_DISTANCE          = 0.7 <m>
 MSL:BEST_FOCUS_DISTANCE             = 0.877 <m>
 MSL:MAXIMUM_FOCUS_DISTANCE          = 1.1 <m>
 MSL:FRAME_RATE                      = 30.889 <fps>
 FIXED_INSTRUMENT_AZIMUTH            = 143.8414
 FIXED_INSTRUMENT_ELEVATION          = -14.3439
 SOLAR_AZIMUTH                       = 257.3686
```

```
 SOLAR_ELEVATION                     = 25.2781
END_GROUP                           = DERIVED_IMAGE_PARMS

/* Processing Data Elements */
GROUP                             = PROCESSING_PARMS
 DARK_LEVEL_CORRECTION               = 117
 SHUTTER_EFFECT_CORRECTION_FLAG      = "N/A"
 RADIOMETRIC_CORRECTION_TYPE         = "N/A"
 RADIANCE_OFFSET                     = "N/A"
 RADIANCE_SCALING_FACTOR             = "N/A"
 FLAT_FIELD_CORRECTION_FLAG          = "N/A"
END_GROUP                         = PROCESSING_PARMS


/* PRIMARY DATA OBJECT */

OBJECT                            = MINIHEADER_TABLE
  RECORD_TYPE                     = FIXED_LENGTH
  FILE_RECORDS                    = 64

  ROWS                            = 1
  COLUMNS                         = 1
  ROW_BYTES                       = 64
  INTERCHANGE_FORMAT              = BINARY

  OBJECT                          = COLUMN
    NAME                          = CAMERA_PRODUCT_ID
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 1
    BYTES                         = 4
    DESCRIPTION                   = "Camera data product ID"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = MAGIC0
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 5
    BYTES                         = 4
    DESCRIPTION                   = "Bit pattern 0xFF00F0CA"
  END_OBJECT                      = COLUMN
```

```
OBJECT                          = COLUMN
  NAME                          = SCLK
  DATA_TYPE                     = MSB_UNSIGNED_INTEGER
  START_BYTE                    = 9
  BYTES                         = 4
  DESCRIPTION                   = "instrument SCLK"
END_OBJECT                      = COLUMN

OBJECT                          = COLUMN
  NAME                          = DETECTOR_ERASE_COUNT
  DATA_TYPE                     = MSB_UNSIGNED_INTEGER
  START_BYTE                    = 13
  BYTES                         = 2
  DESCRIPTION                   = "vertical flush"
END_OBJECT                      = COLUMN

OBJECT                          = COLUMN
  NAME                          = CMD0
  DATA_TYPE                     = MSB_UNSIGNED_INTEGER
  START_BYTE                    = 15
  BYTES                         = 4
  DESCRIPTION                   = ""

  OBJECT                        = BIT_COLUMN
    NAME                        = SPARE
    BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
    START_BIT                   = 1
    BITS                        = 4
    DESCRIPTION                 = "unused"
  END_OBJECT                    = BIT_COLUMN

  OBJECT                        = BIT_COLUMN
    NAME                        = CCD_STATE
    BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
    START_BIT                   = 5
    BITS                        = 4
    DESCRIPTION                 = "refer to section 4 of the MMM SIS"
  END_OBJECT                    = BIT_COLUMN
```

```
OBJECT                          = BIT_COLUMN
  NAME                          = LED1_CONTROL
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 9
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = LED2_CONTROL
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 10
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = LED3_CONTROL
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 11
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = VIDEO_EXPOSURE
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 12
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = CLKDIV2
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 13
  BITS                          = 1
  DESCRIPTION                   = "refer to section 4 of the MMM SIS"
END_OBJECT                      = BIT_COLUMN
```

```
  OBJECT                          = BIT_COLUMN
    NAME                          = LONG_INTEGRATION_MODE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 14
    BITS                          = 1
    DESCRIPTION                   = "0 off, 1 on"
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = TEST_MODE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 15
    BITS                          = 1
    DESCRIPTION                   = "0 off, 1 on"
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = CLKDIV1
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 16
    BITS                          = 1
    DESCRIPTION                   = "refer to section 4 of the MMM SIS"
  END_OBJECT                      = BIT_COLUMN
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = FILTER_NUMBER
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 17
  BYTES                           = 1
  MINIMUM                         = 0
  MAXIMUM                         = 7
  DESCRIPTION                     = "optical filter index"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = EXPOSURE_DURATION
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 18
  BYTES                           = 3
```

```
  DESCRIPTION                = "exposure in ms*10"
END_OBJECT                   = COLUMN

OBJECT                       = COLUMN
  NAME                       = SX
  DATA_TYPE                  = MSB_UNSIGNED_INTEGER
  START_BYTE                 = 21
  BYTES                      = 1
  DESCRIPTION                = "subframe starting column divided by 8"
END_OBJECT                   = COLUMN

OBJECT                       = COLUMN
  NAME                       = SY
  DATA_TYPE                  = MSB_UNSIGNED_INTEGER
  START_BYTE                 = 22
  BYTES                      = 1
  DESCRIPTION                = "subframe starting row divided by 8"
END_OBJECT                   = COLUMN

OBJECT                       = COLUMN
  NAME                       = WIDTH
  DATA_TYPE                  = MSB_UNSIGNED_INTEGER
  START_BYTE                 = 23
  BYTES                      = 1
  DESCRIPTION                = "width of image divided by 8"
END_OBJECT                   = COLUMN

OBJECT                       = COLUMN
  NAME                       = HEIGHT
  DATA_TYPE                  = MSB_UNSIGNED_INTEGER
  START_BYTE                 = 24
  BYTES                      = 1
  DESCRIPTION                = "height of image divided by 8"
END_OBJECT                   = COLUMN

OBJECT                       = COLUMN
  NAME                       = IMAGE_OR_FOCUS_MERGE1
  DATA_TYPE                  = MSB_UNSIGNED_INTEGER
  START_BYTE                 = 25
  BYTES                      = 4
```

```
  DESCRIPTION                     = "For imaging or video products:
                                     Auto focus bits
                                     -----------------------
                                     initial position (15 bits)
                                     step size        (10 bits)
                                     number of steps  (6 bits)
                                     zstack flag      (1 bit)

                                     For focus merge products:
                                       starting CDPID (32 bits)
                                    "
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = IMAGE_OR_FOCUS_MERGE2
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 29
  BYTES                           = 4
  DESCRIPTION                     = "For imaging or video products:
                                     Auto exposure bits
                                     -----------------------
                                     target dn         (8 bits)
                                     exposure fraction (8 bits)
                                     early termination (8 bits)
                                     number of steps   (8 bits)

                                   For focus merge products:
                                     Focus merge bits
                                     -----------------------
                                     number of images  (8 bits)
                                     padding           (22 bits)
                                     image blending    (1 bit)
                                     registration      (1 bit)
                                    "
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = SPARE
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 33
```

```
    BYTES                         = 2
    DESCRIPTION                   = "undefined"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = COLOR_MODE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 35
    BYTES                         = 1
    DESCRIPTION                   = "0   - grayscale JPEG*
                                     1   - 422 color JPEG
                                     2   - 444 color JPEG
                                    0xFF - lossless compression
                                  *Note: see COMPRESSION_QUALITY
"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = INST_CMPRS_QUALITY
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 36
    BYTES                         = 1
    DESCRIPTION                   = "JPEG compression quality: 1 to 100,
                                     if 0 and COLOR_MODE is 0, then
                                     encode image without any compression"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = SPARE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 37
    BYTES                         = 3
    DESCRIPTION                   = ""
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = COMPANDING_MODE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 40
    BYTES                         = 1
```

```
  DESCRIPTION                   = "companding table 0 to 32
                                   0xFF means 16 bit calibration mode"
END_OBJECT                        = COLUMN


OBJECT                            = COLUMN
  NAME                            = CAM_STATUS
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 41
  BYTES                           = 1
  DESCRIPTION                     = ""

  OBJECT                          = BIT_COLUMN
    NAME                          = SPARE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 1
    BITS                          = 1
    DESCRIPTION                   = "undefined"
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = UV_LED
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 2
    BITS                          = 1
    DESCRIPTION                   = ""
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = VIS1_LED
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 3
    BITS                          = 1
    DESCRIPTION                   = ""
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = VIS2_LED
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 4
```

```
    BITS                          = 1
    DESCRIPTION                   = ""
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = SPARE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 5
    BITS                          = 1
    DESCRIPTION                   = "undefined"
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = MASTCAM_FILTER_HALL_STATE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 6
    BITS                          = 1
    DESCRIPTION                   = "0 off, 1 on"
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = MAHLI_COVER_HALL_STATE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 7
    BITS                          = 1
    DESCRIPTION                   = "0 off, 1 on"
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = FOCUS_HALL_STATE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 8
    BITS                          = 1
    DESCRIPTION                   = "0 off, 1 on"
  END_OBJECT                      = BIT_COLUMN

END_OBJECT                        = COLUMN

OBJECT                           = COLUMN
  NAME                           = DEA_SERIAL_NUMBER
```

```
    DATA_TYPE                      = MSB_UNSIGNED_INTEGER
    START_BYTE                     = 42
    BYTES                          = 3
    DESCRIPTION                    = "Serial number assigned to DEA"
  END_OBJECT                       = COLUMN

  OBJECT                            = COLUMN
    NAME                            = FOCUS_POSITION_COUNT
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 45
    BYTES                           = 4
    DESCRIPTION                     = "position of focus motor (in steps)"
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = SPARE
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 49
    BYTES                           = 2
    DESCRIPTION                     = ""
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = FILTER_POSITION_COUNT
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 51
    BYTES                           = 2
    DESCRIPTION                     = "position of filter motor (in steps)"
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = DC_OFFSET
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 53
    BYTES                           = 4
    DESCRIPTION                     = "DC offset bias"
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = INIT_SIZE
```

```
    DATA_TYPE                        = MSB_UNSIGNED_INTEGER
    START_BYTE                       = 57
    BYTES                            = 4
    DESCRIPTION                      = ""
  END_OBJECT                         = COLUMN

  OBJECT                             = COLUMN
    NAME                             = MAGIC1
    DATA_TYPE                        = MSB_UNSIGNED_INTEGER
    START_BYTE                       = 61
    BYTES                            = 4
    DESCRIPTION                      = "Bit pattern 0x1010CC28"
  END_OBJECT                        = COLUMN

END_OBJECT                           = MINIHEADER_TABLE


END
```

Example Mastcam Right (M100) Label Product, 0357MR0014570040301301I01_XXXX.LBL:

```
PDS_VERSION_ID                    = PDS3

/* Pointers to Data Objects */

OBJECT                      = COMPRESSED_FILE
  FILE_NAME                 = "0357MR0014570040301301I01_XXXX.DAT"
  RECORD_TYPE               = UNDEFINED
  FILE_RECORDS              = "N/A"
  ENCODING_TYPE             = "MSLMMM-COMPRESSED"
  INTERCHANGE_FORMAT        = BINARY
  UNCOMPRESSED_FILE_NAME    = ( "0357MR0014570040301301I01_XXXX_00.IMG" )
  REQUIRED_STORAGE_BYTES    = "11072"
  ^MINIHEADER_TABLE         = ("0357MR0014570040301301I01_XXXX.DAT",
                               1 <BYTES> )
  DESCRIPTION              = "The first 64 bytes of the data file
(described by the MINIHEADER_TABLE below) determine the interpretation
of the image in the rest of the file. In particular, if the columns
COLOR_MODE and INST_CMPRS_QUALITY are both 0, the image is a RAW RASTER;
otherwise, the image is a JPEG with a specified mode
(grayscale, 442 colors, or 444 colors) and quality 1 to 100,
or it is LOSSLESS."
END_OBJECT                  = COMPRESSED_FILE

OBJECT                      = UNCOMPRESSED_FILE
  /* DAT2IMG decompression software will generate the following */
  /* IMG files along with corresponding detached PDS labels     */
  FILE_NAME                 = ( "0357MR0014570040301301I01_XXXX_00.IMG" )
  RECORD_TYPE               = FIXED_LENGTH
  FILE_RECORDS              = 972
  RECORD_BYTES              = 64

  /* IMAGE DATA ELEMENTS */
  OBJECT                            = IMAGE
    LINES                           = 144
    LINE_SAMPLES                    = 144
    SAMPLE_TYPE                     = UNSIGNED_INTEGER
    SAMPLE_BITS                     = 8
```

```
    BANDS                             = 3
    FIRST_LINE                        = 33
    FIRST_LINE_SAMPLE                 = 257
  END_OBJECT                          = IMAGE

END_OBJECT                    = UNCOMPRESSED_FILE



/* Identification Data Elements */

MSL:ACTIVE_FLIGHT_STRING_ID           = "B"
DATA_SET_ID                           = "MSL-M-MASTCAM-2-EDR-IMG-V1.0"
DATA_SET_NAME                         = "MSL MARS MAST CAMERA 2 EDR IMAGE V1.0"
COMMAND_SEQUENCE_NUMBER               = 0
GEOMETRY_PROJECTION_TYPE              = RAW
IMAGE_ID                              = "0357MR0014570040301301I01"
IMAGE_TYPE                            = THUMBNAIL
MSL:IMAGE_ACQUIRE_MODE                = IMAGE
INSTRUMENT_HOST_ID                    = MSL
INSTRUMENT_HOST_NAME                  = "MARS SCIENCE LABORATORY"
INSTRUMENT_ID                         = MAST_RIGHT
INSTRUMENT_NAME                       = "MAST CAMERA RIGHT"
INSTRUMENT_SERIAL_NUMBER              = "3004"
FLIGHT_SOFTWARE_VERSION_ID            = "1105031458"
INSTRUMENT_TYPE                       = "IMAGING CAMERA"
INSTRUMENT_VERSION_ID                 = FM
MSL:LOCAL_MEAN_SOLAR_TIME             = "Sol-00357M12:32:04.073"
LOCAL_TRUE_SOLAR_TIME                 = "11:52:50"
MISSION_NAME                          = "MARS SCIENCE LABORATORY"
MISSION_PHASE_NAME                    = "PRIMARY SURFACE MISSION"
OBSERVATION_ID                        = "NULL"
PLANET_DAY_NUMBER                     = 0357
INSTITUTION_NAME                      = "MALIN SPACE SCIENCE SYSTEMS"
PRODUCT_CREATION_TIME                 = 2013-11-09T05:00:50.214
PRODUCT_VERSION_ID                    = "V1.0"
PRODUCT_ID                            = "0357MR0014570040301301I01_XXXX"
SOURCE_PRODUCT_ID                     = "McamRThumbnail_0429185296-00000-1"
MSL:INPUT_PRODUCT_ID                  = "0357MR0014570040301301I01_DXXX"
MSL:CALIBRATION_FILE_NAME             = "N/A"
```

```
RELEASE_ID                          = "0004"
MSL:REQUEST_ID                      = "3001457004"
MSL:CAMERA_PRODUCT_ID               = "1301"
MSL:CAMERA_PRODUCT_ID_COUNT         = 3
ROVER_MOTION_COUNTER_NAME           = ("SITE", "DRIVE", "POSE",
                                       "ARM", "CHIMRA", "DRILL",
                                       "RSM", "HGA",
                                       "DRT", "IC")
ROVER_MOTION_COUNTER                = (11, 748,
                                       4, 0,
                                       0, 0,
                                       208, 74,
                                       0, 0 )
SEQUENCE_ID                         = "mcam01457"
SEQUENCE_VERSION_ID                 = "0"
SOLAR_LONGITUDE                     = 3.652
SPACECRAFT_CLOCK_CNT_PARTITION      = 1
SPACECRAFT_CLOCK_START_COUNT        = "429185301.0000"
SPACECRAFT_CLOCK_STOP_COUNT         = "429185301.4688"
IMAGE_TIME                          = 2013-08-07T22:15:25.698
START_TIME                          = 2013-08-07T22:15:25.698
STOP_TIME                           = 2013-08-07T22:15:32.852
TARGET_NAME                         = "MARS"
TARGET_TYPE                         = "PLANET"

/* Telemetry Data Elements */

APPLICATION_PROCESS_ID              = 424
APPLICATION_PROCESS_NAME            = McamRThumbnail
EARTH_RECEIVED_START_TIME           = 2013-08-08T00:44:33
SPICE_FILE_NAME                     = "chronos.msl_gc120806_v3"
TELEMETRY_PROVIDER_ID               = "NULL"
MSL:TELEMETRY_SOURCE_HOST_NAME      = "NULL"
TELEMETRY_SOURCE_NAME               = "McamRThumbnail_0429185296-00000-1"
TELEMETRY_SOURCE_TYPE               = "DATA PRODUCT"
MSL:COMMUNICATION_SESSION_ID        = "33572"
MSL:PRODUCT_COMPLETION_STATUS       = COMPLETE_CHECKSUM_PASS
MSL:SEQUENCE_EXECUTION_COUNT        = 1
MSL:TELEMETRY_SOURCE_START_TIME     = 2013-08-07T22:15:21
MSL:TELEMETRY_SOURCE_SCLK_START     = "1/429185296-00000"
```

```
/* History Data Elements */

GROUP                                = PDS_HISTORY_PARMS
 SOFTWARE_NAME                        = MMMEDRGEN
 SOFTWARE_VERSION_ID                  = "pds3.0"
 PROCESSING_HISTORY_TEXT              = "CODMAC LEVEL 1 to LEVEL 2
                                         CONVERSION VIA MSSS MMMEDRGEN"
END_GROUP                            = PDS_HISTORY_PARMS

/* Camera Model Data Elements */

GROUP                               = GEOMETRIC_CAMERA_MODEL_PARMS
 ^MODEL_DESC                          = "GEOMETRIC_CM.TXT"
 FILTER_NAME                          = MASTCAM_R4_905NM
 MODEL_TYPE                           = "CAHVOR"
 MODEL_COMPONENT_ID                   = ("C", "A", "H", "V", "O", "R")
 MODEL_COMPONENT_NAME                 = ("CENTER", "AXIS", "HORIZONTAL",
                                         "VERTICAL", "OPTICAL", "RADIAL")
 MODEL_COMPONENT_1                    = ( 6.920460e-01, 6.597721e-01,
-1.911622e+00 )
 MODEL_COMPONENT_2                    = ( 6.459490e-02, 7.617079e-01,
6.446789e-01 )
 MODEL_COMPONENT_3                    = ( -1.662161e+03, 1.857400e+02,
6.408936e+01 )
 MODEL_COMPONENT_4                    = ( -6.685609e+01, -1.027422e+03,
1.318020e+03 )
 MODEL_COMPONENT_5                    = ( 7.103488e-02, 7.546823e-01,
6.522203e-01 )
 MODEL_COMPONENT_6                    = ( -1.060000e-04, 1.436779e+00,
-6.858840e-01 )
 REFERENCE_COORD_SYSTEM_NAME          = ROVER_NAV_FRAME
 COORDINATE_SYSTEM_INDEX_NAME         = ("SITE", "DRIVE", "POSE",
                                         "ARM", "CHIMRA", "DRILL",
                                         "RSM", "HGA",
                                         "DRT", "IC")
 REFERENCE_COORD_SYSTEM_INDEX         = (11, 748, 4,
                                         0, 0, 0,
                                         208, 74,
```

```
                                      0, 0 )
END_GROUP                          = GEOMETRIC_CAMERA_MODEL_PARMS


/* Coordinate System State: Rover */

GROUP                              = ROVER_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                     = telemetry
 COORDINATE_SYSTEM_NAME              = ROVER_NAV_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
 COORDINATE_SYSTEM_INDEX             = (11, 748, 4,
                                        0, 0, 0,
                                        208, 74,
                                        0, 0 )
 ORIGIN_OFFSET_VECTOR                = (-40.856239, -173.398026, 0.007715)
 ORIGIN_ROTATION_QUATERNION          = (0.2169504,
                                        0.0003697,
                                        -0.0095111,
                                        -0.9761362)
 POSITIVE_AZIMUTH_DIRECTION          = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION        = UP
 QUATERNION_MEASUREMENT_METHOD       = TILT_ONLY
 REFERENCE_COORD_SYSTEM_NAME         = SITE_FRAME
END_GROUP                          = ROVER_COORDINATE_SYSTEM_PARMS


/* Coordinate System State: Remote Sensing Mast */

GROUP                              = RSM_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                     = telemetry
 COORDINATE_SYSTEM_NAME              = RSM_HEAD_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
 COORDINATE_SYSTEM_INDEX             = (11, 748, 4,
                                        0, 0, 0,
```

```
                                    208, 74,
                                    0, 0 )
 ORIGIN_OFFSET_VECTOR                = (0.804492, 0.559286, -1.906076)
 ORIGIN_ROTATION_QUATERNION          = ( 0.6821917,
                                     0.2378137,
                                     -0.2506436,
                                     0.6443889)
 POSITIVE_AZIMUTH_DIRECTION          = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION        = UP
 REFERENCE_COORD_SYSTEM_NAME         = ROVER_NAV_FRAME
END_GROUP                          = RSM_COORDINATE_SYSTEM_PARMS

/* Coordinate System State: Robotic Arm */

GROUP                              = ARM_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                     = telemetry
 COORDINATE_SYSTEM_NAME              = ARM_DRILL_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                    "ARM", "CHIMRA", "DRILL",
                                    "RSM", "HGA",
                                    "DRT", "IC")
 COORDINATE_SYSTEM_INDEX             = (11, 748, 4,
                                    0, 0, 0,
                                    208, 74, 0, 0 )
 ORIGIN_OFFSET_VECTOR                = (1.172002, -0.275560, -0.275139)
 ORIGIN_ROTATION_QUATERNION          = ( 0.9559655,
                                     -0.0093984,
                                     0.0026943,
                                     -0.2933163)
 POSITIVE_AZIMUTH_DIRECTION          = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION        = UP
 REFERENCE_COORD_SYSTEM_NAME         = ROVER_NAV_FRAME
END_GROUP                          = ARM_COORDINATE_SYSTEM_PARMS

/* Articulation Device State: Remote Sensing Mast */

GROUP                              = RSM_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID              = RSM
 ARTICULATION_DEVICE_NAME            = "REMOTE SENSING MAST"
 ARTICULATION_DEVICE_ANGLE_NAME      = ("AZIMUTH-MEASURED",
```

```
                                         "ELEVATION-MEASURED",
                                         "AZIMUTH-REQUESTED",
                                         "ELEVATION-REQUESTED",
                                         "AZIMUTH-INITIAL",
                                         "ELEVATION-INITIAL",
                                         "AZIMUTH-FINAL",
                                         "ELEVATION-FINAL")
 ARTICULATION_DEVICE_ANGLE            = ( 4.680811 <rad>, 0.881660 <rad>,
                                          4.682363 <rad>, 0.885409 <rad>,
                                          6.274221 <rad>, 1.026664 <rad>,
                                          4.682561 <rad>, 0.885404 <rad> )
 ARTICULATION_DEVICE_MODE             = DEPLOYED
END_GROUP                           = RSM_ARTICULATION_STATE_PARMS


/* Articulation Device State: Robotic Arm */

GROUP                               = ARM_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID               = ARM
 ARTICULATION_DEVICE_NAME             = "SAMPLE ARM"
 ARTICULATION_DEVICE_ANGLE_NAME       = ("JOINT 1 AZIMUTH-ENCODER",
                                         "JOINT 2 ELEVATION-ENCODER",
                                         "JOINT 3 ELBOW-ENCODER",
                                         "JOINT 4 WRIST-ENCODER",
                                         "JOINT 5 TURRET-ENCODER",
                                         "JOINT 1 AZIMUTH-RESOLVER",
                                         "JOINT 2 ELEVATION-RESOLVER",
                                         "JOINT 3 ELBOW-RESOLVER",
                                         "JOINT 4 WRIST-RESOLVER",
                                         "JOINT 5 TURRET-RESOLVER")
 ARTICULATION_DEVICE_ANGLE            = ( 1.572189 <rad>,
                                          -0.277767 <rad>,
                                          -2.816293 <rad>,
                                          3.121097 <rad>,
                                          0.593767 <rad>,
                                          1.568393 <rad>,
                                          -0.277792 <rad>,
                                          -2.825467 <rad>,
                                          3.116582 <rad>,
                                          0.593480 <rad> )
```

```
 ARTICULATION_DEVICE_MODE              = "FREE SPACE"
 ARTICULATION_DEVICE_TEMP_NAME         = ("AZIMUTH JOINT",
                                          "ELEVATION JOINT",
                                          "ELBOW JOINT",
                                          "WRIST JOINT",
                                          "TURRET JOINT")
 ARTICULATION_DEVICE_TEMP              = ( -34.1245 <degC>,
                                           -38.5651 <degC>,
                                           -26.0659 <degC>,
                                           -34.9685 <degC>,
                                           -36.9949 <degC> )
 CONTACT_SENSOR_STATE_NAME             = ( "MAHLI SWITCH 1", "MAHLI SWITCH 2",
                                           "DRT SWITCH 1", "DRT SWITCH 2",
                                           "DRILL SWITCH 1", "DRILL SWITCH 2",
                                           "APXS DOOR SWITCH", "APXS CONTACT
SWITCH" )
 CONTACT_SENSOR_STATE                  = ( "NO CONTACT","NO CONTACT","NO
CONTACT","NO CONTACT","NO CONTACT","NO CONTACT","NO CONTACT","CLOSED" )

 ARTICULATION_DEV_VECTOR              = ( 0.0034051989205181599,
0.018728595227003098, 0.99981880187988292)
 ARTICULATION_DEV_VECTOR_NAME          = "GRAVITY"
 ARTICULATION_DEV_INSTRUMENT_ID        = "PORTIONER TUBE"
END_GROUP                           = ARM_ARTICULATION_STATE_PARMS

/* Articulation Device State: Mobility Chassis */

GROUP                                = CHASSIS_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID                = CHASSIS
 ARTICULATION_DEVICE_NAME              = "MOBILITY CHASSIS"
 ARTICULATION_DEVICE_ANGLE_NAME        = ("LEFT FRONT WHEEL",
                                          "RIGHT FRONT WHEEL",
                                          "LEFT REAR WHEEL",
                                          "RIGHT REAR WHEEL",
                                          "LEFT BOGIE",
                                          "RIGHT BOGIE",
                                          "LEFT DIFFERENTIAL",
                                          "RIGHT DIFFERENTIAL")
 ARTICULATION_DEVICE_ANGLE             = ( -0.000000 <rad>, -0.000128 <rad>,
-0.000043 <rad>, -0.000043 <rad>,
```

```
                                     -0.000809 <rad>, -0.044734 <rad>,
                                     -0.006893 <rad>, 0.005790 <rad> )
 ARTICULATION_DEVICE_MODE              = DEPLOYED
END_GROUP                            = CHASSIS_ARTICULATION_STATE_PARMS


/* Articulation Device State: High Gain Antenna */

GROUP                                = HGA_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID                = HGA
 ARTICULATION_DEVICE_NAME              = "HIGH GAIN ANTENNA"
 ARTICULATION_DEVICE_ANGLE_NAME        = ("AZIMUTH", "ELEVATION")
 ARTICULATION_DEVICE_ANGLE             = ( 0.000011 <rad>, -0.784964 <rad> )
 ARTICULATION_DEVICE_MODE              = "DEPLOYED"
END_GROUP                            = HGA_ARTICULATION_STATE_PARMS


/* Coordinate System State: Site */

GROUP                                = SITE_COORDINATE_SYSTEM_PARMS
 COORDINATE_SYSTEM_NAME                = SITE_FRAME
 COORDINATE_SYSTEM_INDEX_NAME          = ("SITE" )
 COORDINATE_SYSTEM_INDEX               = (11 )
 ORIGIN_OFFSET_VECTOR                  = (-133.152954, -129.029709, 0.546427 )
 ORIGIN_ROTATION_QUATERNION            = (1.0000000,
                                          0.0000000,
                                          0.0000000,
                                          0.0000000 )
 POSITIVE_AZIMUTH_DIRECTION            = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION          = UP
 REFERENCE_COORD_SYSTEM_NAME           = SITE_FRAME
END_GROUP                            = SITE_COORDINATE_SYSTEM_PARMS


/* Observation Request */

GROUP                                = OBSERVATION_REQUEST_PARMS
 COMMAND_INSTRUMENT_ID                 = MAST_RIGHT
 RATIONALE_DESC                        = "To test use of thumbnails for
multi-spectral analysis"
```

```
END_GROUP                          = OBSERVATION_REQUEST_PARMS


/* Image Request */

GROUP                              = IMAGE_REQUEST_PARMS
 FIRST_LINE                          = 33
 FIRST_LINE_SAMPLE                   = 257
 LINES                               = 1152
 LINE_SAMPLES                        = 1152
 EXPOSURE_TYPE                       = AUTO
 EXPOSURE_DURATION                   = "N/A"
 INST_CMPRS_MODE                     = 3
 INST_CMPRS_NAME                     = "JPEG DISCRETE COSINE TRANSFORM (DCT);
HUFFMAN/QUALITY"
 INST_CMPRS_QUALITY                  = "N/A"
 AUTO_EXPOSURE_DATA_CUT              = "NULL"
 AUTO_EXPOSURE_PERCENT               = 010
 AUTO_EXPOSURE_PIXEL_FRACTION        = 002
 MAX_AUTO_EXPOS_ITERATION_COUNT      = 8
 MSL:AUTO_FOCUS_ZSTACK_FLAG          = "NULL"
 MSL:INSTRUMENT_FOCUS_POSITION_CNT   = "NULL"
 MSL:INSTRUMENT_FOCUS_STEP_SIZE      = "NULL"
 MSL:INSTRUMENT_FOCUS_STEPS          = "NULL"
 FILTER_NAME                         = "MASTCAM_R4_905NM"
 FILTER_NUMBER                       = "4"
 MSL:INVERSE_LUT_FILE_NAME           = MMM_LUT0
 FLAT_FIELD_CORRECTION_FLAG          = FALSE
END_GROUP                          = IMAGE_REQUEST_PARMS


/* Video Request */

GROUP                              = VIDEO_REQUEST_PARMS
 GROUP_APPLICABILITY_FLAG            = FALSE
 MSL:COMMANDED_VIDEO_FRAMES          = "N/A"
 INTERFRAME_DELAY                    = "N/A"
END_GROUP                          = VIDEO_REQUEST_PARMS

/* ZStack Request */
```

```
GROUP                                 = ZSTACK_REQUEST_PARMS
 GROUP_APPLICABILITY_FLAG               = FALSE
 MSL:ZSTACK_IMAGE_DEPTH                  = "N/A"
 MSL:IMAGE_BLENDING_FLAG                 = "N/A"
 MSL:IMAGE_REGISTRATION_FLAG             = "N/A"
END_GROUP                             = ZSTACK_REQUEST_PARMS


/* Instrument State Results */

GROUP                                 = INSTRUMENT_STATE_PARMS
 HORIZONTAL_FOV                         = 4.7296
 VERTICAL_FOV                           = 4.8085
 DETECTOR_FIRST_LINE                    = 1
 DETECTOR_LINES                         = 1200
 MSL:DETECTOR_SAMPLES                   = 1648
 DETECTOR_TO_IMAGE_ROTATION             = 0.0
 EXPOSURE_DURATION                      = 468.8 <ms>
 FILTER_NAME                            = MASTCAM_R4_905NM
 FILTER_NUMBER                          = "4"
 CENTER_FILTER_WAVELENGTH               = 905 <nm>
 FLAT_FIELD_CORRECTION_FLAG             = FALSE
 MSL:INSTRUMENT_CLOCK_START_COUNT       = "429185301.0000"
 MSL:SENSOR_READOUT_RATE                = 10 <MHz>
 INSTRUMENT_TEMPERATURE_NAME            = ( "DEA_TEMP", "FPA_TEMP",
                                            "OPTICS_TEMP", "ELECTRONICS",
                                            "ELECTRONICS_A", "ELECTRONICS_B" )
 INSTRUMENT_TEMPERATURE                 = ( 0.0000 <degC>,
                                            0.0000 <degC>,
                                            -17.6023 <degC>,
                                            -17.6115 <degC>,
                                            "NULL",
                                            "NULL" )
 MSL:INSTRUMENT_TEMPERATURE_STATUS      = ( -42,
                                            -42,
                                            0,
                                            0,
                                            "UNK",
                                            "UNK" )
```

```
 SAMPLE_BIT_METHOD                    = "HARDWARE"
 SAMPLE_BIT_MODE_ID                   = MMM_LUT0
 MSL:FOCUS_POSITION_COUNT             = 2380
 MSL:FILTER_POSITION_COUNT            = -1176
 MSL:COVER_HALL_SENSOR_FLAG           = "N/A"
 MSL:FILTER_HALL_SENSOR_FLAG          = 0
 MSL:FOCUS_HALL_SENSOR_FLAG           = 1
 MSL:LED_STATE_NAME                   = ("VIS1", "VIS2", "UV")
 MSL:LED_STATE_FLAG                   = ( "N/A", "N/A", "N/A" )
 DETECTOR_ERASE_COUNT                 = 4094
END_GROUP                           = INSTRUMENT_STATE_PARMS


/* Image Data Elements */

GROUP                               = IMAGE_PARMS
 INST_CMPRS_MODE                      = 3
 INST_CMPRS_NAME                      = "JPEG DISCRETE COSINE TRANSFORM (DCT);
HUFFMAN/QUALITY"
 INST_CMPRS_QUALITY                   = 95
 MSL:INVERSE_LUT_FILE_NAME            = MMM_LUT0
 PIXEL_AVERAGING_HEIGHT               = 8
 PIXEL_AVERAGING_WIDTH                = 8
END_GROUP                           = IMAGE_PARMS

/* Video Data Elements */

GROUP                               = VIDEO_PARMS
 GROUP_APPLICABILITY_FLAG             = FALSE
 MSL:GOP_FRAME_INDEX                  = "N/A"
 MSL:GOP_TOTAL_FRAMES                 = "N/A"
 MSL:GOP_OFFSET                       = ( "N/A" )
 MSL:GOP_LENGTH                       = ( "N/A" )
END_GROUP                           = VIDEO_PARMS


/* Derived Data Elements */

GROUP                               = DERIVED_IMAGE_PARMS
 MSL:INFINITY_CONSTANT                = 999999
```

```
 MSL:COVER_STATE_FLAG                   = "N/A"
 MSL:MINIMUM_FOCUS_DISTANCE             = 2.6 <m>
 MSL:BEST_FOCUS_DISTANCE                = 2.825 <m>
 MSL:MAXIMUM_FOCUS_DISTANCE             = 3.1 <m>
 MSL:FRAME_RATE                         = "N/A"
 FIXED_INSTRUMENT_AZIMUTH               = 290.2369
 FIXED_INSTRUMENT_ELEVATION             = -41.5769
 SOLAR_AZIMUTH                          = 26.0653
 SOLAR_ELEVATION                        = 83.2805
END_GROUP                              = DERIVED_IMAGE_PARMS

/* Processing Data Elements */
GROUP                                 = PROCESSING_PARMS
 DARK_LEVEL_CORRECTION                  = 117
 SHUTTER_EFFECT_CORRECTION_FLAG         = "N/A"
 RADIOMETRIC_CORRECTION_TYPE            = "N/A"
 RADIANCE_OFFSET                        = "N/A"
 RADIANCE_SCALING_FACTOR                = "N/A"
 FLAT_FIELD_CORRECTION_FLAG             = "N/A"
END_GROUP                             = PROCESSING_PARMS


/* PRIMARY DATA OBJECT */

OBJECT                                = MINIHEADER_TABLE
  RECORD_TYPE                         = FIXED_LENGTH
  FILE_RECORDS                        = 64

  ROWS                                = 1
  COLUMNS                             = 1
  ROW_BYTES                           = 64
  INTERCHANGE_FORMAT                  = BINARY

  OBJECT                              = COLUMN
    NAME                              = CAMERA_PRODUCT_ID
    DATA_TYPE                         = MSB_UNSIGNED_INTEGER
    START_BYTE                        = 1
    BYTES                             = 4
    DESCRIPTION                       = "Camera data product ID"
  END_OBJECT                          = COLUMN
```

```
OBJECT                          = COLUMN
  NAME                          = MAGIC0
  DATA_TYPE                     = MSB_UNSIGNED_INTEGER
  START_BYTE                    = 5
  BYTES                         = 4
  DESCRIPTION                   = "Bit pattern 0xFF00F0CA"
END_OBJECT                      = COLUMN

OBJECT                          = COLUMN
  NAME                          = SCLK
  DATA_TYPE                     = MSB_UNSIGNED_INTEGER
  START_BYTE                    = 9
  BYTES                         = 4
  DESCRIPTION                   = "instrument SCLK"
END_OBJECT                      = COLUMN

OBJECT                          = COLUMN
  NAME                          = DETECTOR_ERASE_COUNT
  DATA_TYPE                     = MSB_UNSIGNED_INTEGER
  START_BYTE                    = 13
  BYTES                         = 2
  DESCRIPTION                   = "vertical flush"
END_OBJECT                      = COLUMN

OBJECT                          = COLUMN
  NAME                          = CMD0
  DATA_TYPE                     = MSB_UNSIGNED_INTEGER
  START_BYTE                    = 15
  BYTES                         = 4
  DESCRIPTION                   = ""

  OBJECT                        = BIT_COLUMN
    NAME                        = SPARE
    BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
    START_BIT                   = 1
    BITS                        = 4
    DESCRIPTION                 = "unused"
  END_OBJECT                    = BIT_COLUMN
```

```
OBJECT                          = BIT_COLUMN
  NAME                          = CCD_STATE
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 5
  BITS                          = 4
  DESCRIPTION                   = "refer to section 4 of the MMM SIS"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = LED1_CONTROL
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 9
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = LED2_CONTROL
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 10
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = LED3_CONTROL
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 11
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = VIDEO_EXPOSURE
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 12
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN
```

```
    OBJECT                          = BIT_COLUMN
      NAME                          = CLKDIV2
      BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
      START_BIT                     = 13
      BITS                          = 1
      DESCRIPTION                   = "refer to section 4 of the MMM SIS"
    END_OBJECT                      = BIT_COLUMN

    OBJECT                          = BIT_COLUMN
      NAME                          = LONG_INTEGRATION_MODE
      BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
      START_BIT                     = 14
      BITS                          = 1
      DESCRIPTION                   = "0 off, 1 on"
    END_OBJECT                      = BIT_COLUMN

    OBJECT                          = BIT_COLUMN
      NAME                          = TEST_MODE
      BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
      START_BIT                     = 15
      BITS                          = 1
      DESCRIPTION                   = "0 off, 1 on"
    END_OBJECT                      = BIT_COLUMN

    OBJECT                          = BIT_COLUMN
      NAME                          = CLKDIV1
      BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
      START_BIT                     = 16
      BITS                          = 1
      DESCRIPTION                   = "refer to section 4 of the MMM SIS"
    END_OBJECT                      = BIT_COLUMN
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = FILTER_NUMBER
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 17
    BYTES                           = 1
    MINIMUM                         = 0
    MAXIMUM                         = 7
```

```
  DESCRIPTION                    = "optical filter index"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = EXPOSURE_DURATION
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 18
  BYTES                          = 3
  DESCRIPTION                  = "exposure in ms*10"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = SX
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 21
  BYTES                          = 1
  DESCRIPTION                    = "subframe starting column divided by 8"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = SY
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 22
  BYTES                          = 1
  DESCRIPTION                    = "subframe starting row divided by 8"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = WIDTH
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 23
  BYTES                          = 1
  DESCRIPTION                    = "width of image divided by 8"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = HEIGHT
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 24
  BYTES                          = 1
```

```
    DESCRIPTION                  = "height of image divided by 8"
  END_OBJECT                     = COLUMN

  OBJECT                         = COLUMN
    NAME                         = IMAGE_OR_FOCUS_MERGE1
    DATA_TYPE                    = MSB_UNSIGNED_INTEGER
    START_BYTE                   = 25
    BYTES                        = 4
    DESCRIPTION                  = "For imaging or video products:
                                    Auto focus bits
                                    -----------------------
                                    initial position (15 bits)
                                    step size        (10 bits)
                                    number of steps  (6 bits)
                                    zstack flag      (1 bit)

                                    For focus merge products:
                                      starting CDPID (32 bits)
                                   "
  END_OBJECT                     = COLUMN

  OBJECT                         = COLUMN
    NAME                         = IMAGE_OR_FOCUS_MERGE2
    DATA_TYPE                    = MSB_UNSIGNED_INTEGER
    START_BYTE                   = 29
    BYTES                        = 4
    DESCRIPTION                  = "For imaging or video products:
                                    Auto exposure bits
                                    -----------------------
                                    target dn         (8 bits)
                                    exposure fraction (8 bits)
                                    early termination (8 bits)
                                    number of steps   (8 bits)

                                  For focus merge products:
                                    Focus merge bits
                                    -----------------------
                                    number of images  (8 bits)
                                    padding           (22 bits)
                                    image blending    (1 bit)
```

```
                                    registration      (1 bit)
                                   "
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = SPARE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 33
    BYTES                         = 2
    DESCRIPTION                   = "undefined"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = COLOR_MODE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 35
    BYTES                         = 1
    DESCRIPTION                   = "0   - grayscale JPEG*
                                     1   - 422 color JPEG
                                     2   - 444 color JPEG
                                    0xFF - lossless compression
                                  *Note: see COMPRESSION_QUALITY
"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = INST_CMPRS_QUALITY
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 36
    BYTES                         = 1
    DESCRIPTION                   = "JPEG compression quality: 1 to 100,
                                     if 0 and COLOR_MODE is 0, then
                                     encode image without any compression"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = SPARE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 37
    BYTES                         = 3
```

```
  DESCRIPTION                      = ""
END_OBJECT                         = COLUMN

OBJECT                             = COLUMN
  NAME                             = COMPANDING_MODE
  DATA_TYPE                        = MSB_UNSIGNED_INTEGER
  START_BYTE                       = 40
  BYTES                            = 1
  DESCRIPTION                    = "companding table 0 to 32
                                    0xFF means 16 bit calibration mode"
END_OBJECT                         = COLUMN


OBJECT                             = COLUMN
  NAME                             = CAM_STATUS
  DATA_TYPE                        = MSB_UNSIGNED_INTEGER
  START_BYTE                       = 41
  BYTES                            = 1
  DESCRIPTION                      = ""

  OBJECT                           = BIT_COLUMN
    NAME                           = SPARE
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 1
    BITS                           = 1
    DESCRIPTION                    = "undefined"
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = UV_LED
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 2
    BITS                           = 1
    DESCRIPTION                    = ""
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = VIS1_LED
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 3
```

```
  BITS                         = 1
  DESCRIPTION                  = ""
END_OBJECT                     = BIT_COLUMN

OBJECT                         = BIT_COLUMN
  NAME                         = VIS2_LED
  BIT_DATA_TYPE                = MSB_UNSIGNED_INTEGER
  START_BIT                    = 4
  BITS                         = 1
  DESCRIPTION                  = ""
END_OBJECT                     = BIT_COLUMN

OBJECT                         = BIT_COLUMN
  NAME                         = SPARE
  BIT_DATA_TYPE                = MSB_UNSIGNED_INTEGER
  START_BIT                    = 5
  BITS                         = 1
  DESCRIPTION                  = "undefined"
END_OBJECT                     = BIT_COLUMN

OBJECT                         = BIT_COLUMN
  NAME                         = MASTCAM_FILTER_HALL_STATE
  BIT_DATA_TYPE                = MSB_UNSIGNED_INTEGER
  START_BIT                    = 6
  BITS                         = 1
  DESCRIPTION                  = "0 off, 1 on"
END_OBJECT                     = BIT_COLUMN

OBJECT                         = BIT_COLUMN
  NAME                         = MAHLI_COVER_HALL_STATE
  BIT_DATA_TYPE                = MSB_UNSIGNED_INTEGER
  START_BIT                    = 7
  BITS                         = 1
  DESCRIPTION                  = "0 off, 1 on"
END_OBJECT                     = BIT_COLUMN

OBJECT                         = BIT_COLUMN
  NAME                         = FOCUS_HALL_STATE
  BIT_DATA_TYPE                = MSB_UNSIGNED_INTEGER
  START_BIT                    = 8
```

```
    BITS                          = 1
    DESCRIPTION                   = "0 off, 1 on"
  END_OBJECT                      = BIT_COLUMN

END_OBJECT                        = COLUMN

OBJECT                           = COLUMN
  NAME                           = DEA_SERIAL_NUMBER
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 42
  BYTES                          = 3
  DESCRIPTION                    = "Serial number assigned to DEA"
END_OBJECT                       = COLUMN

OBJECT                            = COLUMN
  NAME                            = FOCUS_POSITION_COUNT
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 45
  BYTES                           = 4
  DESCRIPTION                     = "position of focus motor (in steps)"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = SPARE
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 49
  BYTES                           = 2
  DESCRIPTION                     = ""
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = FILTER_POSITION_COUNT
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 51
  BYTES                           = 2
  DESCRIPTION                     = "position of filter motor (in steps)"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = DC_OFFSET
```

```
    DATA_TYPE                        = MSB_UNSIGNED_INTEGER
    START_BYTE                       = 53
    BYTES                            = 4
    DESCRIPTION                      = "DC offset bias"
  END_OBJECT                         = COLUMN

  OBJECT                             = COLUMN
    NAME                             = INIT_SIZE
    DATA_TYPE                        = MSB_UNSIGNED_INTEGER
    START_BYTE                       = 57
    BYTES                            = 4
    DESCRIPTION                      = ""
  END_OBJECT                         = COLUMN

  OBJECT                             = COLUMN
    NAME                             = MAGIC1
    DATA_TYPE                        = MSB_UNSIGNED_INTEGER
    START_BYTE                       = 61
    BYTES                            = 4
    DESCRIPTION                      = "Bit pattern 0x1010CC28"
  END_OBJECT                        = COLUMN

END_OBJECT                           = MINIHEADER_TABLE


END
```

Example MAHLI Label Product, 0303MH0002900000103786R00_XXXX .LBL:

```
PDS_VERSION_ID                    = PDS3

/* Pointers to Data Objects */

OBJECT                        = COMPRESSED_FILE
  FILE_NAME                   = "0303MH0002900000103786R00_XXXX.DAT"
  RECORD_TYPE                 = UNDEFINED
  FILE_RECORDS                = "N/A"
  ENCODING_TYPE               = "MSLMMM-COMPRESSED"
  INTERCHANGE_FORMAT          = BINARY
  UNCOMPRESSED_FILE_NAME      = ( "0303MH0002900000103786R00_XXXX_00.IMG" )
  REQUIRED_STORAGE_BYTES      = "1193472"
  ^MINIHEADER_TABLE           = ("0303MH0002900000103786R00_XXXX.DAT",
                                 1 <BYTES> )
  DESCRIPTION                = "The first 64 bytes of the data file
(described by the MINIHEADER_TABLE below) determine the interpretation
of the image in the rest of the file. In particular, if the columns
COLOR_MODE and INST_CMPRS_QUALITY are both 0, the image is a RAW RASTER;
otherwise, the image is a JPEG with a specified mode
(grayscale, 442 colors, or 444 colors) and quality 1 to 100,
or it is LOSSLESS."
END_OBJECT                    = COMPRESSED_FILE

OBJECT                        = UNCOMPRESSED_FILE
  /* DAT2IMG decompression software will generate the following */
  /* IMG files along with corresponding detached PDS labels     */
  FILE_NAME                   = ( "0303MH0002900000103786R00_XXXX_00.IMG" )
  RECORD_TYPE                 = FIXED_LENGTH
  FILE_RECORDS                = 87912
  RECORD_BYTES                = 64

  /* IMAGE DATA ELEMENTS */
  OBJECT                              = IMAGE
    LINES                             = 1184
    LINE_SAMPLES                      = 1584
    SAMPLE_TYPE                       = UNSIGNED_INTEGER
    SAMPLE_BITS                       = 8
```

```
    BANDS                              = 3
    FIRST_LINE                         = 17
    FIRST_LINE_SAMPLE                  = 33
  END_OBJECT                           = IMAGE

END_OBJECT                     = UNCOMPRESSED_FILE



/* Identification Data Elements */

MSL:ACTIVE_FLIGHT_STRING_ID            = "B"
DATA_SET_ID                            = "MSL-M-MAHLI-2-EDR-Z-V1.0"
DATA_SET_NAME                          = "MSL MARS HAND LENS IMAGER 2 EDR ZSTACK
V1.0"
COMMAND_SEQUENCE_NUMBER                = 0
GEOMETRY_PROJECTION_TYPE               = RAW
IMAGE_ID                               = "0303MH0002900000103786R00"
IMAGE_TYPE                             = REGULAR
MSL:IMAGE_ACQUIRE_MODE                 = IMAGE
INSTRUMENT_HOST_ID                     = MSL
INSTRUMENT_HOST_NAME                   = "MARS SCIENCE LABORATORY"
INSTRUMENT_ID                          = MAHLI
INSTRUMENT_NAME                        = "MARS HAND LENS IMAGER CAMERA"
INSTRUMENT_SERIAL_NUMBER               = "3002"
FLIGHT_SOFTWARE_VERSION_ID             = "1105031459"
INSTRUMENT_TYPE                        = "IMAGING CAMERA"
INSTRUMENT_VERSION_ID                  = FM
MSL:LOCAL_MEAN_SOLAR_TIME              = "Sol-00303M15:00:31.419"
LOCAL_TRUE_SOLAR_TIME                  = "14:09:47"
MISSION_NAME                           = "MARS SCIENCE LABORATORY"
MISSION_PHASE_NAME                     = "PRIMARY SURFACE MISSION"
OBSERVATION_ID                         = "NULL"
PLANET_DAY_NUMBER                      = 0303
INSTITUTION_NAME                       = "MALIN SPACE SCIENCE SYSTEMS"
PRODUCT_CREATION_TIME                  = 2013-11-09T01:44:22.408
PRODUCT_VERSION_ID                     = "V1.0"
PRODUCT_ID                             = "0303MH0002900000103786R00_XXXX"
SOURCE_PRODUCT_ID                      = "MhliZstack_0424400646-22351-1"
MSL:INPUT_PRODUCT_ID                   = "0303MH0002900000103786R00_DXXX"
```

```
MSL:CALIBRATION_FILE_NAME            = "N/A"
RELEASE_ID                           = "0004"
MSL:REQUEST_ID                       = "NULL"
MSL:CAMERA_PRODUCT_ID                = "3786"
MSL:CAMERA_PRODUCT_ID_COUNT          = 1
ROVER_MOTION_COUNTER_NAME            = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
ROVER_MOTION_COUNTER                 = (6, 450,
                                        6, 102,
                                        12, 0,
                                        90, 74,
                                        0, 0 )
SEQUENCE_ID                          = "mhli00290"
SEQUENCE_VERSION_ID                  = "0"
SOLAR_LONGITUDE                      = 335.040
SPACECRAFT_CLOCK_CNT_PARTITION       = 1
SPACECRAFT_CLOCK_START_COUNT         = "424400634.0000"
SPACECRAFT_CLOCK_STOP_COUNT          = "424400634.0124"
IMAGE_TIME                           = 2013-06-13T13:10:14.742
START_TIME                           = 2013-06-13T13:10:14.742
STOP_TIME                            = 2013-06-13T13:10:14.931
TARGET_NAME                          = "MARS"
TARGET_TYPE                          = "PLANET"

/* Telemetry Data Elements */

APPLICATION_PROCESS_ID               = 450
APPLICATION_PROCESS_NAME             = MhliZstack
EARTH_RECEIVED_START_TIME            = 2013-06-16T04:15:29
SPICE_FILE_NAME                      = "chronos.msl_gc120806_v3"
TELEMETRY_PROVIDER_ID                = "NULL"
MSL:TELEMETRY_SOURCE_HOST_NAME       = "NULL"
TELEMETRY_SOURCE_NAME                = "MhliZstack_0424400646-22351-1"
TELEMETRY_SOURCE_TYPE                = "DATA PRODUCT"
MSL:COMMUNICATION_SESSION_ID         = "33061"
MSL:PRODUCT_COMPLETION_STATUS        = COMPLETE_CHECKSUM_PASS
MSL:SEQUENCE_EXECUTION_COUNT         = 1
MSL:TELEMETRY_SOURCE_START_TIME      = 2013-06-13T13:10:27
```

```
MSL:TELEMETRY_SOURCE_SCLK_START     = "1/424400646-22351"


/* History Data Elements */

GROUP                               = PDS_HISTORY_PARMS
 SOFTWARE_NAME                       = MMMEDRGEN
 SOFTWARE_VERSION_ID                 = "pds3.0"
 PROCESSING_HISTORY_TEXT             = "CODMAC LEVEL 1 to LEVEL 2
                                        CONVERSION VIA MSSS MMMEDRGEN"
END_GROUP                           = PDS_HISTORY_PARMS

/* Camera Model Data Elements */

GROUP                              = GEOMETRIC_CAMERA_MODEL_PARMS
 ^MODEL_DESC                         = "GEOMETRIC_CM.TXT"
 FILTER_NAME                         = "N/A"
 MODEL_TYPE                          = "CAHVOR"
 MODEL_COMPONENT_ID                  = ("C", "A", "H", "V", "O", "R")
 MODEL_COMPONENT_NAME                = ("CENTER", "AXIS", "HORIZONTAL",
                                        "VERTICAL", "OPTICAL", "RADIAL")
 MODEL_COMPONENT_1                   = ( 0.000000e+00, 0.000000e+00,
0.000000e+00 )
 MODEL_COMPONENT_2                   = ( 0.000000e+00, 0.000000e+00,
0.000000e+00 )
 MODEL_COMPONENT_3                   = ( 0.000000e+00, 0.000000e+00,
0.000000e+00 )
 MODEL_COMPONENT_4                   = ( 0.000000e+00, 0.000000e+00,
0.000000e+00 )
 MODEL_COMPONENT_5                   = ( 0.000000e+00, 0.000000e+00,
0.000000e+00 )
 MODEL_COMPONENT_6                   = ( 0.000000e+00, 0.000000e+00,
0.000000e+00 )
 REFERENCE_COORD_SYSTEM_NAME         = ROVER_NAV_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
 REFERENCE_COORD_SYSTEM_INDEX        = (6, 450, 6,
                                        102, 12, 0,
```

```
                                     90, 74,
                                     0, 0 )
END_GROUP                          = GEOMETRIC_CAMERA_MODEL_PARMS


/* Coordinate System State: Rover */

GROUP                              = ROVER_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                     = telemetry
 COORDINATE_SYSTEM_NAME              = ROVER_NAV_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
 COORDINATE_SYSTEM_INDEX             = (6, 450, 6,
                                        102, 12, 0,
                                        90, 74,
                                        0, 0 )
 ORIGIN_OFFSET_VECTOR                = (-18.116644, -11.245091, -1.864943)
 ORIGIN_ROTATION_QUATERNION          = (0.3024752,
                                        0.0607284,
                                        0.0501238,
                                        -0.9498992)
 POSITIVE_AZIMUTH_DIRECTION          = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION        = UP
 QUATERNION_MEASUREMENT_METHOD       = TILT_ONLY
 REFERENCE_COORD_SYSTEM_NAME         = SITE_FRAME
END_GROUP                          = ROVER_COORDINATE_SYSTEM_PARMS


/* Coordinate System State: Remote Sensing Mast */

GROUP                              = RSM_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                     = telemetry
 COORDINATE_SYSTEM_NAME              = RSM_HEAD_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
 COORDINATE_SYSTEM_INDEX             = (6, 450, 6,
```

```
                                        102, 12, 0,
                                        90, 74,
                                        0, 0 )
  ORIGIN_OFFSET_VECTOR                = (0.804364, 0.559454, -1.906076)
  ORIGIN_ROTATION_QUATERNION          = ( 0.9047642,
                                         -0.0437895,
                                         -0.4116981,
                                         -0.0999445)
  POSITIVE_AZIMUTH_DIRECTION          = CLOCKWISE
  POSITIVE_ELEVATION_DIRECTION        = UP
  REFERENCE_COORD_SYSTEM_NAME         = ROVER_NAV_FRAME
END_GROUP                           = RSM_COORDINATE_SYSTEM_PARMS

/* Coordinate System State: Robotic Arm */

GROUP                               = ARM_COORDINATE_SYSTEM_PARMS
  MSL:SOLUTION_ID                     = telemetry
  COORDINATE_SYSTEM_NAME              = ARM_DRILL_FRAME
  COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
  COORDINATE_SYSTEM_INDEX             = (6, 450, 6,
                                        102, 12, 0,
                                        90, 74, 0, 0 )
  ORIGIN_OFFSET_VECTOR                = (2.076466, -0.534593, -0.801675)
  ORIGIN_ROTATION_QUATERNION          = ( 0.4351125,
                                         -0.7609830,
                                         0.4188884,
                                         0.2368848)
  POSITIVE_AZIMUTH_DIRECTION          = CLOCKWISE
  POSITIVE_ELEVATION_DIRECTION        = UP
  REFERENCE_COORD_SYSTEM_NAME         = ROVER_NAV_FRAME
END_GROUP                           = ARM_COORDINATE_SYSTEM_PARMS

/* Articulation Device State: Remote Sensing Mast */

GROUP                               = RSM_ARTICULATION_STATE_PARMS
  ARTICULATION_DEVICE_ID              = RSM
  ARTICULATION_DEVICE_NAME            = "REMOTE SENSING MAST"
```

```
 ARTICULATION_DEVICE_ANGLE_NAME      = ("AZIMUTH-MEASURED",
                                         "ELEVATION-MEASURED",
                                         "AZIMUTH-REQUESTED",
                                         "ELEVATION-REQUESTED",
                                         "AZIMUTH-INITIAL",
                                         "ELEVATION-INITIAL",
                                         "AZIMUTH-FINAL",
                                         "ELEVATION-FINAL")
 ARTICULATION_DEVICE_ANGLE           = ( 2.947423 <rad>, 0.734415 <rad>,
                                          2.950158 <rad>, 0.738686 <rad>,
                                          2.960756 <rad>, 0.743397 <rad>,
                                          2.950235 <rad>, 0.738717 <rad> )
 ARTICULATION_DEVICE_MODE            = DEPLOYED
END_GROUP                           = RSM_ARTICULATION_STATE_PARMS


/* Articulation Device State: Robotic Arm */

GROUP                               = ARM_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID              = ARM
 ARTICULATION_DEVICE_NAME            = "SAMPLE ARM"
 ARTICULATION_DEVICE_ANGLE_NAME      = ("JOINT 1 AZIMUTH-ENCODER",
                                         "JOINT 2 ELEVATION-ENCODER",
                                         "JOINT 3 ELBOW-ENCODER",
                                         "JOINT 4 WRIST-ENCODER",
                                         "JOINT 5 TURRET-ENCODER",
                                         "JOINT 1 AZIMUTH-RESOLVER",
                                         "JOINT 2 ELEVATION-RESOLVER",
                                         "JOINT 3 ELBOW-RESOLVER",
                                         "JOINT 4 WRIST-RESOLVER",
                                         "JOINT 5 TURRET-RESOLVER")
 ARTICULATION_DEVICE_ANGLE           = ( 0.000012 <rad>,
                                          -1.570802 <rad>,
                                          1.570819 <rad>,
                                          0.000000 <rad>,
                                          3.141508 <rad>,
                                          -0.000974 <rad>,
                                          -1.570499 <rad>,
                                          1.569625 <rad>,
                                          -0.004197 <rad>,
```

```
                                          3.136877 <rad> )
 ARTICULATION_DEVICE_MODE             = "FREE SPACE"
 ARTICULATION_DEVICE_TEMP_NAME        = ("AZIMUTH JOINT",
                                         "ELEVATION JOINT",
                                         "ELBOW JOINT",
                                         "WRIST JOINT",
                                         "TURRET JOINT")
 ARTICULATION_DEVICE_TEMP             = ( -11.8811 <degC>,
                                          -12.0156 <degC>,
                                          -1.5866 <degC>,
                                          -3.4263 <degC>,
                                          -10.4327 <degC> )
 CONTACT_SENSOR_STATE_NAME            = ( "MAHLI SWITCH 1", "MAHLI SWITCH 2",
                                          "DRT SWITCH 1", "DRT SWITCH 2",
                                          "DRILL SWITCH 1", "DRILL SWITCH 2",
                                          "APXS DOOR SWITCH", "APXS CONTACT
SWITCH" )
 CONTACT_SENSOR_STATE                 = ( "NO CONTACT","NO CONTACT","NO
CONTACT","NO CONTACT","NO CONTACT","NO CONTACT","NO CONTACT","CLOSED" )

 ARTICULATION_DEV_VECTOR             = ( -0.14569418132305145,
-0.058487489819526672, 0.98759931325912476)
 ARTICULATION_DEV_VECTOR_NAME         = "GRAVITY"
 ARTICULATION_DEV_INSTRUMENT_ID       = "MAHLI"
END_GROUP                           = ARM_ARTICULATION_STATE_PARMS

/* Articulation Device State: Mobility Chassis */

GROUP                                = CHASSIS_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID               = CHASSIS
 ARTICULATION_DEVICE_NAME             = "MOBILITY CHASSIS"
 ARTICULATION_DEVICE_ANGLE_NAME       = ("LEFT FRONT WHEEL",
                                         "RIGHT FRONT WHEEL",
                                         "LEFT REAR WHEEL",
                                         "RIGHT REAR WHEEL",
                                         "LEFT BOGIE",
                                         "RIGHT BOGIE",
                                         "LEFT DIFFERENTIAL",
                                         "RIGHT DIFFERENTIAL")
 ARTICULATION_DEVICE_ANGLE            = ( -0.000000 <rad>, -0.000000 <rad>,
```

```
-0.000000 <rad>, -0.000000 <rad>,
                                         -0.032099 <rad>, -0.064801 <rad>,
                                         0.006100 <rad>, -0.007613 <rad> )
 ARTICULATION_DEVICE_MODE               = DEPLOYED
END_GROUP                             = CHASSIS_ARTICULATION_STATE_PARMS


/* Articulation Device State: High Gain Antenna */

GROUP                                 = HGA_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID                 = HGA
 ARTICULATION_DEVICE_NAME               = "HIGH GAIN ANTENNA"
 ARTICULATION_DEVICE_ANGLE_NAME         = ("AZIMUTH", "ELEVATION")
 ARTICULATION_DEVICE_ANGLE              = ( 0.000000 <rad>, -0.784997 <rad> )
 ARTICULATION_DEVICE_MODE               = "DEPLOYED"
END_GROUP                             = HGA_ARTICULATION_STATE_PARMS


/* Coordinate System State: Site */

GROUP                                 = SITE_COORDINATE_SYSTEM_PARMS
 COORDINATE_SYSTEM_NAME                 = SITE_FRAME
 COORDINATE_SYSTEM_INDEX_NAME           = ("SITE" )
 COORDINATE_SYSTEM_INDEX                = (6 )
 ORIGIN_OFFSET_VECTOR                   = (32.373859, 46.404690, 1.506085 )
 ORIGIN_ROTATION_QUATERNION             = (1.0000000,
                                           0.0000000,
                                           0.0000000,
                                           0.0000000 )
 POSITIVE_AZIMUTH_DIRECTION             = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION           = UP
 REFERENCE_COORD_SYSTEM_NAME            = SITE_FRAME
END_GROUP                             = SITE_COORDINATE_SYSTEM_PARMS


/* Observation Request */

GROUP                                 = OBSERVATION_REQUEST_PARMS
 COMMAND_INSTRUMENT_ID                  = MAHLI
 RATIONALE_DESC                         = "Rock target Measles_Point - Point
```

```
Lake outcrop - toolframe distance near 10 cm - focus stack acquired Sol 303
with MSL CAMERA_PRODUCT_IDs 3738-3745 - best focus image product"
END_GROUP                          = OBSERVATION_REQUEST_PARMS


/* Image Request */

GROUP                              = IMAGE_REQUEST_PARMS
 FIRST_LINE                          = "NULL"
 FIRST_LINE_SAMPLE                   = "NULL"
 LINES                               = "NULL"
 LINE_SAMPLES                        = "NULL"
 EXPOSURE_TYPE                       = "N/A"
 EXPOSURE_DURATION                   = "N/A"
 INST_CMPRS_MODE                     = 3
 INST_CMPRS_NAME                     = "JPEG DISCRETE COSINE TRANSFORM (DCT);
HUFFMAN/QUALITY"
 INST_CMPRS_QUALITY                  = "N/A"
 AUTO_EXPOSURE_DATA_CUT              = "NULL"
 AUTO_EXPOSURE_PERCENT               = "NULL"
 AUTO_EXPOSURE_PIXEL_FRACTION        = "NULL"
 MAX_AUTO_EXPOS_ITERATION_COUNT      = "NULL"
 MSL:AUTO_FOCUS_ZSTACK_FLAG          = "NULL"
 MSL:INSTRUMENT_FOCUS_POSITION_CNT   = "NULL"
 MSL:INSTRUMENT_FOCUS_STEP_SIZE      = "NULL"
 MSL:INSTRUMENT_FOCUS_STEPS          = "NULL"
 FILTER_NAME                         = "N/A"
 FILTER_NUMBER                       = "N/A"
 MSL:INVERSE_LUT_FILE_NAME           = "NULL"
 FLAT_FIELD_CORRECTION_FLAG          = FALSE
END_GROUP                          = IMAGE_REQUEST_PARMS


/* Video Request */

GROUP                              = VIDEO_REQUEST_PARMS
 GROUP_APPLICABILITY_FLAG            = FALSE
 MSL:COMMANDED_VIDEO_FRAMES          = "N/A"
 INTERFRAME_DELAY                    = "N/A"
END_GROUP                          = VIDEO_REQUEST_PARMS
```

```
/* ZStack Request */

GROUP                                  = ZSTACK_REQUEST_PARMS
 GROUP_APPLICABILITY_FLAG                = TRUE
 MSL:ZSTACK_IMAGE_DEPTH                   = 8
 MSL:IMAGE_BLENDING_FLAG                  = FALSE
 MSL:IMAGE_REGISTRATION_FLAG              = FALSE
END_GROUP                              = ZSTACK_REQUEST_PARMS


/* Instrument State Results */

GROUP                                  = INSTRUMENT_STATE_PARMS
 HORIZONTAL_FOV                          = "N/A"
 VERTICAL_FOV                            = "N/A"
 DETECTOR_FIRST_LINE                     = 1
 DETECTOR_LINES                          = 1200
 MSL:DETECTOR_SAMPLES                    = 1648
 DETECTOR_TO_IMAGE_ROTATION              = 0.0
 EXPOSURE_DURATION                       = 12.4 <ms>
 FILTER_NAME                             = "N/A"
 FILTER_NUMBER                           = "N/A"
 CENTER_FILTER_WAVELENGTH                = "N/A"
 FLAT_FIELD_CORRECTION_FLAG              = FALSE
 MSL:INSTRUMENT_CLOCK_START_COUNT        = "424400634.0000"
 MSL:SENSOR_READOUT_RATE                 = 5 <MHz>
 INSTRUMENT_TEMPERATURE_NAME             = ( "DEA_TEMP", "FPA_TEMP",
                                             "OPTICS_TEMP", "ELECTRONICS",
                                             "ELECTRONICS_A", "ELECTRONICS_B" )
 INSTRUMENT_TEMPERATURE                  = ( 0.0000 <degC>,
                                             1.7110 <degC>,
                                             1.8707 <degC>,
                                             1.8707 <degC>,
                                             "NULL",
                                             "NULL" )
 MSL:INSTRUMENT_TEMPERATURE_STATUS       = ( 0,
                                             0,
                                             0,
                                             -42,
```

```
                                                    "UNK",
                                                    "UNK" )
  SAMPLE_BIT_METHOD                             = "HARDWARE"
  SAMPLE_BIT_MODE_ID                            = MMM_LUT0
  MSL:FOCUS_POSITION_COUNT                      = 13479
  MSL:FILTER_POSITION_COUNT                     = "N/A"
  MSL:COVER_HALL_SENSOR_FLAG                    = 1
  MSL:FILTER_HALL_SENSOR_FLAG                   = "N/A"
  MSL:FOCUS_HALL_SENSOR_FLAG                    = 0
  MSL:LED_STATE_NAME                            = ("VIS1", "VIS2", "UV")
  MSL:LED_STATE_FLAG                            = ( OFF, OFF, OFF )
  DETECTOR_ERASE_COUNT                          = 4094
END_GROUP                                     = INSTRUMENT_STATE_PARMS


/* Image Data Elements */

GROUP                                         = IMAGE_PARMS
  INST_CMPRS_MODE                               = 3
  INST_CMPRS_NAME                               = "JPEG DISCRETE COSINE TRANSFORM (DCT);
HUFFMAN/QUALITY"
  INST_CMPRS_QUALITY                            = 95
  MSL:INVERSE_LUT_FILE_NAME                     = MMM_LUT0
  PIXEL_AVERAGING_HEIGHT                        = 1
  PIXEL_AVERAGING_WIDTH                         = 1
END_GROUP                                     = IMAGE_PARMS

/* Video Data Elements */

GROUP                                         = VIDEO_PARMS
  GROUP_APPLICABILITY_FLAG                      = FALSE
  MSL:GOP_FRAME_INDEX                           = "N/A"
  MSL:GOP_TOTAL_FRAMES                          = "N/A"
  MSL:GOP_OFFSET                                = ( "N/A" )
  MSL:GOP_LENGTH                                = ( "N/A" )
END_GROUP                                     = VIDEO_PARMS


/* Derived Data Elements */
```

```
GROUP                                   = DERIVED_IMAGE_PARMS
 MSL:INFINITY_CONSTANT                    = 999999
 MSL:COVER_STATE_FLAG                     = OPEN
 MSL:MINIMUM_FOCUS_DISTANCE               = "NULL"
 MSL:BEST_FOCUS_DISTANCE                  = "NULL"
 MSL:MAXIMUM_FOCUS_DISTANCE               = "NULL"
 MSL:FRAME_RATE                           = "N/A"
 FIXED_INSTRUMENT_AZIMUTH                 = "NULL"
 FIXED_INSTRUMENT_ELEVATION               = "NULL"
 SOLAR_AZIMUTH                            = "NULL"
 SOLAR_ELEVATION                          = "NULL"
END_GROUP                               = DERIVED_IMAGE_PARMS

/* Processing Data Elements */
GROUP                                  = PROCESSING_PARMS
 DARK_LEVEL_CORRECTION                    = 120
 SHUTTER_EFFECT_CORRECTION_FLAG           = "N/A"
 RADIOMETRIC_CORRECTION_TYPE              = "N/A"
 RADIANCE_OFFSET                          = "N/A"
 RADIANCE_SCALING_FACTOR                  = "N/A"
 FLAT_FIELD_CORRECTION_FLAG               = "N/A"
END_GROUP                              = PROCESSING_PARMS


/* PRIMARY DATA OBJECT */

OBJECT                                 = MINIHEADER_TABLE
  RECORD_TYPE                          = FIXED_LENGTH
  FILE_RECORDS                         = 64

  ROWS                                 = 1
  COLUMNS                              = 1
  ROW_BYTES                            = 64
  INTERCHANGE_FORMAT                   = BINARY

  OBJECT                               = COLUMN
    NAME                               = CAMERA_PRODUCT_ID
    DATA_TYPE                          = MSB_UNSIGNED_INTEGER
    START_BYTE                         = 1
    BYTES                              = 4
```

```
  DESCRIPTION                     = "Camera data product ID"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = MAGIC0
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 5
  BYTES                           = 4
  DESCRIPTION                     = "Bit pattern 0xFF00F0CA"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = SCLK
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 9
  BYTES                           = 4
  DESCRIPTION                     = "instrument SCLK"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = DETECTOR_ERASE_COUNT
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 13
  BYTES                           = 2
  DESCRIPTION                     = "vertical flush"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = CMD0
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 15
  BYTES                           = 4
  DESCRIPTION                     = ""

  OBJECT                          = BIT_COLUMN
    NAME                          = SPARE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 1
    BITS                          = 4
    DESCRIPTION                   = "unused"
```

```
END_OBJECT                    = BIT_COLUMN

OBJECT                        = BIT_COLUMN
  NAME                        = CCD_STATE
  BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BIT                   = 5
  BITS                        = 4
  DESCRIPTION                 = "refer to section 4 of the MMM SIS"
END_OBJECT                    = BIT_COLUMN

OBJECT                        = BIT_COLUMN
  NAME                        = LED1_CONTROL
  BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BIT                   = 9
  BITS                        = 1
  DESCRIPTION                 = "0 off, 1 on"
END_OBJECT                    = BIT_COLUMN

OBJECT                        = BIT_COLUMN
  NAME                        = LED2_CONTROL
  BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BIT                   = 10
  BITS                        = 1
  DESCRIPTION                 = "0 off, 1 on"
END_OBJECT                    = BIT_COLUMN

OBJECT                        = BIT_COLUMN
  NAME                        = LED3_CONTROL
  BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BIT                   = 11
  BITS                        = 1
  DESCRIPTION                 = "0 off, 1 on"
END_OBJECT                    = BIT_COLUMN

OBJECT                        = BIT_COLUMN
  NAME                        = VIDEO_EXPOSURE
  BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BIT                   = 12
  BITS                        = 1
  DESCRIPTION                 = "0 off, 1 on"
```

```
    END_OBJECT                    = BIT_COLUMN

    OBJECT                        = BIT_COLUMN
      NAME                        = CLKDIV2
      BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
      START_BIT                   = 13
      BITS                        = 1
      DESCRIPTION                 = "refer to section 4 of the MMM SIS"
    END_OBJECT                    = BIT_COLUMN

    OBJECT                        = BIT_COLUMN
      NAME                        = LONG_INTEGRATION_MODE
      BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
      START_BIT                   = 14
      BITS                        = 1
      DESCRIPTION                 = "0 off, 1 on"
    END_OBJECT                    = BIT_COLUMN

    OBJECT                        = BIT_COLUMN
      NAME                        = TEST_MODE
      BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
      START_BIT                   = 15
      BITS                        = 1
      DESCRIPTION                 = "0 off, 1 on"
    END_OBJECT                    = BIT_COLUMN

    OBJECT                        = BIT_COLUMN
      NAME                        = CLKDIV1
      BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
      START_BIT                   = 16
      BITS                        = 1
      DESCRIPTION                 = "refer to section 4 of the MMM SIS"
    END_OBJECT                    = BIT_COLUMN
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = FILTER_NUMBER
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 17
    BYTES                         = 1
```

```
  MINIMUM                        = 0
  MAXIMUM                        = 7
  DESCRIPTION                    = "optical filter index"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = EXPOSURE_DURATION
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 18
  BYTES                          = 3
  DESCRIPTION                  = "exposure in ms*10"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = SX
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 21
  BYTES                          = 1
  DESCRIPTION                    = "subframe starting column divided by 8"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = SY
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 22
  BYTES                          = 1
  DESCRIPTION                    = "subframe starting row divided by 8"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = WIDTH
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 23
  BYTES                          = 1
  DESCRIPTION                    = "width of image divided by 8"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = HEIGHT
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
```

```
    START_BYTE                    = 24
    BYTES                         = 1
    DESCRIPTION                   = "height of image divided by 8"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = IMAGE_OR_FOCUS_MERGE1
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 25
    BYTES                         = 4
    DESCRIPTION                   = "For imaging or video products:
                                     Auto focus bits
                                     -----------------------
                                     initial position (15 bits)
                                     step size        (10 bits)
                                     number of steps  (6 bits)
                                     zstack flag      (1 bit)

                                     For focus merge products:
                                       starting CDPID (32 bits)
                                    "
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = IMAGE_OR_FOCUS_MERGE2
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 29
    BYTES                         = 4
    DESCRIPTION                   = "For imaging or video products:
                                     Auto exposure bits
                                     -----------------------
                                     target dn         (8 bits)
                                     exposure fraction (8 bits)
                                     early termination (8 bits)
                                     number of steps   (8 bits)

                                    For focus merge products:
                                     Focus merge bits
                                     -----------------------
                                     number of images  (8 bits)
```

```
                                     padding              (22 bits)
                                     image blending       (1 bit)
                                     registration         (1 bit)
                                    "
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = SPARE
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 33
    BYTES                           = 2
    DESCRIPTION                     = "undefined"
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = COLOR_MODE
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 35
    BYTES                           = 1
    DESCRIPTION                     = "0   - grayscale JPEG*
                                       1   - 422 color JPEG
                                       2   - 444 color JPEG
                                      0xFF - lossless compression
                                    *Note: see COMPRESSION_QUALITY
"
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = INST_CMPRS_QUALITY
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 36
    BYTES                           = 1
    DESCRIPTION                     = "JPEG compression quality: 1 to 100,
                                       if 0 and COLOR_MODE is 0, then
                                       encode image without any compression"
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = SPARE
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
```

```
    START_BYTE                    = 37
    BYTES                         = 3
    DESCRIPTION                   = ""
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = COMPANDING_MODE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 40
    BYTES                         = 1
    DESCRIPTION                 = "companding table 0 to 32
                                   0xFF means 16 bit calibration mode"
  END_OBJECT                      = COLUMN


  OBJECT                          = COLUMN
    NAME                          = CAM_STATUS
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 41
    BYTES                         = 1
    DESCRIPTION                   = ""

    OBJECT                        = BIT_COLUMN
      NAME                        = SPARE
      BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
      START_BIT                   = 1
      BITS                        = 1
      DESCRIPTION                 = "undefined"
    END_OBJECT                    = BIT_COLUMN

    OBJECT                        = BIT_COLUMN
      NAME                        = UV_LED
      BIT_DATA_TYPE               = MSB_UNSIGNED_INTEGER
      START_BIT                   = 2
      BITS                        = 1
      DESCRIPTION                 = ""
    END_OBJECT                    = BIT_COLUMN

    OBJECT                        = BIT_COLUMN
      NAME                        = VIS1_LED
```

```
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 3
    BITS                           = 1
    DESCRIPTION                    = ""
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = VIS2_LED
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 4
    BITS                           = 1
    DESCRIPTION                    = ""
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = SPARE
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 5
    BITS                           = 1
    DESCRIPTION                    = "undefined"
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = MASTCAM_FILTER_HALL_STATE
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 6
    BITS                           = 1
    DESCRIPTION                    = "0 off, 1 on"
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = MAHLI_COVER_HALL_STATE
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 7
    BITS                           = 1
    DESCRIPTION                    = "0 off, 1 on"
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = FOCUS_HALL_STATE
```

```
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 8
    BITS                           = 1
    DESCRIPTION                    = "0 off, 1 on"
  END_OBJECT                       = BIT_COLUMN

END_OBJECT                         = COLUMN

OBJECT                            = COLUMN
  NAME                            = DEA_SERIAL_NUMBER
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 42
  BYTES                           = 3
  DESCRIPTION                     = "Serial number assigned to DEA"
END_OBJECT                        = COLUMN

OBJECT                             = COLUMN
  NAME                             = FOCUS_POSITION_COUNT
  DATA_TYPE                        = MSB_UNSIGNED_INTEGER
  START_BYTE                       = 45
  BYTES                            = 4
  DESCRIPTION                      = "position of focus motor (in steps)"
END_OBJECT                         = COLUMN

OBJECT                             = COLUMN
  NAME                             = SPARE
  DATA_TYPE                        = MSB_UNSIGNED_INTEGER
  START_BYTE                       = 49
  BYTES                            = 2
  DESCRIPTION                      = ""
END_OBJECT                         = COLUMN

OBJECT                             = COLUMN
  NAME                             = FILTER_POSITION_COUNT
  DATA_TYPE                        = MSB_UNSIGNED_INTEGER
  START_BYTE                       = 51
  BYTES                            = 2
  DESCRIPTION                      = "position of filter motor (in steps)"
END_OBJECT                         = COLUMN
```

```
  OBJECT                               = COLUMN
    NAME                               = DC_OFFSET
    DATA_TYPE                          = MSB_UNSIGNED_INTEGER
    START_BYTE                         = 53
    BYTES                              = 4
    DESCRIPTION                        = "DC offset bias"
  END_OBJECT                           = COLUMN

  OBJECT                               = COLUMN
    NAME                               = INIT_SIZE
    DATA_TYPE                          = MSB_UNSIGNED_INTEGER
    START_BYTE                         = 57
    BYTES                              = 4
    DESCRIPTION                        = ""
  END_OBJECT                           = COLUMN

  OBJECT                               = COLUMN
    NAME                               = MAGIC1
    DATA_TYPE                          = MSB_UNSIGNED_INTEGER
    START_BYTE                         = 61
    BYTES                              = 4
    DESCRIPTION                        = "Bit pattern 0x1010CC28"
  END_OBJECT                          = COLUMN

END_OBJECT                             = MINIHEADER_TABLE


END
```

Example MARDI Label Product, 0315MD0000480000101533E01_XXXX .LBL:

```
PDS_VERSION_ID                    = PDS3

/* Pointers to Data Objects */

OBJECT                      = COMPRESSED_FILE
  FILE_NAME                 = "0315MD0000480000101533E01_XXXX.DAT"
  RECORD_TYPE               = UNDEFINED
  FILE_RECORDS              = "N/A"
  ENCODING_TYPE             = "MSLMMM-COMPRESSED"
  INTERCHANGE_FORMAT        = BINARY
  UNCOMPRESSED_FILE_NAME    = ( "0315MD0000480000101533E01_XXXX_00.IMG" )
  REQUIRED_STORAGE_BYTES    = "189568"
  ^MINIHEADER_TABLE         = ("0315MD0000480000101533E01_XXXX.DAT",
                               1 <BYTES> )
  DESCRIPTION              = "The first 64 bytes of the data file
(described by the MINIHEADER_TABLE below) determine the interpretation
of the image in the rest of the file. In particular, if the columns
COLOR_MODE and INST_CMPRS_QUALITY are both 0, the image is a RAW RASTER;
otherwise, the image is a JPEG with a specified mode
(grayscale, 442 colors, or 444 colors) and quality 1 to 100,
or it is LOSSLESS."
END_OBJECT                  = COMPRESSED_FILE

OBJECT                      = UNCOMPRESSED_FILE
  /* DAT2IMG decompression software will generate the following */
  /* IMG files along with corresponding detached PDS labels     */
  FILE_NAME                 = ( "0315MD0000480000101533E01_XXXX_00.IMG" )
  RECORD_TYPE               = FIXED_LENGTH
  FILE_RECORDS              = 92700
  RECORD_BYTES              = 64

  /* IMAGE DATA ELEMENTS */
  OBJECT                            = IMAGE
    LINES                           = 1200
    LINE_SAMPLES                    = 1648
    SAMPLE_TYPE                     = UNSIGNED_INTEGER
    SAMPLE_BITS                     = 8
```

```
    BANDS                              = 3
    FIRST_LINE                         = 1
    FIRST_LINE_SAMPLE                  = 1
  END_OBJECT                           = IMAGE

END_OBJECT                     = UNCOMPRESSED_FILE


/* Identification Data Elements */

MSL:ACTIVE_FLIGHT_STRING_ID            = "B"
DATA_SET_ID                            = "MSL-M-MARDI-2-EDR-IMG-V1.0"
DATA_SET_NAME                          = "MSL MARS DESCENT IMAGER 2 EDR IMAGE
V1.0"
COMMAND_SEQUENCE_NUMBER                = 0
GEOMETRY_PROJECTION_TYPE               = RAW
IMAGE_ID                               = "0315MD0000480000101533E01"
IMAGE_TYPE                             = REGULAR
MSL:IMAGE_ACQUIRE_MODE                 = IMAGE
INSTRUMENT_HOST_ID                     = MSL
INSTRUMENT_HOST_NAME                   = "MARS SCIENCE LABORATORY"
INSTRUMENT_ID                          = MARDI
INSTRUMENT_NAME                        = "MARS DESCENT IMAGER CAMERA"
INSTRUMENT_SERIAL_NUMBER               = "3001"
FLIGHT_SOFTWARE_VERSION_ID             = "1105031458"
INSTRUMENT_TYPE                        = "IMAGING CAMERA"
INSTRUMENT_VERSION_ID                  = FM
MSL:LOCAL_MEAN_SOLAR_TIME              = "Sol-00315M19:00:26.670"
LOCAL_TRUE_SOLAR_TIME                  = "18:11:04"
MISSION_NAME                           = "MARS SCIENCE LABORATORY"
MISSION_PHASE_NAME                     = "PRIMARY SURFACE MISSION"
OBSERVATION_ID                         = "NULL"
PLANET_DAY_NUMBER                      = 0315
INSTITUTION_NAME                       = "MALIN SPACE SCIENCE SYSTEMS"
PRODUCT_CREATION_TIME                  = 2013-11-08T21:54:17.970
PRODUCT_VERSION_ID                     = "V1.0"
PRODUCT_ID                             = "0315MD0000480000101533E01_XXXX"
SOURCE_PRODUCT_ID                      = "MrdiImage_0425480710-13634-1"
MSL:INPUT_PRODUCT_ID                   = "0315MD0000480000101533E01_DXXX"
```

```
MSL:CALIBRATION_FILE_NAME            = "N/A"
RELEASE_ID                           = "0004"
MSL:REQUEST_ID                       = "48000"
MSL:CAMERA_PRODUCT_ID                = "1533"
MSL:CAMERA_PRODUCT_ID_COUNT          = 1
ROVER_MOTION_COUNTER_NAME            = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
ROVER_MOTION_COUNTER                 = (6, 704,
                                        4, 0,
                                        0, 0,
                                        1266, 148,
                                        0, 0 )
SEQUENCE_ID                          = "mrdi00048"
SEQUENCE_VERSION_ID                  = "0"
SOLAR_LONGITUDE                      = 341.735
SPACECRAFT_CLOCK_CNT_PARTITION       = 1
SPACECRAFT_CLOCK_START_COUNT         = "425480718.0000"
SPACECRAFT_CLOCK_STOP_COUNT          = "425480718.3571"
IMAGE_TIME                           = 2013-06-26T01:11:48.664
START_TIME                           = 2013-06-26T01:11:48.664
STOP_TIME                            = 2013-06-26T01:11:54.113
TARGET_NAME                          = "MARS"
TARGET_TYPE                          = "PLANET"

/* Telemetry Data Elements */

APPLICATION_PROCESS_ID               = 462
APPLICATION_PROCESS_NAME             = MrdiImage
EARTH_RECEIVED_START_TIME            = 2013-06-26T13:31:05
SPICE_FILE_NAME                      = "chronos.msl_gc120806_v3"
TELEMETRY_PROVIDER_ID                = "NULL"
MSL:TELEMETRY_SOURCE_HOST_NAME       = "NULL"
TELEMETRY_SOURCE_NAME                = "MrdiImage_0425480710-13634-1"
TELEMETRY_SOURCE_TYPE                = "DATA PRODUCT"
MSL:COMMUNICATION_SESSION_ID         = "33163"
MSL:PRODUCT_COMPLETION_STATUS        = COMPLETE_CHECKSUM_PASS
MSL:SEQUENCE_EXECUTION_COUNT         = 1
MSL:TELEMETRY_SOURCE_START_TIME      = 2013-06-26T01:11:41
```

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MSL:TELEMETRY_SOURCE_SCLK_START     = "1/425480710-13634"


/* History Data Elements */

GROUP                               = PDS_HISTORY_PARMS
 SOFTWARE_NAME                       = MMMEDRGEN
 SOFTWARE_VERSION_ID                 = "pds3.0"
 PROCESSING_HISTORY_TEXT             = "CODMAC LEVEL 1 to LEVEL 2
                                        CONVERSION VIA MSSS MMMEDRGEN"
END_GROUP                           = PDS_HISTORY_PARMS

/* Camera Model Data Elements */

GROUP                              = GEOMETRIC_CAMERA_MODEL_PARMS
 ^MODEL_DESC                         = "GEOMETRIC_CM.TXT"
 FILTER_NAME                         = "N/A"
 MODEL_TYPE                          = "CAHVOR"
 MODEL_COMPONENT_ID                  = ("C", "A", "H", "V", "O", "R")
 MODEL_COMPONENT_NAME                = ("CENTER", "AXIS", "HORIZONTAL",
                                        "VERTICAL", "OPTICAL", "RADIAL")
 MODEL_COMPONENT_1                   = ( 7.616360e-01, -6.482750e-01,
-7.016540e-01 )
 MODEL_COMPONENT_2                   = ( 1.309000e-03, -1.977000e-03,
9.999970e-01 )
 MODEL_COMPONENT_3                   = ( -2.440923e+00, -1.304197e+03,
8.154112e+02 )
 MODEL_COMPONENT_4                   = ( 1.302018e+03, -4.684829e+00,
5.857655e+02 )
 MODEL_COMPONENT_5                   = ( 8.060000e-04, -2.426000e-03,
9.999970e-01 )
 MODEL_COMPONENT_6                   = ( -1.100000e-05, -3.209140e-01,
1.139230e-01 )
 REFERENCE_COORD_SYSTEM_NAME         = ROVER_NAV_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
 REFERENCE_COORD_SYSTEM_INDEX        = (6, 704, 4,
                                        0, 0, 0,
```

```
                                       1266, 148,
                                       0, 0 )
END_GROUP                          = GEOMETRIC_CAMERA_MODEL_PARMS


/* Coordinate System State: Rover */

GROUP                              = ROVER_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                     = telemetry
 COORDINATE_SYSTEM_NAME              = ROVER_NAV_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
 COORDINATE_SYSTEM_INDEX             = (6, 704, 4,
                                       0, 0, 0,
                                       1266, 148,
                                       0, 0 )
 ORIGIN_OFFSET_VECTOR                = (-58.991257, -15.887711, -2.131994)
 ORIGIN_ROTATION_QUATERNION          = (0.6092077,
                                       0.0273430,
                                       0.0462151,
                                       0.7911906)
 POSITIVE_AZIMUTH_DIRECTION          = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION        = UP
 QUATERNION_MEASUREMENT_METHOD       = TILT_ONLY
 REFERENCE_COORD_SYSTEM_NAME         = SITE_FRAME
END_GROUP                          = ROVER_COORDINATE_SYSTEM_PARMS


/* Coordinate System State: Remote Sensing Mast */

GROUP                              = RSM_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                     = telemetry
 COORDINATE_SYSTEM_NAME              = RSM_HEAD_FRAME
 COORDINATE_SYSTEM_INDEX_NAME        = ("SITE", "DRIVE", "POSE",
                                        "ARM", "CHIMRA", "DRILL",
                                        "RSM", "HGA",
                                        "DRT", "IC")
 COORDINATE_SYSTEM_INDEX             = (6, 704, 4,
```

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                                           0, 0, 0,
                                           1266, 148,
                                           0, 0 )
 ORIGIN_OFFSET_VECTOR                    = (0.804361, 0.559425, -1.906076)
 ORIGIN_ROTATION_QUATERNION              = ( 0.9127074,
                                            -0.0005491,
                                            -0.4085866,
                                            -0.0046748)
 POSITIVE_AZIMUTH_DIRECTION              = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION            = UP
 REFERENCE_COORD_SYSTEM_NAME             = ROVER_NAV_FRAME
END_GROUP                              = RSM_COORDINATE_SYSTEM_PARMS

/* Coordinate System State: Robotic Arm */

GROUP                                  = ARM_COORDINATE_SYSTEM_PARMS
 MSL:SOLUTION_ID                         = telemetry
 COORDINATE_SYSTEM_NAME                  = ARM_DRILL_FRAME
 COORDINATE_SYSTEM_INDEX_NAME            = ("SITE", "DRIVE", "POSE",
                                           "ARM", "CHIMRA", "DRILL",
                                           "RSM", "HGA",
                                           "DRT", "IC")
 COORDINATE_SYSTEM_INDEX                 = (6, 704, 4,
                                           0, 0, 0,
                                           1266, 148, 0, 0 )
 ORIGIN_OFFSET_VECTOR                    = (1.240132, -0.475736, -0.243845)
 ORIGIN_ROTATION_QUATERNION              = ( 0.9969326,
                                            -0.0102931,
                                            -0.0009803,
                                            0.0775790)
 POSITIVE_AZIMUTH_DIRECTION              = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION            = UP
 REFERENCE_COORD_SYSTEM_NAME             = ROVER_NAV_FRAME
END_GROUP                              = ARM_COORDINATE_SYSTEM_PARMS

/* Articulation Device State: Remote Sensing Mast */

GROUP                                  = RSM_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID                  = RSM
 ARTICULATION_DEVICE_NAME                = "REMOTE SENSING MAST"
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 ARTICULATION_DEVICE_ANGLE_NAME      = ("AZIMUTH-MEASURED",
                                        "ELEVATION-MEASURED",
                                        "AZIMUTH-REQUESTED",
                                        "ELEVATION-REQUESTED",
                                        "AZIMUTH-INITIAL",
                                        "ELEVATION-INITIAL",
                                        "AZIMUTH-FINAL",
                                        "ELEVATION-FINAL")
 ARTICULATION_DEVICE_ANGLE           = ( 3.157122 <rad>, 0.746360 <rad>,
                                         3.159046 <rad>, 0.750492 <rad>,
                                         4.218146 <rad>, 1.127906 <rad>,
                                         3.158993 <rad>, 0.750531 <rad> )
 ARTICULATION_DEVICE_MODE            = DEPLOYED
END_GROUP                          = RSM_ARTICULATION_STATE_PARMS


/* Articulation Device State: Robotic Arm */

GROUP                              = ARM_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID              = ARM
 ARTICULATION_DEVICE_NAME            = "SAMPLE ARM"
 ARTICULATION_DEVICE_ANGLE_NAME      = ("JOINT 1 AZIMUTH-ENCODER",
                                        "JOINT 2 ELEVATION-ENCODER",
                                        "JOINT 3 ELBOW-ENCODER",
                                        "JOINT 4 WRIST-ENCODER",
                                        "JOINT 5 TURRET-ENCODER",
                                        "JOINT 1 AZIMUTH-RESOLVER",
                                        "JOINT 2 ELEVATION-RESOLVER",
                                        "JOINT 3 ELBOW-RESOLVER",
                                        "JOINT 4 WRIST-RESOLVER",
                                        "JOINT 5 TURRET-RESOLVER")
 ARTICULATION_DEVICE_ANGLE           = ( 1.572096 <rad>,
                                         -0.277767 <rad>,
                                         -2.816316 <rad>,
                                         3.121097 <rad>,
                                         0.593776 <rad>,
                                         1.568250 <rad>,
                                         -0.277768 <rad>,
                                         -2.825443 <rad>,
                                         3.116558 <rad>,
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                                          0.593432 <rad> )
 ARTICULATION_DEVICE_MODE             = "FREE SPACE"
 ARTICULATION_DEVICE_TEMP_NAME        = ("AZIMUTH JOINT",
                                         "ELEVATION JOINT",
                                         "ELBOW JOINT",
                                         "WRIST JOINT",
                                         "TURRET JOINT")
 ARTICULATION_DEVICE_TEMP             = ( -22.3978 <degC>,
                                          -23.4409 <degC>,
                                          -22.2680 <degC>,
                                          -21.5148 <degC>,
                                          -13.9743 <degC> )
 CONTACT_SENSOR_STATE_NAME            = ( "MAHLI SWITCH 1", "MAHLI SWITCH 2",
                                          "DRT SWITCH 1", "DRT SWITCH 2",
                                          "DRILL SWITCH 1", "DRILL SWITCH 2",
                                          "APXS DOOR SWITCH", "APXS CONTACT
SWITCH" )
 CONTACT_SENSOR_STATE                 = ( "NO CONTACT","NO CONTACT","NO
CONTACT","NO CONTACT","NO CONTACT","NO CONTACT","NO CONTACT","CLOSED" )

 ARTICULATION_DEV_VECTOR             = ( -0.013042145408689977,
0.10644498467445375, 0.99423307180404663)
 ARTICULATION_DEV_VECTOR_NAME         = "GRAVITY"
 ARTICULATION_DEV_INSTRUMENT_ID       = "APXS"
END_GROUP                           = ARM_ARTICULATION_STATE_PARMS

/* Articulation Device State: Mobility Chassis */

GROUP                                = CHASSIS_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID               = CHASSIS
 ARTICULATION_DEVICE_NAME             = "MOBILITY CHASSIS"
 ARTICULATION_DEVICE_ANGLE_NAME       = ("LEFT FRONT WHEEL",
                                         "RIGHT FRONT WHEEL",
                                         "LEFT REAR WHEEL",
                                         "RIGHT REAR WHEEL",
                                         "LEFT BOGIE",
                                         "RIGHT BOGIE",
                                         "LEFT DIFFERENTIAL",
                                         "RIGHT DIFFERENTIAL")
 ARTICULATION_DEVICE_ANGLE            = ( -0.000000 <rad>, -0.000000 <rad>,
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-0.000128 <rad>, -0.000128 <rad>,
                                          0.163894 <rad>, -0.037788 <rad>,
                                          -0.036699 <rad>, 0.034214 <rad> )
 ARTICULATION_DEVICE_MODE             = DEPLOYED
END_GROUP                           = CHASSIS_ARTICULATION_STATE_PARMS


/* Articulation Device State: High Gain Antenna */

GROUP                               = HGA_ARTICULATION_STATE_PARMS
 ARTICULATION_DEVICE_ID               = HGA
 ARTICULATION_DEVICE_NAME             = "HIGH GAIN ANTENNA"
 ARTICULATION_DEVICE_ANGLE_NAME       = ("AZIMUTH", "ELEVATION")
 ARTICULATION_DEVICE_ANGLE            = ( 0.000033 <rad>, -0.784997 <rad> )
 ARTICULATION_DEVICE_MODE             = "DEPLOYED"
END_GROUP                           = HGA_ARTICULATION_STATE_PARMS


/* Coordinate System State: Site */

GROUP                               = SITE_COORDINATE_SYSTEM_PARMS
 COORDINATE_SYSTEM_NAME               = SITE_FRAME
 COORDINATE_SYSTEM_INDEX_NAME         = ("SITE" )
 COORDINATE_SYSTEM_INDEX              = (6 )
 ORIGIN_OFFSET_VECTOR                 = (32.373859, 46.404690, 1.506085 )
 ORIGIN_ROTATION_QUATERNION           = (1.0000000,
                                         0.0000000,
                                         0.0000000,
                                         0.0000000 )
 POSITIVE_AZIMUTH_DIRECTION           = CLOCKWISE
 POSITIVE_ELEVATION_DIRECTION         = UP
 REFERENCE_COORD_SYSTEM_NAME          = SITE_FRAME
END_GROUP                           = SITE_COORDINATE_SYSTEM_PARMS


/* Observation Request */

GROUP                               = OBSERVATION_REQUEST_PARMS
 COMMAND_INSTRUMENT_ID                = MARDI
 RATIONALE_DESC                       = "MARDI twilight image at Shaler at
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approximately 19:00 LMST"
END_GROUP                          = OBSERVATION_REQUEST_PARMS


/* Image Request */

GROUP                              = IMAGE_REQUEST_PARMS
 FIRST_LINE                          = 1
 FIRST_LINE_SAMPLE                   = 1
 LINES                               = 1200
 LINE_SAMPLES                        = 1648
 EXPOSURE_TYPE                       = AUTO
 EXPOSURE_DURATION                   = "N/A"
 INST_CMPRS_MODE                     = 3
 INST_CMPRS_NAME                     = "JPEG DISCRETE COSINE TRANSFORM (DCT);
HUFFMAN/QUALITY"
 INST_CMPRS_QUALITY                  = "N/A"
 AUTO_EXPOSURE_DATA_CUT              = "NULL"
 AUTO_EXPOSURE_PERCENT               = 010
 AUTO_EXPOSURE_PIXEL_FRACTION        = 002
 MAX_AUTO_EXPOS_ITERATION_COUNT      = 8
 MSL:AUTO_FOCUS_ZSTACK_FLAG          = "N/A"
 MSL:INSTRUMENT_FOCUS_POSITION_CNT   = "N/A"
 MSL:INSTRUMENT_FOCUS_STEP_SIZE      = "N/A"
 MSL:INSTRUMENT_FOCUS_STEPS          = "N/A"
 FILTER_NAME                         = "N/A"
 FILTER_NUMBER                       = "N/A"
 MSL:INVERSE_LUT_FILE_NAME           = MMM_LUT0
 FLAT_FIELD_CORRECTION_FLAG          = FALSE
END_GROUP                          = IMAGE_REQUEST_PARMS


/* Video Request */

GROUP                              = VIDEO_REQUEST_PARMS
 GROUP_APPLICABILITY_FLAG            = FALSE
 MSL:COMMANDED_VIDEO_FRAMES          = "N/A"
 INTERFRAME_DELAY                    = "N/A"
END_GROUP                          = VIDEO_REQUEST_PARMS
```

```
/* ZStack Request */

GROUP                               = ZSTACK_REQUEST_PARMS
 GROUP_APPLICABILITY_FLAG             = FALSE
 MSL:ZSTACK_IMAGE_DEPTH                = "N/A"
 MSL:IMAGE_BLENDING_FLAG               = "N/A"
 MSL:IMAGE_REGISTRATION_FLAG           = "N/A"
END_GROUP                           = ZSTACK_REQUEST_PARMS


/* Instrument State Results */

GROUP                               = INSTRUMENT_STATE_PARMS
 HORIZONTAL_FOV                       = 64.6674
 VERTICAL_FOV                         = 49.4895
 DETECTOR_FIRST_LINE                  = 1
 DETECTOR_LINES                       = 1200
 MSL:DETECTOR_SAMPLES                 = 1648
 DETECTOR_TO_IMAGE_ROTATION           = 0.0
 EXPOSURE_DURATION                    = 357.1 <ms>
 FILTER_NAME                          = "N/A"
 FILTER_NUMBER                        = "N/A"
 CENTER_FILTER_WAVELENGTH             = "N/A"
 FLAT_FIELD_CORRECTION_FLAG           = FALSE
 MSL:INSTRUMENT_CLOCK_START_COUNT     = "425480718.0000"
 MSL:SENSOR_READOUT_RATE              = 10 <MHz>
 INSTRUMENT_TEMPERATURE_NAME          = ( "DEA_TEMP", "FPA_TEMP",
                                        "OPTICS_TEMP", "ELECTRONICS",
                                        "ELECTRONICS_A", "ELECTRONICS_B" )
 INSTRUMENT_TEMPERATURE               = ( 0.0000 <degC>,
                                        0.0000 <degC>,
                                        "NULL",
                                        "NULL",
                                        "NULL",
                                        "NULL" )
 MSL:INSTRUMENT_TEMPERATURE_STATUS    = ( 0,
                                        -42,
                                        "UNK",
                                        "UNK",
                                        "UNK",
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                                          "UNK" )
 SAMPLE_BIT_METHOD                      = "HARDWARE"
 SAMPLE_BIT_MODE_ID                     = MMM_LUT0
 MSL:FOCUS_POSITION_COUNT               = "N/A"
 MSL:FILTER_POSITION_COUNT              = "N/A"
 MSL:COVER_HALL_SENSOR_FLAG             = "N/A"
 MSL:FILTER_HALL_SENSOR_FLAG            = "N/A"
 MSL:FOCUS_HALL_SENSOR_FLAG             = "N/A"
 MSL:LED_STATE_NAME                     = ("VIS1", "VIS2", "UV")
 MSL:LED_STATE_FLAG                     = ( "N/A", "N/A", "N/A" )
 DETECTOR_ERASE_COUNT                   = 4094
END_GROUP                             = INSTRUMENT_STATE_PARMS


/* Image Data Elements */

GROUP                                 = IMAGE_PARMS
 INST_CMPRS_MODE                        = 3
 INST_CMPRS_NAME                        = "JPEG DISCRETE COSINE TRANSFORM (DCT);
HUFFMAN/QUALITY"
 INST_CMPRS_QUALITY                     = 85
 MSL:INVERSE_LUT_FILE_NAME              = MMM_LUT0
 PIXEL_AVERAGING_HEIGHT                 = 1
 PIXEL_AVERAGING_WIDTH                  = 1
END_GROUP                             = IMAGE_PARMS

/* Video Data Elements */

GROUP                                 = VIDEO_PARMS
 GROUP_APPLICABILITY_FLAG               = FALSE
 MSL:GOP_FRAME_INDEX                    = "N/A"
 MSL:GOP_TOTAL_FRAMES                   = "N/A"
 MSL:GOP_OFFSET                         = ( "N/A" )
 MSL:GOP_LENGTH                         = ( "N/A" )
END_GROUP                             = VIDEO_PARMS


/* Derived Data Elements */

GROUP                                 = DERIVED_IMAGE_PARMS
```

```
 MSL:INFINITY_CONSTANT               = 999999
 MSL:COVER_STATE_FLAG                = "N/A"
 MSL:MINIMUM_FOCUS_DISTANCE          = 2 <m>
 MSL:BEST_FOCUS_DISTANCE             = "NULL"
 MSL:MAXIMUM_FOCUS_DISTANCE          = 999999
 MSL:FRAME_RATE                      = "N/A"
 FIXED_INSTRUMENT_AZIMUTH            = 200.5415
 FIXED_INSTRUMENT_ELEVATION          = 83.9842
 SOLAR_AZIMUTH                       = 262.2220
 SOLAR_ELEVATION                     = -1.0910
END_GROUP                          = DERIVED_IMAGE_PARMS

/* Processing Data Elements */
GROUP                             = PROCESSING_PARMS
 DARK_LEVEL_CORRECTION               = 120
 SHUTTER_EFFECT_CORRECTION_FLAG      = "N/A"
 RADIOMETRIC_CORRECTION_TYPE         = "N/A"
 RADIANCE_OFFSET                     = "N/A"
 RADIANCE_SCALING_FACTOR             = "N/A"
 FLAT_FIELD_CORRECTION_FLAG          = "N/A"
END_GROUP                         = PROCESSING_PARMS


/* PRIMARY DATA OBJECT */

OBJECT                            = MINIHEADER_TABLE
  RECORD_TYPE                     = FIXED_LENGTH
  FILE_RECORDS                    = 64

  ROWS                            = 1
  COLUMNS                         = 1
  ROW_BYTES                       = 64
  INTERCHANGE_FORMAT              = BINARY

  OBJECT                          = COLUMN
    NAME                          = CAMERA_PRODUCT_ID
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 1
    BYTES                         = 4
    DESCRIPTION                   = "Camera data product ID"
```

```
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = MAGIC0
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 5
  BYTES                           = 4
  DESCRIPTION                     = "Bit pattern 0xFF00F0CA"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = SCLK
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 9
  BYTES                           = 4
  DESCRIPTION                     = "instrument SCLK"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = DETECTOR_ERASE_COUNT
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 13
  BYTES                           = 2
  DESCRIPTION                     = "vertical flush"
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = CMD0
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 15
  BYTES                           = 4
  DESCRIPTION                     = ""

  OBJECT                          = BIT_COLUMN
    NAME                          = SPARE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 1
    BITS                          = 4
    DESCRIPTION                   = "unused"
  END_OBJECT                      = BIT_COLUMN
```

```
OBJECT                          = BIT_COLUMN
  NAME                          = CCD_STATE
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 5
  BITS                          = 4
  DESCRIPTION                   = "refer to section 4 of the MMM SIS"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = LED1_CONTROL
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 9
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = LED2_CONTROL
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 10
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = LED3_CONTROL
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 11
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN

OBJECT                          = BIT_COLUMN
  NAME                          = VIDEO_EXPOSURE
  BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BIT                     = 12
  BITS                          = 1
  DESCRIPTION                   = "0 off, 1 on"
END_OBJECT                      = BIT_COLUMN
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```
  OBJECT                          = BIT_COLUMN
    NAME                          = CLKDIV2
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 13
    BITS                          = 1
    DESCRIPTION                   = "refer to section 4 of the MMM SIS"
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = LONG_INTEGRATION_MODE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 14
    BITS                          = 1
    DESCRIPTION                   = "0 off, 1 on"
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = TEST_MODE
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 15
    BITS                          = 1
    DESCRIPTION                   = "0 off, 1 on"
  END_OBJECT                      = BIT_COLUMN

  OBJECT                          = BIT_COLUMN
    NAME                          = CLKDIV1
    BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
    START_BIT                     = 16
    BITS                          = 1
    DESCRIPTION                   = "refer to section 4 of the MMM SIS"
  END_OBJECT                      = BIT_COLUMN
END_OBJECT                        = COLUMN

OBJECT                            = COLUMN
  NAME                            = FILTER_NUMBER
  DATA_TYPE                       = MSB_UNSIGNED_INTEGER
  START_BYTE                      = 17
  BYTES                           = 1
  MINIMUM                         = 0
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  MAXIMUM                        = 7
  DESCRIPTION                    = "optical filter index"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = EXPOSURE_DURATION
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 18
  BYTES                          = 3
  DESCRIPTION                  = "exposure in ms*10"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = SX
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 21
  BYTES                          = 1
  DESCRIPTION                    = "subframe starting column divided by 8"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = SY
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 22
  BYTES                          = 1
  DESCRIPTION                    = "subframe starting row divided by 8"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = WIDTH
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 23
  BYTES                          = 1
  DESCRIPTION                    = "width of image divided by 8"
END_OBJECT                       = COLUMN

OBJECT                           = COLUMN
  NAME                           = HEIGHT
  DATA_TYPE                      = MSB_UNSIGNED_INTEGER
  START_BYTE                     = 24
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    BYTES                          = 1
    DESCRIPTION                    = "height of image divided by 8"
  END_OBJECT                       = COLUMN

  OBJECT                           = COLUMN
    NAME                           = IMAGE_OR_FOCUS_MERGE1
    DATA_TYPE                      = MSB_UNSIGNED_INTEGER
    START_BYTE                     = 25
    BYTES                          = 4
    DESCRIPTION                    = "For imaging or video products:
                                       Auto focus bits
                                       -----------------------
                                       initial position (15 bits)
                                       step size        (10 bits)
                                       number of steps  (6 bits)
                                       zstack flag      (1 bit)

                                       For focus merge products:
                                         starting CDPID (32 bits)
                                     "
  END_OBJECT                       = COLUMN

  OBJECT                           = COLUMN
    NAME                           = IMAGE_OR_FOCUS_MERGE2
    DATA_TYPE                      = MSB_UNSIGNED_INTEGER
    START_BYTE                     = 29
    BYTES                          = 4
    DESCRIPTION                    = "For imaging or video products:
                                       Auto exposure bits
                                       -----------------------
                                       target dn          (8 bits)
                                       exposure fraction  (8 bits)
                                       early termination  (8 bits)
                                       number of steps    (8 bits)

                                     For focus merge products:
                                       Focus merge bits
                                       -----------------------
                                       number of images   (8 bits)
                                       padding            (22 bits)
```

```
                                     image blending    (1 bit)
                                     registration      (1 bit)
                                    "
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = SPARE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 33
    BYTES                         = 2
    DESCRIPTION                   = "undefined"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = COLOR_MODE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 35
    BYTES                         = 1
    DESCRIPTION                   = "0    - grayscale JPEG*
                                     1    - 422 color JPEG
                                     2    - 444 color JPEG
                                    0xFF - lossless compression
                                  *Note: see COMPRESSION_QUALITY
"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = INST_CMPRS_QUALITY
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 36
    BYTES                         = 1
    DESCRIPTION                   = "JPEG compression quality: 1 to 100,
                                     if 0 and COLOR_MODE is 0, then
                                     encode image without any compression"
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                          = SPARE
    DATA_TYPE                     = MSB_UNSIGNED_INTEGER
    START_BYTE                    = 37
```

```
    BYTES                           = 3
    DESCRIPTION                     = ""
  END_OBJECT                        = COLUMN

  OBJECT                            = COLUMN
    NAME                            = COMPANDING_MODE
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 40
    BYTES                           = 1
    DESCRIPTION                   = "companding table 0 to 32
                                     0xFF means 16 bit calibration mode"
  END_OBJECT                        = COLUMN


  OBJECT                            = COLUMN
    NAME                            = CAM_STATUS
    DATA_TYPE                       = MSB_UNSIGNED_INTEGER
    START_BYTE                      = 41
    BYTES                           = 1
    DESCRIPTION                     = ""

    OBJECT                          = BIT_COLUMN
      NAME                          = SPARE
      BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
      START_BIT                     = 1
      BITS                          = 1
      DESCRIPTION                   = "undefined"
    END_OBJECT                      = BIT_COLUMN

    OBJECT                          = BIT_COLUMN
      NAME                          = UV_LED
      BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
      START_BIT                     = 2
      BITS                          = 1
      DESCRIPTION                   = ""
    END_OBJECT                      = BIT_COLUMN

    OBJECT                          = BIT_COLUMN
      NAME                          = VIS1_LED
      BIT_DATA_TYPE                 = MSB_UNSIGNED_INTEGER
```

```
    START_BIT                      = 3
    BITS                           = 1
    DESCRIPTION                    = ""
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = VIS2_LED
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 4
    BITS                           = 1
    DESCRIPTION                    = ""
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = SPARE
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 5
    BITS                           = 1
    DESCRIPTION                    = "undefined"
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = MASTCAM_FILTER_HALL_STATE
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 6
    BITS                           = 1
    DESCRIPTION                    = "0 off, 1 on"
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = MAHLI_COVER_HALL_STATE
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
    START_BIT                      = 7
    BITS                           = 1
    DESCRIPTION                    = "0 off, 1 on"
  END_OBJECT                       = BIT_COLUMN

  OBJECT                           = BIT_COLUMN
    NAME                           = FOCUS_HALL_STATE
    BIT_DATA_TYPE                  = MSB_UNSIGNED_INTEGER
```

```
    START_BIT                       = 8
    BITS                            = 1
    DESCRIPTION                     = "0 off, 1 on"
  END_OBJECT                        = BIT_COLUMN

END_OBJECT                          = COLUMN

OBJECT                             = COLUMN
  NAME                             = DEA_SERIAL_NUMBER
  DATA_TYPE                        = MSB_UNSIGNED_INTEGER
  START_BYTE                       = 42
  BYTES                            = 3
  DESCRIPTION                      = "Serial number assigned to DEA"
END_OBJECT                         = COLUMN

OBJECT                              = COLUMN
  NAME                              = FOCUS_POSITION_COUNT
  DATA_TYPE                         = MSB_UNSIGNED_INTEGER
  START_BYTE                        = 45
  BYTES                             = 4
  DESCRIPTION                       = "position of focus motor (in steps)"
END_OBJECT                          = COLUMN

OBJECT                              = COLUMN
  NAME                              = SPARE
  DATA_TYPE                         = MSB_UNSIGNED_INTEGER
  START_BYTE                        = 49
  BYTES                             = 2
  DESCRIPTION                       = ""
END_OBJECT                          = COLUMN

OBJECT                              = COLUMN
  NAME                              = FILTER_POSITION_COUNT
  DATA_TYPE                         = MSB_UNSIGNED_INTEGER
  START_BYTE                        = 51
  BYTES                             = 2
  DESCRIPTION                       = "position of filter motor (in steps)"
END_OBJECT                          = COLUMN

OBJECT                              = COLUMN
```

```
    NAME                              = DC_OFFSET
    DATA_TYPE                         = MSB_UNSIGNED_INTEGER
    START_BYTE                        = 53
    BYTES                             = 4
    DESCRIPTION                       = "DC offset bias"
  END_OBJECT                          = COLUMN

  OBJECT                              = COLUMN
    NAME                              = INIT_SIZE
    DATA_TYPE                         = MSB_UNSIGNED_INTEGER
    START_BYTE                        = 57
    BYTES                             = 4
    DESCRIPTION                       = ""
  END_OBJECT                          = COLUMN

  OBJECT                              = COLUMN
    NAME                              = MAGIC1
    DATA_TYPE                         = MSB_UNSIGNED_INTEGER
    START_BYTE                        = 61
    BYTES                             = 4
    DESCRIPTION                       = "Bit pattern 0x1010CC28"
  END_OBJECT                         = COLUMN

END_OBJECT                            = MINIHEADER_TABLE


END
```

APPENDIX B: MMM DECOMPANDING TABLES

Each table contains 256 entries for DN values of 0 through 255.
The first number in the name indicates the decompanding table.
The second number (0) indicates the version.

decompand0.0.table
0, 2, 3, 3, 4, 5, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 18, 19, 20, 22, 24, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 46, 48, 50, 53, 55, 58, 61, 63, 66, 69, 72, 75, 78, 81, 84, 87, 90, 94, 97, 100, 104, 107, 111, 115, 118, 122, 126, 130, 134, 138, 142, 146, 150, 154, 159, 163, 168, 172, 177, 181, 186, 191, 196, 201, 206, 211, 216, 221, 226, 231, 236, 241, 247, 252, 258, 263, 269, 274, 280, 286, 292, 298, 304, 310, 316, 322, 328, 334, 341, 347, 354, 360, 367, 373, 380, 387, 394, 401, 408, 415, 422, 429, 436, 443, 450, 458, 465, 472, 480, 487, 495, 503, 510, 518, 526, 534, 542, 550, 558, 566, 575, 583, 591, 600, 608, 617, 626, 634, 643, 652, 661, 670, 679, 688, 697, 706, 715, 724, 733, 743, 752, 761, 771, 781, 790, 800, 810, 819, 829, 839, 849, 859, 869, 880, 890, 900, 911, 921, 932, 942, 953, 964, 974, 985, 996, 1007, 1018, 1029, 1040, 1051, 1062, 1074, 1085, 1096, 1108, 1119, 1131, 1142, 1154, 1166, 1177, 1189, 1201, 1213, 1225, 1237, 1249, 1262, 1274, 1286, 1299, 1311, 1324, 1336, 1349, 1362, 1374, 1387, 1400, 1413, 1426, 1439, 1452, 1465, 1479, 1492, 1505, 1519, 1532, 1545, 1559, 1573, 1586, 1600, 1614, 1628, 1642, 1656, 1670, 1684, 1698, 1712, 1727, 1741, 1755, 1770, 1784, 1799, 1814, 1828, 1843, 1858, 1873, 1888, 1903, 1918, 1933, 1948, 1963, 1979, 1994, 2009, 2025, 2033

decompand1.0.table
0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255

decompand2.0.table
0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286,

288, 290, 292, 294, 296, 298, 300, 302, 304, 306, 308, 310, 312, 314, 316, 318, 320, 322, 324, 326, 328, 330, 332, 334, 336, 338, 340, 342, 344, 346, 348, 350, 352, 354, 356, 358, 360, 362, 364, 366, 368, 370, 372, 374, 376, 378, 380, 382, 384, 386, 388, 390, 392, 394, 396, 398, 400, 402, 404, 406, 408, 410, 412, 414, 416, 418, 420, 422, 424, 426, 428, 430, 432, 434, 436, 438, 440, 442, 444, 446, 448, 450, 452, 454, 456, 458, 460, 462, 464, 466, 468, 470, 472, 474, 476, 478, 480, 482, 484, 486, 488, 490, 492, 494, 496, 498, 500, 502, 504, 506, 508, 510

decompand3.0.table
1, 4, 7, 10, 13, 16, 19, 22, 25, 28, 31, 34, 37, 40, 43, 46, 49, 52, 55, 58, 61, 64, 67, 70, 73, 76, 79, 82, 85, 88, 91, 94, 97, 100, 103, 106, 109, 112, 115, 118, 121, 124, 127, 130, 133, 136, 139, 142, 145, 148, 151, 154, 157, 160, 163, 166, 169, 172, 175, 178, 181, 184, 187, 190, 193, 196, 199, 202, 205, 208, 211, 214, 217, 220, 223, 226, 229, 232, 235, 238, 241, 244, 247, 250, 253, 256, 259, 262, 265, 268, 271, 274, 277, 280, 283, 286, 289, 292, 295, 298, 301, 304, 307, 310, 313, 316, 319, 322, 325, 328, 331, 334, 337, 340, 343, 346, 349, 352, 355, 358, 361, 364, 367, 370, 373, 376, 379, 382, 385, 388, 391, 394, 397, 400, 403, 406, 409, 412, 415, 418, 421, 424, 427, 430, 433, 436, 439, 442, 445, 448, 451, 454, 457, 460, 463, 466, 469, 472, 475, 478, 481, 484, 487, 490, 493, 496, 499, 502, 505, 508, 511, 514, 517, 520, 523, 526, 529, 532, 535, 538, 541, 544, 547, 550, 553, 556, 559, 562, 565, 568, 571, 574, 577, 580, 583, 586, 589, 592, 595, 598, 601, 604, 607, 610, 613, 616, 619, 622, 625, 628, 631, 634, 637, 640, 643, 646, 649, 652, 655, 658, 661, 664, 667, 670, 673, 676, 679, 682, 685, 688, 691, 694, 697, 700, 703, 706, 709, 712, 715, 718, 721, 724, 727, 730, 733, 736, 739, 742, 745, 748, 751, 754, 757, 760, 763, 765

decompand4.0.table
1, 5, 9, 13, 17, 21, 25, 29, 33, 37, 41, 45, 49, 53, 57, 61, 65, 69, 73, 77, 81, 85, 89, 93, 97, 101, 105, 109, 113, 117, 121, 125, 129, 133, 137, 141, 145, 149, 153, 157, 161, 165, 169, 173, 177, 181, 185, 189, 193, 197, 201, 205, 209, 213, 217, 221, 225, 229, 233, 237, 241, 245, 249, 253, 257, 261, 265, 269, 273, 277, 281, 285, 289, 293, 297, 301, 305, 309, 313, 317, 321, 325, 329, 333, 337, 341, 345, 349, 353, 357, 361, 365, 369, 373, 377, 381, 385, 389, 393, 397, 401, 405, 409, 413, 417, 421, 425, 429, 433, 437, 441, 445, 449, 453, 457, 461, 465, 469, 473, 477, 481, 485, 489, 493, 497, 501, 505, 509, 513, 517, 521, 525, 529, 533, 537, 541, 545, 549, 553, 557, 561, 565, 569, 573, 577, 581, 585, 589, 593, 597, 601, 605, 609, 613, 617, 621, 625, 629, 633, 637, 641, 645, 649, 653, 657, 661, 665, 669, 673, 677, 681, 685, 689, 693, 697, 701, 705, 709, 713, 717, 721, 725, 729, 733, 737, 741, 745, 749, 753, 757, 761, 765, 769, 773, 777, 781, 785, 789, 793, 797, 801, 805, 809, 813, 817, 821, 825, 829, 833, 837, 841, 845, 849, 853, 857, 861, 865, 869, 873, 877, 881, 885, 889, 893, 897, 901, 905, 909, 913, 917, 921, 925, 929, 933, 937, 941, 945, 949, 953, 957, 961, 965, 969, 973, 977, 981, 985, 989, 993, 997, 1001, 1005, 1009, 1013, 1017, 1020

decompand5.0.table
2, 7, 12, 17, 22, 27, 32, 37, 42, 47, 52, 57, 62, 67, 72, 77, 82, 87, 92, 97, 102, 107, 112, 117, 122, 127, 132, 137, 142, 147, 152, 157, 162, 167, 172, 177, 182, 187, 192, 197, 202, 207, 212, 217, 222, 227, 232, 237, 242, 247, 252, 257, 262, 267, 272, 277, 282, 287, 292, 297, 302, 307, 312, 317, 322, 327, 332, 337, 342, 347, 352, 357, 362, 367, 372, 377, 382, 387, 392, 397, 402, 407, 412, 417, 422, 427, 432, 437, 442, 447, 452, 457, 462, 467, 472, 477, 482, 487, 492, 497, 502, 507, 512, 517, 522, 527, 532, 537, 542, 547, 552, 557, 562, 567, 572, 577, 582, 587, 592, 597, 602, 607, 612, 617, 622, 627, 632, 637, 642, 647, 652, 657, 662, 667, 672, 677,

682, 687, 692, 697, 702, 707, 712, 717, 722, 727, 732, 737, 742, 747, 752, 757, 762, 767, 772, 777, 782, 787, 792, 797, 802, 807, 812, 817, 822, 827, 832, 837, 842, 847, 852, 857, 862, 867, 872, 877, 882, 887, 892, 897, 902, 907, 912, 917, 922, 927, 932, 937, 942, 947, 952, 957, 962, 967, 972, 977, 982, 987, 992, 997, 1002, 1007, 1012, 1017, 1022, 1027, 1032, 1037, 1042, 1047, 1052, 1057, 1062, 1067, 1072, 1077, 1082, 1087, 1092, 1097, 1102, 1107, 1112, 1117, 1122, 1127, 1132, 1137, 1142, 1147, 1152, 1157, 1162, 1167, 1172, 1177, 1182, 1187, 1192, 1197, 1202, 1207, 1212, 1217, 1222, 1227, 1232, 1237, 1242, 1247, 1252, 1257, 1262, 1267, 1272, 1275

decompand6.0.table
2, 8, 14, 20, 26, 32, 38, 44, 50, 56, 62, 68, 74, 80, 86, 92, 98, 104, 110, 116, 122, 128, 134, 140, 146, 152, 158, 164, 170, 176, 182, 188, 194, 200, 206, 212, 218, 224, 230, 236, 242, 248, 254, 260, 266, 272, 278, 284, 290, 296, 302, 308, 314, 320, 326, 332, 338, 344, 350, 356, 362, 368, 374, 380, 386, 392, 398, 404, 410, 416, 422, 428, 434, 440, 446, 452, 458, 464, 470, 476, 482, 488, 494, 500, 506, 512, 518, 524, 530, 536, 542, 548, 554, 560, 566, 572, 578, 584, 590, 596, 602, 608, 614, 620, 626, 632, 638, 644, 650, 656, 662, 668, 674, 680, 686, 692, 698, 704, 710, 716, 722, 728, 734, 740, 746, 752, 758, 764, 770, 776, 782, 788, 794, 800, 806, 812, 818, 824, 830, 836, 842, 848, 854, 860, 866, 872, 878, 884, 890, 896, 902, 908, 914, 920, 926, 932, 938, 944, 950, 956, 962, 968, 974, 980, 986, 992, 998, 1004, 1010, 1016, 1022, 1028, 1034, 1040, 1046, 1052, 1058, 1064, 1070, 1076, 1082, 1088, 1094, 1100, 1106, 1112, 1118, 1124, 1130, 1136, 1142, 1148, 1154, 1160, 1166, 1172, 1178, 1184, 1190, 1196, 1202, 1208, 1214, 1220, 1226, 1232, 1238, 1244, 1250, 1256, 1262, 1268, 1274, 1280, 1286, 1292, 1298, 1304, 1310, 1316, 1322, 1328, 1334, 1340, 1346, 1352, 1358, 1364, 1370, 1376, 1382, 1388, 1394, 1400, 1406, 1412, 1418, 1424, 1430, 1436, 1442, 1448, 1454, 1460, 1466, 1472, 1478, 1484, 1490, 1496, 1502, 1508, 1514, 1520, 1526, 1530

decompand7.0.table
3, 10, 17, 24, 31, 38, 45, 52, 59, 66, 73, 80, 87, 94, 101, 108, 115, 122, 129, 136, 143, 150, 157, 164, 171, 178, 185, 192, 199, 206, 213, 220, 227, 234, 241, 248, 255, 262, 269, 276, 283, 290, 297, 304, 311, 318, 325, 332, 339, 346, 353, 360, 367, 374, 381, 388, 395, 402, 409, 416, 423, 430, 437, 444, 451, 458, 465, 472, 479, 486, 493, 500, 507, 514, 521, 528, 535, 542, 549, 556, 563, 570, 577, 584, 591, 598, 605, 612, 619, 626, 633, 640, 647, 654, 661, 668, 675, 682, 689, 696, 703, 710, 717, 724, 731, 738, 745, 752, 759, 766, 773, 780, 787, 794, 801, 808, 815, 822, 829, 836, 843, 850, 857, 864, 871, 878, 885, 892, 899, 906, 913, 920, 927, 934, 941, 948, 955, 962, 969, 976, 983, 990, 997, 1004, 1011, 1018, 1025, 1032, 1039, 1046, 1053, 1060, 1067, 1074, 1081, 1088, 1095, 1102, 1109, 1116, 1123, 1130, 1137, 1144, 1151, 1158, 1165, 1172, 1179, 1186, 1193, 1200, 1207, 1214, 1221, 1228, 1235, 1242, 1249, 1256, 1263, 1270, 1277, 1284, 1291, 1298, 1305, 1312, 1319, 1326, 1333, 1340, 1347, 1354, 1361, 1368, 1375, 1382, 1389, 1396, 1403, 1410, 1417, 1424, 1431, 1438, 1445, 1452, 1459, 1466, 1473, 1480, 1487, 1494, 1501, 1508, 1515, 1522, 1529, 1536, 1543, 1550, 1557, 1564, 1571, 1578, 1585, 1592, 1599, 1606, 1613, 1620, 1627, 1634, 1641, 1648, 1655, 1662, 1669, 1676, 1683, 1690, 1697, 1704, 1711, 1718, 1725, 1732, 1739, 1746, 1753, 1760, 1767, 1774, 1781, 1785

decompand8.0.table
3, 11, 19, 27, 35, 43, 51, 59, 67, 75, 83, 91, 99, 107, 115, 123, 131, 139, 147, 155, 163, 171, 179, 187, 195, 203, 211, 219, 227, 235, 243, 251, 259, 267, 275, 283, 291, 299, 307, 315, 323, 331, 339, 347, 355, 363, 371, 379, 387, 395, 403, 411, 419, 427, 435, 443,

451, 459, 467, 475, 483, 491, 499, 507, 515, 523, 531, 539, 547, 555, 563, 571, 579, 587, 595, 603, 611, 619, 627, 635, 643, 651, 659, 667, 675, 683, 691, 699, 707, 715, 723, 731, 739, 747, 755, 763, 771, 779, 787, 795, 803, 811, 819, 827, 835, 843, 851, 859, 867, 875, 883, 891, 899, 907, 915, 923, 931, 939, 947, 955, 963, 971, 979, 987, 995, 1003, 1011, 1019, 1027, 1035, 1043, 1051, 1059, 1067, 1075, 1083, 1091, 1099, 1107, 1115, 1123, 1131, 1139, 1147, 1155, 1163, 1171, 1179, 1187, 1195, 1203, 1211, 1219, 1227, 1235, 1243, 1251, 1259, 1267, 1275, 1283, 1291, 1299, 1307, 1315, 1323, 1331, 1339, 1347, 1355, 1363, 1371, 1379, 1387, 1395, 1403, 1411, 1419, 1427, 1435, 1443, 1451, 1459, 1467, 1475, 1483, 1491, 1499, 1507, 1515, 1523, 1531, 1539, 1547, 1555, 1563, 1571, 1579, 1587, 1595, 1603, 1611, 1619, 1627, 1635, 1643, 1651, 1659, 1667, 1675, 1683, 1691, 1699, 1707, 1715, 1723, 1731, 1739, 1747, 1755, 1763, 1771, 1779, 1787, 1795, 1803, 1811, 1819, 1827, 1835, 1843, 1851, 1859, 1867, 1875, 1883, 1891, 1899, 1907, 1915, 1923, 1931, 1939, 1947, 1955, 1963, 1971, 1979, 1987, 1995, 2003, 2011, 2019, 2027, 2035, 2040

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6, 20, 34, 48, 62, 76, 90, 104, 118, 132, 146, 160, 174, 188, 202, 216, 230, 244, 258, 272, 286, 300, 314, 328, 342, 356, 370, 384, 398, 412, 426, 440, 454, 468, 482, 496, 510, 524, 538, 552, 566, 580, 594, 608, 622, 636, 650, 664, 678, 692, 706, 720, 734, 748, 762, 776, 790, 804, 818, 832, 846, 860, 874, 888, 902, 916, 930, 944, 958, 972, 986, 1000, 1014, 1028, 1042, 1056, 1070, 1084, 1098, 1112, 1126, 1140, 1154, 1168, 1182, 1196, 1210, 1224, 1238, 1252, 1266, 1280, 1294, 1308, 1322, 1336, 1350, 1364, 1378, 1392, 1406, 1420, 1434, 1448, 1462, 1476, 1490, 1504, 1518, 1532, 1546, 1560, 1574, 1588, 1602, 1616, 1630, 1644, 1658, 1672, 1686, 1700, 1714, 1728, 1742, 1756, 1770, 1784, 1798, 1812, 1826, 1840, 1854, 1868, 1882, 1896, 1910, 1924, 1938, 1952, 1966, 1980, 1994, 2008, 2022, 2036, 2050, 2064, 2078, 2092, 2106, 2120, 2134, 2148, 2162, 2176, 2190, 2204, 2218, 2232, 2246, 2260, 2274, 2288, 2302, 2316, 2330, 2344, 2358, 2372, 2386, 2400, 2414, 2428, 2442, 2456, 2470, 2484, 2498, 2512, 2526, 2540, 2554, 2568, 2582, 2596, 2610, 2624, 2638, 2652, 2666, 2680, 2694, 2708, 2722, 2736, 2750, 2764, 2778, 2792, 2806, 2820, 2834, 2848, 2862, 2876, 2890, 2904, 2918, 2932, 2946, 2960, 2974, 2988, 3002, 3016, 3030, 3044, 3058, 3072, 3086, 3100, 3114, 3128, 3142, 3156, 3170, 3184, 3198, 3212, 3226, 3240, 3254, 3268, 3282, 3296, 3310, 3324, 3338, 3352, 3366, 3380, 3394, 3408, 3422, 3436, 3450, 3464, 3478, 3492, 3506, 3520, 3534, 3548, 3562, 3570

decompand31.0.table
7, 22, 37, 52, 67, 82, 97, 112, 127, 142, 157, 172, 187, 202, 217, 232, 247, 262, 277, 292, 307, 322, 337, 352, 367, 382, 397, 412, 427, 442, 457, 472, 487, 502, 517, 532, 547, 562, 577, 592, 607, 622, 637, 652, 667, 682, 697, 712, 727, 742, 757, 772, 787, 802, 817, 832, 847, 862, 877, 892, 907, 922, 937, 952, 967, 982, 997, 1012, 1027, 1042, 1057, 1072, 1087, 1102, 1117, 1132, 1147, 1162, 1177, 1192, 1207, 1222, 1237, 1252, 1267, 1282, 1297, 1312, 1327, 1342, 1357, 1372, 1387, 1402, 1417, 1432, 1447, 1462, 1477, 1492, 1507, 1522, 1537, 1552, 1567, 1582, 1597, 1612, 1627, 1642, 1657, 1672, 1687, 1702, 1717, 1732, 1747, 1762, 1777, 1792, 1807, 1822, 1837, 1852, 1867, 1882, 1897, 1912, 1927, 1942, 1957, 1972, 1987, 2002, 2017, 2032, 2047, 2062, 2077, 2092, 2107, 2122, 2137, 2152, 2167, 2182, 2197, 2212, 2227, 2242, 2257, 2272, 2287, 2302, 2317, 2332, 2347, 2362, 2377, 2392, 2407, 2422, 2437, 2452, 2467, 2482, 2497, 2512, 2527, 2542, 2557, 2572, 2587, 2602, 2617, 2632, 2647, 2662, 2677, 2692, 2707, 2722, 2737, 2752, 2767, 2782, 2797, 2812, 2827, 2842, 2857, 2872, 2887, 2902, 2917, 2932, 2947, 2962, 2977, 2992, 3007, 3022, 3037, 3052, 3067, 3082, 3097, 3112, 3127, 3142, 3157, 3172, 3187, 3202, 3217, 3232, 3247, 3262, 3277, 3292, 3307, 3322, 3337, 3352, 3367, 3382, 3397, 3412, 3427, 3442, 3457, 3472, 3487, 3502, 3517, 3532, 3547, 3562, 3577, 3592, 3607, 3622, 3637, 3652, 3667, 3682, 3697, 3712, 3727, 3742, 3757, 3772, 3787, 3802, 3817, 3825

decompand32.0.table
7, 23, 39, 55, 71, 87, 103, 119, 135, 151, 167, 183, 199, 215, 231, 247, 263, 279, 295, 311, 327, 343, 359, 375, 391, 407, 423, 439, 455, 471, 487, 503, 519, 535, 551, 567, 583, 599, 615, 631, 647, 663, 679, 695, 711, 727, 743, 759, 775, 791, 807, 823, 839, 855, 871, 887, 903, 919, 935, 951, 967, 983, 999, 1015, 1031, 1047, 1063, 1079, 1095, 1111, 1127, 1143, 1159, 1175, 1191, 1207, 1223, 1239, 1255, 1271, 1287, 1303, 1319, 1335, 1351, 1367, 1383, 1399, 1415, 1431, 1447, 1463, 1479, 1495, 1511, 1527, 1543, 1559,

1575, 1591, 1607, 1623, 1639, 1655, 1671, 1687, 1703, 1719, 1735, 1751, 1767, 1783, 1799, 1815, 1831, 1847, 1863, 1879, 1895, 1911, 1927, 1943, 1959, 1975, 1991, 2007, 2023, 2039, 2055, 2071, 2087, 2103, 2119, 2135, 2151, 2167, 2183, 2199, 2215, 2231, 2247, 2263, 2279, 2295, 2311, 2327, 2343, 2359, 2375, 2391, 2407, 2423, 2439, 2455, 2471, 2487, 2503, 2519, 2535, 2551, 2567, 2583, 2599, 2615, 2631, 2647, 2663, 2679, 2695, 2711, 2727, 2743, 2759, 2775, 2791, 2807, 2823, 2839, 2855, 2871, 2887, 2903, 2919, 2935, 2951, 2967, 2983, 2999, 3015, 3031, 3047, 3063, 3079, 3095, 3111, 3127, 3143, 3159, 3175, 3191, 3207, 3223, 3239, 3255, 3271, 3287, 3303, 3319, 3335, 3351, 3367, 3383, 3399, 3415, 3431, 3447, 3463, 3479, 3495, 3511, 3527, 3543, 3559, 3575, 3591, 3607, 3623, 3639, 3655, 3671, 3687, 3703, 3719, 3735, 3751, 3767, 3783, 3799, 3815, 3831, 3847, 3863, 3879, 3895, 3911, 3927, 3943, 3959, 3975, 3991, 4007, 4023, 4039, 4055, 4071, 4080

APPENDIX C: HUFFMAN TABLES

With lossless compression, a first-difference variable length coding is applied to the 8-bit input pixel stream segmented as shown in Section 4.4.5.3, Losslessly Compressed 8 Bit Image. The pixels are packed four pixels per word and ordered most-significant byte to least-significant byte.

The compressed output of each segment is preceded by a synchronization word, 0xFFFF0000. Compressed data output is left-justified in the more-significant bits of each word. Pad bits of 0 follow the end of each segment when the compressed segment is not an integer multiple of 32-bits.

The Huffman code tables are shown below.

```
typedef unsigned char uint8;

/*
    These tables represent the Huffman tree.  Each i is a node.  If the
    LEFT bit is set in flags, then left is the index of the next node in
    the tree; if it's clear, left is a leaf and contains the decoded value.
    RIGHT is handled similarly.
*/
uint8 flags[255] = {
0x03,0x03,0x03,0x01,0x03,0x01,0x01,0x03,0x02,0x02,0x00,0x01,0x01,0x03,0x01,0x00,
0x02,0x01,0x01,0x00,0x02,0x02,0x00,0x00,0x03,0x03,0x00,0x03,0x01,0x01,0x03,0x02,
0x02,0x00,0x01,0x01,0x03,0x00,0x01,0x02,0x02,0x00,0x02,0x02,0x00,0x00,0x03,0x03,
0x03,0x01,0x01,0x01,0x03,0x02,0x02,0x00,0x03,0x03,0x03,0x02,0x03,0x03,0x00,0x00,
0x03,0x00,0x00,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,0x00,0x00,0x03,
0x00,0x00,0x03,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,0x00,0x00,0x03,
0x00,0x00,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,0x00,0x00,0x03,0x00,
0x00,0x03,0x03,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,0x00,0x00,0x03,
0x00,0x00,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,0x00,0x00,0x03,0x00,
0x00,0x03,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,0x00,0x00,0x03,0x00,
0x00,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,0x00,0x00,0x03,0x00,0x00,
0x02,0x02,0x02,0x01,0x01,0x03,0x03,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,
0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,
0x00,0x00,0x03,0x00,0x00,0x03,0x03,0x03,0x03,0x00,0x00,0x03,0x00,0x00,0x03,0x03,
0x00,0x00,0x01,0x00,0x03,0x00,0x01,0x00,0x00,0x03,0x03,0x01,0x01,0x03,0x02,0x02,
0x00,0x01,0x01,0x03,0x00,0x03,0x00,0x03,0x02,0x00,0x00,0x02,0x02,0x00,0x00};

uint8 left[255] = {
0x01,0x02,0x03,0x04,0x05,0x06,0x07,0x08,0xed,0x17,0x1b,0x0c,0x0d,0x0e,0x0f,0xdd,
0x1f,0x12,0x13,0x2a,0x08,0xf4,0xf0,0xff,0x19,0x1a,0xfb,0x1c,0x1d,0x1e,0x1f,0x14,
0x18,0x1c,0x23,0x24,0x25,0x20,0x27,0x24,0x28,0xaa,0x09,0xf3,0xef,0x02,0x2f,0x30,
0x31,0x32,0x33,0x34,0x35,0x15,0xe7,0x1d,0x39,0x3a,0x3b,0x21,0x3d,0x3e,0xa8,0xa5,
0x41,0xa1,0x9f,0x44,0x45,0x46,0xab,0x9b,0x49,0x9d,0x97,0x4c,0x4d,0x95,0x93,0x50,
0x91,0x8f,0x53,0x54,0x55,0x56,0x9c,0x8b,0x59,0x89,0x87,0x5c,0x5d,0x8d,0x83,0x60,
0x81,0xc3,0x63,0x64,0x65,0x7d,0xc5,0x68,0x79,0x77,0x6b,0x6c,0x75,0xc8,0x6f,0x71,
0x6f,0x72,0x73,0x74,0x75,0x76,0x6d,0x86,0x79,0x69,0x67,0x7c,0x7d,0xbc,0xb5,0x80,
0xad,0x85,0x83,0x84,0x85,0x5d,0x5b,0x88,0x59,0x57,0x8b,0x8c,0x55,0x53,0x8f,0x51,
0x4f,0x92,0x93,0x94,0x95,0x4d,0x4b,0x98,0x49,0x47,0x9b,0x9c,0x45,0x43,0x9f,0x41,
0x3f,0xa2,0xa3,0xa4,0x3d,0x3b,0xa7,0x39,0x37,0xaa,0xab,0x35,0x33,0xae,0x31,0x2f,
0x06,0x0a,0xf2,0xb4,0xb5,0xb6,0xb7,0xb8,0xb9,0xba,0x2d,0x6b,0xbd,0xaf,0xb1,0xc0,
0xc1,0xb7,0xb9,0xc4,0xbe,0xc0,0xc7,0xc8,0xc9,0xca,0xcc,0xcc,0xce,0xd0,0xcf,0xd0,
0xd2,0xd4,0xd3,0xb3,0x61,0xd6,0xd7,0xd8,0xd9,0xbb,0x63,0xdc,0xc1,0x64,0xdf,0xe0,
0x73,0x7a,0xe3,0x7f,0xe5,0x25,0xe7,0xd7,0xfd,0xea,0xeb,0xec,0xed,0xee,0x12,0x16,
0x1a,0xf2,0xf3,0xf4,0x1e,0xf6,0xde,0xf8,0x26,0x2b,0xd9,0x07,0x0b,0xf1,0x04};

uint8 right[255] = {
0x2e,0x18,0x17,0x00,0x14,0xf8,0x0c,0x0b,0x09,0x0a,0xe5,0xec,0xe8,0x10,0xe1,0x23,
```

```
0x11,0xdc,0xd8,0xa9,0x15,0x16,0x10,0x01,0x2d,0x1b,0x05,0x2a,0xf7,0x0d,0x22,0x20,
0x21,0xe4,0xeb,0x19,0x26,0xe0,0xdf,0x28,0x29,0xa6,0x2b,0x2c,0x11,0xfe,0xe9,0xe8,
0xb0,0xfa,0xf6,0x0e,0x38,0x36,0x37,0xe3,0x71,0x52,0x43,0x3c,0x40,0x3f,0xa7,0xa2,
0x42,0xa0,0x9e,0x4b,0x48,0x47,0xa4,0xa3,0x4a,0x98,0x96,0x4f,0x4e,0x94,0x92,0x51,
0x90,0x8e,0x62,0x5b,0x58,0x57,0x9a,0x8a,0x5a,0x88,0x99,0x5f,0x5e,0x84,0x82,0x61,
0xc2,0xc4,0x6a,0x67,0x66,0x7c,0xc6,0x69,0x78,0x76,0x6e,0x6d,0xc7,0x72,0x70,0x70,
0x6e,0x91,0x82,0x7b,0x78,0x77,0x8c,0x6a,0x7a,0x68,0x66,0x7f,0x7e,0xb4,0xac,0x81,
0xae,0x6c,0x8a,0x87,0x86,0x5c,0x5a,0x89,0x58,0x56,0x8e,0x8d,0x54,0x52,0x90,0x50,
0x4e,0xa1,0x9a,0x97,0x96,0x4c,0x4a,0x99,0x48,0x46,0x9e,0x9d,0x44,0x42,0xa0,0x40,
0x3e,0xa9,0xa6,0xa5,0x3c,0x3a,0xa8,0x38,0x36,0xad,0xac,0x34,0x32,0xaf,0x30,0x2e,
0xb1,0xb2,0xb3,0xee,0xea,0xd5,0xc6,0xbf,0xbc,0xbb,0x2c,0x5f,0xbe,0xb0,0xb2,0xc3,
0xc2,0xb8,0xba,0xc5,0xbf,0xc9,0xce,0xcb,0xca,0xcb,0xcd,0xcd,0xcf,0xd1,0xd2,0xd1,
0xd3,0x5e,0xd4,0xb6,0x60,0xe4,0xde,0xdb,0xda,0xbd,0x62,0xdd,0x65,0x74,0xe2,0xe1,
0x7b,0x7e,0x29,0x80,0xe6,0xdb,0xda,0xd6,0x03,0xfe,0xfb,0xf9,0xf5,0xf1,0xef,0xf0,
0xe6,0x13,0xe9,0xf5,0xe2,0xf7,0x22,0xfa,0xf9,0xd5,0x27,0xfc,0xfd,0x0f,0xfc};
```

The following pseudo-code outlines the decoding process for a function that returns the coded difference.

```
LEFT=1
RIGHT=2

uint8 getNextValue()
{
    int node = 0; /* start at the root */
    int bit;

    for bit in bit_stream:
    {
      if ( bit == 0 )
      {
          /* go left */
          if(flags[node]&LEFT) node = left[node];
          else return left[node];
       }
       else
      {
          /* go right */
          if(flags[node]&RIGHT) node = right[node];
          else return right[node];
       }
    }
}
```

APPENDIX D: COLOR INTERPOLATION KERNELS

For the JPEG compression of MARDI, MAHLI, and broadband (filter 0) Mastcam images, color (three-component) JPEG compression is used. This requires that a full RGB color version of the image be formed from the raw Bayer-pattern image prior to compression. This is done by the compression logic in each camera's Digital Electronics Assembly (DEA).

At each Bayer filter position (R, G1, G2, and B) a 5x5 matrix, which interpolates the neighborhood values around that pixel is used to estimate the two missing colors. The matrices used are described in Figure 2 of Ref 15 which are

```
#define  A  0.25
#define  B  0.125
#define  C  0.5
#define  D  0.75
#define  E  0.1875
#define  F  0.0625
#define  G  0.625


/* red location */
float red_loc_r[] =
{
  0,   0,   0,   0,   0,
  0,   0,   0,   0,   0,
  0,   0,   1,   0,   0,
  0,   0,   0,   0,   0,
  0,   0,   0,   0,   0
};

float red_loc_g[] =
{
  0,   0,  -B,   0,   0,
  0,   0,   A,   0,   0,
 -B,   A,   C,   A,  -B,
  0,   0,   A,   0,   0,
  0,   0,  -B,   0,   0
};

float red_loc_b[] =
{
  0,   0,  -E,   0,   0,
  0,   A,   0,   A,   0,
 -E,   0,   D,   0,  -E,
  0,   A,   0,   A,   0,
  0,   0,  -E,   0,   0
};


/* blue location */
float blu_loc_r[] =
{
  0,   0,  -E,   0,    0,
  0,   A,   0,   A,    0,
```

```
 -E,   0,   D,   0,   -E,
  0,   A,   0,   A,    0,
  0,   0,  -E,   0,    0
};

float blu_loc_g[] =
{
  0,   0,  -B,   0,   0,
  0,   0,   A,   0,   0,
 -B,   A,   C,   A,  -B,
  0,   0,   A,   0,   0,
  0,   0,  -B,   0,   0
};

float blu_loc_b[] =
{
  0,   0,   0,   0,   0,
  0,   0,   0,   0,   0,
  0,   0,   1,   0,   0,
  0,   0,   0,   0,   0,
  0,   0,   0,   0,   0
};


/* green location, red row */
float grn_loc_red_row_r[] =
{
  0,   0,   F,   0,    0,
  0,  -B,   0,  -B,    0,
 -B,   C,   G,   C,   -B,
  0,  -B,   0,  -B,    0,
  0,   0,   F,   0,    0
};

float grn_loc_red_row_g[] =
{
  0,   0,   0,   0,   0,
  0,   0,   0,   0,   0,
  0,   0,   1,   0,   0,
  0,   0,   0,   0,   0,
  0,   0,   0,   0,   0
};

float grn_loc_red_row_b[] =
{
  0,   0,  -B,   0,   0,
  0,  -B,   C,  -B,   0,
  F,   0,   G,   0,   F,
  0,  -B,   C,  -B,   0,
  0,   0,  -B,   0,   0
};

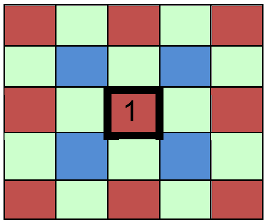
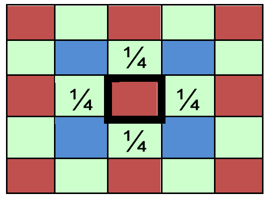
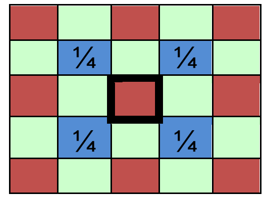
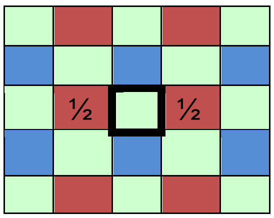
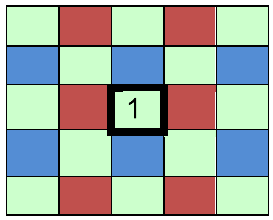
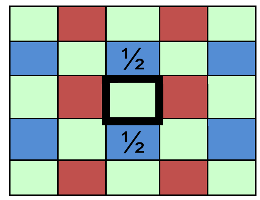
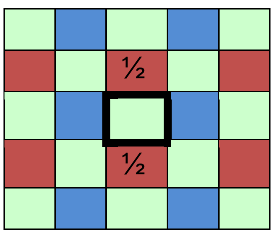
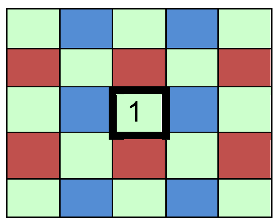
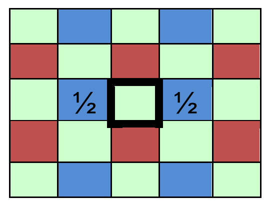
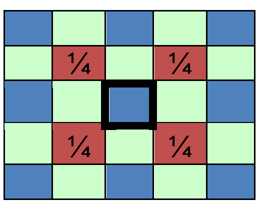
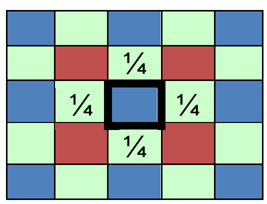
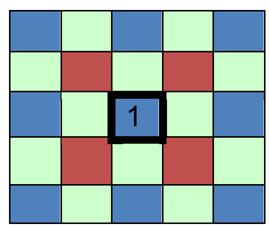
/* green location, blue row */
float grn_loc_blu_row_r[] =
{
  0,   0,  -B,   0,   0,
```

```
  0,  -B,   C,  -B,   0,
  F,   0,   G,   0,   F,
  0,  -B,   C,  -B,   0,
  0,   0,  -B,   0,   0
};

float grn_loc_blu_row_g[] =
{
  0,   0,   0,   0,   0,
  0,   0,   0,   0,   0,
  0,   0,   1,   0,   0,
  0,   0,   0,   0,   0,
  0,   0,   0,   0,   0
};

float grn_loc_blu_row_b[] =
{
  0,   0,   F,   0,   0,
  0,  -B,   0,  -B,   0,
 -B,   C,   G,   C,  -B,
  0,  -B,   0,  -B,   0,
  0,   0,   F,   0,   0
};
```

The source of color at each Bayer pattern position can be represented in graphic format as follows:

Filter Sets		
Red Mask	Green Mask	Blue Mask
		
		
		
		

The masks used for each filter position in graphic format in graphic format as follows:

L0	L1	L2	L3	L4	L5	L6	L7
Bayer	Green	Blue	Red	Red	Identity	Identity	Identity

R0	R1	R2	R3	R4	R5	R6	R7
Bayer	Green	Blue	Red	Identity	Identity	Identity	Blue

For narrowband images where the Bayer filters are effectively transparent (wavelengths redward of 800 nm) no interpolation is done, and the image is treated as a one-component (grayscale) image.

For narrowband images where the Bayer filter transmissions are non-uniform (440-800 nm) the logic bilinearly interpolates the dominant Bayer position to fill the other positions (for example, for the 550 nm filter, the interpolation uses only the green Bayer positions) and the image is treated as a grayscale image.

For images that have no intrinsic color (depth maps), no interpolation is done and the image is treated as a grayscale image.

APPENDIX E: JPEG COMPRESSION

JPEG images are compressed onboard the MMM instruments using a baseline JPEG encoder core by Alma Technologies (JPEG-E 1L51NS00).

The MMM implementation of this core conforms to baseline JPEGs specified by the Joint Photographic Experts Group in ITU-T Recommendation T.81 (see Reference 11).

The first four bytes as defined by the standard are 0xFFD8 which is the SOI marker.
The end of data is defined by the EOI marker 0xFFD9.
Only Y or Y,Cb,Cr colorspaces are used.

ALMA Technologies – http://www.alma-tech.com

APPENDIX F: IMAGE ID (PICNO) NAMING SCHEME FOR CRUISE DATA FOR MASTCAM, MAHLI, AND MARDI

Background Info:

Instrument checkouts occurred three times during MSL's cruise to Mars: March 3, 2012, April 20, 2012, and June 14, 2012. The same sequence was used for each of these checkouts. Once the sequence executed and the products were downlinked, the products were erased from the rover's onboard data storage.

Image ID (PICNO) Edits:

The file naming convention for Mastcam, MAHLI, and MARDI cruise data has the same structure as surface data PICNOs. The fields, characters, and positions are the same, however, due to the same sequence being run at 3 different dates during MSL's Cruise phase, the PICNO itself is slightly different than what is defined in Section 3.4.

The following is an example of what each character in the PICNO name for cruise maps to:

SSSSIIFFFFFFLLLXXCCCCCPGV_XXXX.ZZZ

S: phase identifier – 4 characters, "CRU_" for all products
I: instrument - 2 letters
F: full seqid - 6 digits (sequence ID, override value)
L: seq line - 3 digits (command number in sequence, override value)
X: CDPID counter - 2 digits, 00 for all products
C: overall acquisition number of the command (see table below) - 5 digits (override value)
P: product type - 1 letter
G: GOP counter - 1 letter (0-9,A-F for GOP frame 0-15)
V: version - 1 digit
XXXX: processing code (only XXXX, no RDR products are generated for cruise data)
ZZZ: file extension (can be DAT, IMG, LBL)

Due to the version of the rover flight software running during Cruise, executing the same sequence multiple times and ending with erasure of the products, and camera settings during Cruise, some values in the PICNO differ from what is in the .LBL file. For example, take the following cruise product: CRU_MR0000040020000014C01_XXXX, and compare the value in the PICNO to the value in the .LBL to see the differences.

Example of a Cruise product:

CRU_MR0000040020000014C00_XXXX		
PICNO	**Translation**	**Value in .LBL**
CRU_	Cruise product	MISSION_PHASE = CRUISE AND APPROACH
MR	Mastcam Right (100 mm) camera	INSTRUMENT_ID = MAST_RIGHT
000004	Sequence ID of 4	SEQUENCE_ID = aut_04096

002	Product was the 3rd command to execute in the sequence (command 1 = 000; command 2 = 001, command 3 = 002, etc.)	(value not reported in .LBL)
00	CDPID counter of 0	CAMERA_PRODUCT_ID_COUNT = 0
00014	14th Mastcam Right product acquired during the cruise phase	CAMERA_PRODUCT_ID = 2
C	Product type is a losslessly compressed raster 8-bit image	(value not reported in .LBL)
0	GOP counter of 0	GOP_TOTAL_FRAMES = N/A
0	Product version of 0	(value not reported in .LBL)
XXXX	EDR product	DATA_SET_ID = MSL-M-MASTCAM-2-EDR-IMG-V1.0

Explanations of the differences in SEQUENCE_ID and CAMERA_PRODUCT_ID between the PICNO and what is reported in the .LBL file:

A known rover flight software bug is responsible for SEQUENCE_ID = aut_04096 for Mastcam and MAHLI; this was the expected value for the MARDI EDL sequence. This bug was fixed for MAHLI on sol 5 and for Mastcam on sol 267.

Due to the fact that the same sequence was executed three times and the products erased at the end of each acquisition, the CAMERA_PRODUCT_ID in the .LBL is actually correct for each sequence because the DEA has no record of the previously acquired products. Therefore, to make the products unique, this value is being manually changed to reflect the overall acquisition number of the command. An example of this is provided here.

Example of how Cruise product's CCCCC value is being assigned:

Date of Execution	Sequence ID	Mast Camera	CAMERA_PRODUCT_ID	CCCCC Value in PICNO
March 3, 2012	4	Left	1	00001
		Left	2	00002
		Left	3	00003
		Left	4	00004
		Right	1	00005
		Right	2	00006
		Right	3	00007
		Right	4	00008
April 20, 2012	4	Left	1	00009
		Left	2	00010
		Left	3	00011
		Left	4	00012
		Right	1	00013
		Right	2	00014
		Right	3	00015
		Right	4	00016
June 14, 2012	4	Left	1	00017

		Left	2	00018
		Left	3	00019
		Left	4	00020
		Right	1	00021
		Right	2	00022
		Right	3	00023
		Right	4	00024

APPENDIX G: IMAGE ID (PICNO) NAMING SCHEME FOR PRE_ATLO AND ATLO DATA FOR MAHLI ONLY

Background Info:

The PRE_ATLO data set includes images acquired during the camera development phase (DEV_), stand-alone (instrument) thermal vacuum testing (TVC_), stand-alone (instrument) calibration (CAL_), and delivery (DEL_) of the MAHLI instrument to JPL-Caltech from August 15, 2008 to October 16, 2008. MAHLI was not integrated with the rover, mechanically nor electronically, at any point during this phase.

The Assembly, Test, and Launch Operations (ALTO) (ATL_) data set includes images acquired from November 5, 2010 to November 11, 2011. MAHLI was integrated with or at least connected to the rover when the data were acquired during this period.

Image ID (PICNO) Description:

The file naming convention for MAHLI PRE_ATLO and ALTO data (collectively known as pre-launch data) has the same structure as surface data PICNOs. The fields, characters, and positions are the same, however, due to the fact that the instrument was not integrated with the rover during PRE_ATLO, flight software was still in development during ALTO and some camera settings were disabled during both PRE_ATLO and ATLO, the PICNO itself is slightly different than what is defined in Section 3.4.

The following is an example of what each character in the PICNO name for pre-launch data maps to:

SSSSIIFFFFFFLLLXXCCCCCPGV_XXXX.ZZZ

S: phase identifier – 4 characters, (can be DEV_, TVC_, CAL_, DEL, or ATL_)
I: instrument - 2 letters (always MH)
F: full seqid - 6 digits (sequence ID, override value)
L: seq line - 3 digits (command number in sequence)
X: CDPID counter - 2 digits, 00 for all products
C: complete CDPID - 5 digits (acquisition number of the command, override value)
P: product type - 1 letter
G: GOP counter - 1 letter (0-9,A-F for GOP frame 0-15)
V: version - 1 digit
XXXX: processing code (only XXXX, no RDR products are generated for pre-launch data)
ZZZ: file extension (can be DAT, IMG, LBL)

Example of a PRE_ATLO development (DEV) product (the following structure also applies to the calibration (CAL) and delivery (DEL) products):

DEV_MH0809050070000547B00_XXXX		
PICNO	**Translation**	**Value in .LBL**
DEV_	PRE_ATLO development product	MISSION_PHASE = DEVELOPMENT
MH	MAHLI	INSTRUMENT_ID = MAHLI

080905	Sequence ID of 080905 (080905 = 5th PRE_ATLO test performed during September 2008)	SEQUENCE_ID = N/A
007	Product was the 8th command to execute during the test (command 1 = 000; command 2 = 001, command 3 = 002, etc.)	(value not reported in .LBL)
00	CDPID counter of 0	CAMERA_PRODUCT_ID_COUNT = 0
00547	547th MAHLI product acquired during the DEV_ test period	CAMERA_PRODUCT_ID = 1
B	Product type is a raster 8-bit image	(value not reported in .LBL)
0	GOP counter of 0	GOP_TOTAL_FRAMES = N/A
0	Product version of 0	(value not reported in .LBL)
XXXX	EDR product	DATA_SET_ID = MSL-M-MAHLI-2-EDR-IMG-V1.0

Explanations of the differences in SEQUENCE_ID and CAMERA_PRODUCT_ID between the PICNO and what is reported in the .LBL file:

Some of the PRE_ATLO products were acquired with a single command instead of a full sequence. The SEQUENCE_ID keyword in these images will have the value "N/A" in the .LBL file despite the PICNO containing a number. In these cases, the number in the PICNO corresponds to the date and test number executed and not an actual sequence ID.

Due to the fact that some camera settings were disabled during the acquisition for some PRE_ATLO products, the CAMERA_PRODUCT_ID in the .LBL file has a value of 1 as opposed to a nominally assigned CDPID. Therefore, to make the products unique, the CCCCC value reported in the PICNO reflects the overall acquisition number of the command during a given test period.

Example of a PRE_ATLO Thermal Vacuum product:

TVC_MH0809170040000676E00_XXXX		
PICNO	**Translation**	**Value in .LBL**
TVC_	PRE_ATLO thermal vacuum testing product	MISSION_PHASE = DEVELOPMENT
MH	MAHLI	INSTRUMENT_ID = MAHLI
080917	Sequence ID of 080917 (080917 = 17th PRE_ATLO test performed during September 2008)	SEQUENCE_ID = N/A
004	Product was the 5th command to execute in the a sequence (command 1 = 000; command 2 = 001, command 3 = 002, etc.) repeated many times during the test	(value not reported in .LBL)
00	CDPID counter of 0	CAMERA_PRODUCT_ID_COUNT = 0
00676	676th MAHLI product acquired during PRE_ATLO thermal vacuum testing	CAMERA_PRODUCT_ID = 452

	(TVC_)	
E	Product type is a JPEG 422 image	(value not reported in .LBL)
0	GOP counter of 0	GOP_TOTAL_FRAMES = N/A
0	Product version of 0	(value not reported in .LBL)
XXXX	EDR product	DATA_SET_ID = MSL-M-MAHLI-2-EDR-IMG-V1.0

Explanations of the differences in SEQUENCE_ID and CAMERA_PRODUCT_ID between the PICNO and what is reported in the .LBL file:

Some of the PRE_ATLO products were acquired with a single command instead of a full sequence. The SEQUENCE_ID keyword in these images will have the value “N/A” in the .LBL file despite the PICNO containing a number. In these cases, the number in the PICNO corresponds to the date and sequence number executed and not an actual sequence ID.

For most of thermal vacuum testing, camera settings were enabled. For these products, the CAMERA_PRODUCT_ID in the .LBL file will still have a value that differs from what is seen in the PICNO. This is a result of the above-mentioned manual overrides to the PICNO in order to make the other products unique. The value in the .LBL file will be the actual CDPID that was assigned to the product during testing.

Example of ATLO product with SEQUENCE_ID:

ATL_MH0090060030001393E01_XXXX		
PICNO	**Translation**	**Value in .LBL**
ATL_	ATLO product	MISSION_PHASE = DEVELOPMENT
MH	MAHLI	INSTRUMENT_ID = MAHLI
009006	Sequence ID of 9006	SEQUENCE_ID = mhli09006
003	Product was the 4th command to execute in the sequence (command 1 = 000; command 2 = 001, command 3 = 002, etc.)	(value not reported in .LBL)
00	CDPID counter of 0	CAMERA_PRODUCT_ID_COUNT = 0
01393	1393rd MAHLI product acquired during ATLO	CAMERA_PRODUCT_ID = 1393
E	Product type is a JPEG 422 image	(value not reported in .LBL)
0	GOP counter of 0	GOP_TOTAL_FRAMES = N/A
1	Product version of 1	(value not reported in .LBL)
XXXX	EDR product	DATA_SET_ID = MSL-M-MAHLI-2-EDR-IMG-V1.0

Example of ATLO product without SEQUENCE_ID:

ATL_MH1111010010001395I01_XXXX		
PICNO	**Translation**	**Value in .LBL**
ATL_	ATLO product	MISSION_PHASE = DEVELOPMENT
MH	MAHLI	INSTRUMENT_ID = MAHLI
111101	Sequence ID of 9006 Sequence ID of 111101 (111101 = 1st PRE_ATLO test performed during November 2011)	SEQUENCE_ID = N/A
001	Product was the 2nd command to execute in the sequence (command 1 = 000; command 2 = 001, command 3 = 002, etc.)	(value not reported in .LBL)
00	CDPID counter of 0	CAMERA_PRODUCT_ID_COUNT = 0
01395	1395th MAHLI product acquired during ATLO	CAMERA_PRODUCT_ID = 1
I	Product type is a JPEG 444 thumbnail	(value not reported in .LBL)
0	GOP counter of 0	GOP_TOTAL_FRAMES = N/A
1	Product version of 1	(value not reported in .LBL)
XXXX	EDR product	DATA_SET_ID = MSL-M-MAHLI-2-EDR-IMG-V1.0

Explanations of the differences in SEQUENCE_ID and CAMERA_PRODUCT_ID between the PICNO and what is reported in the .LBL file:

Some of the ATLO products were acquired with a single command instead of a full sequence. The SEQUENCE_ID keyword in these images will have the value “N/A” in the .LBL file despite the PICNO containing a number. In these cases, the number in the PICNO corresponds to the date and sequence number executed and not an actual sequence ID.

Due to the fact that some camera functions were disabled during the acquisition for some ATLO products, the CAMERA_PRODUCT_ID in the .LBL file will have a value of 1 as opposed to a nominally assigned CDPID. Therefore, to make the products unique, the CCCCC value reported in the PICNO reflects the overall acquisition number of the command during a given test period.