Mars 2020 (M2020)

Software Interface Specification

Interface Title: **MOXIE Data Products**

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Mars 2020 Project

Software Interface Specification (SIS)

MOXIE Data Products

Version 0.7 (Draft)

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JPL D-99962

February 12, 2021

Jet Propulsion Laboratory
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CHANGE LOG

Date	Sections changed	Reason for change	Revision
07/25/19	Section 1.3 Appendix A	Update references Add EDR label example	v0.2
10/17/19	Section 2.4.2	Update filename structure	v0.21
12/02/19	Signatures	Add Adrian Ponce as Investigation Scientist	v0.22
04/28/20	Figure 2-3 Section 3 Section 4 Appendix A	Add information	v0.23
05/07/20	Section 4	Add information	v0.24
05/12/20	Section 2.3.1 Section 2.4.2	Remove RIMFAX reference	v0.25
06/01/20	Section 3.2.7 Section 3.2.8	Add information	v0.26
06/22/20	Section 2 Section 3	Re-arrange and add information	v0.27
08/27/20	All sections	Merge info from secondary draft	v0.30
08/31/20	All sections	Add information	v0.32
10/19/20	All sections	Added calibrated and derived data product descriptions, revised all other sections	v0.63
10/26/20	3.2.1.1 5.2.1 5.2.2	Remove underscores from attribute values Change order of parameters in derived data product, add constant *fs* for PO2_A Update values of constants *fp*, *fq*, *fr*, *fs*	v0.64
02/12/21	All sections	Implement comments from PDS peer reviews	v0.7

OPEN ISSUE ITEMS

Revision	Open issue	Closed
v0.63	Calibrated quantity PCO2_C uncorrected from factory temperature and total pressure, pending updated calibration.	No
v0.63	Calibrated quantity PCO_C uncorrected from factory temperature and total pressure, pending updated calibration.	No
v0.63	Calibrated quantity PCO2_A uncorrected from factory temperature and total pressure, pending updated calibration.	No
v0.63	Calibrated quantity PO2_A uncorrected from factory temperature and pressure, pending updated calibration.	No
v0.63	Derived quantity F_O2_CS_G_HR equation to be added.	No
v0.63	Derived quantity X_O2_CS equation to be added.	No
v0.63	Derived quantity U_CO2_1_CS equation to be added.	No
v0.63	Derived quantity U_CO2_O_CS equation to be added.	No
v0.63	Derived quantity V_OC_OP equation to be added.	No
v0.63	Derived quantity V_OC_SD equation to be added.	No

ACRONYMS AND ABBREVIATIONS

aASR	apparent Area Specific Resistance
AMMOS	Advanced Multi-mission Operations System
AMPCS	Advanced Multi-mission data Processing and Control System
APID	Application ID
APT	Algorithm Parameter Table
ASCII	American Standard Code for Information Interchange
ASR	Area Specific Resistance
CAC	Carbon dioxide Acquisition and Compression
ccASR	conversion-corrected Area Specific Resistance
CL	Current Limit
CR	Carriage Return
CS	Composition Sensor
CS3	Common Software Services Subsystem
CSV	Comma-Separated Value
CPU	Central Processing Unit
CU	Calibrated Unit
DN	Digital Number
DPO	Data Product Object
EDR	Experiment Data Record
EDL	Entry, Descent and Landing
EI	Experiment Intent
FEI	File Exchange Interface
FGICD	Flight Ground Interface Control Document
FM	Flight Model
FPGA	Field Programmable Gate Array
FSW	Flight Software
GDS	Ground Data System
HEPA	High Efficiency Particulate Air
iASR	intrinsic Area Specific Resistance
ID	Identifier
IDS	Instrument Data System
ISRU	In-Situ Resource Utilization
JMS	Java Message System
JPL	Jet Propulsion Laboratory
LF	Line Feed

LMST	Local Mean Solar Time
LTST	Local True Solar Time
MEDA	Mars Environmental Dynamics Analyzer
MIPL	Multi-mission Image Processing Laboratory
MIT	Massachusetts Institute of Technology
MOXIE	Mars Oxygen ISRU Experiment
MPCS	Multi-mission data Processing and Control System
MY	Mars Year
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
OCS	Operations Cloud Store
OCV	Open Circuit Voltage
ODL	Object Description Language
PDS	Planetary Data System
P	Pressure
PI	Principal Investigator
PMC	Process Monitoring and Control
PWM	Pulse Width Modulation
RAMP	Rover Avionics Mounting Panel
RCE	Rover Compute Element
RCT	Run Control Table
RDR	Reduced Data Record
RDS	Radiation and Dust Sensor
RMC	Rover Motion Counter
RPM	Revolutions Per Minute
RPT	Run Parameter Table
sccm	standard cubic centimeters per minute
SCLK	Spacecraft Clock
SFDU	Standard Format Data Unit
SIS	Software Interface Specification
SL	Safety Limit
SPICE	Spacecraft, Planet, Instrument, Camera matrix, Events
SOXE	Solid Oxide Electrolysis
SPT	Safety Parameter Table
T	Temperature
TDS	Telemetry Data System
TL	Temperature Limit
UTC	Universal Time Coordinated

VFCD	Viscous Flow Control Device
YAML	YAML Ain’t Markup Language
XML	eXtensible Markup Language

TABLE OF CONTENTS

1 Quick start guide

MOXIE produces oxygen from Mars' atmospheric carbon dioxide using electrolysis. In this quick start guide, you will examine the oxygen mass flow rate and the current through the electrolytic cells where the oxygen is produced.

1.1 Plot the oxygen mass flow rate versus time

1. Navigate to the derived data directory, `data_derived/`.

2. In data_derived/, navigate to a MOXIE run directory. Each directory contains data from one MOXIE run. The directory name tells you the Martian day ("sol") on which MOXIE started producing oxygen. Each MOXIE run lasts around 3.5 hours: 2.5 hours of warmup followed by 1 hour of oxygen production.

3. Open the CSV file, and using your favorite plotting program, plot the column T on the *x*-axis, and the column F_O2_I_G_HR on the *y*-axis. T is time in seconds, and F_S_O2_I_G_HR is the oxygen mass flow rate (F_O2), derived from the current through the electrolytic cells (I), in grams per hour (G_HR).

5. Examine the field description of F_S_O2_I_G_HR in Section 6.1.3.11 of this document. Notice that F_S_O2_I_G_HR is derived from the parameters IT and IB in the calibrated data product.

1.2 Plot the currents versus time

1. Navigate to the calibrated data directory, data_calibrated/

2. In data_calibrated/, navigate to the same MOXIE run directory as before.

3. Open the CSV file, and plot IT and IB against SW_TIME. SW_TIME is the time in seconds, and IT and IB are the currents (I) through the top five (IT) and bottom five (IB) of the ten electrolytic cells.

5. Examine the description of IT and IB in Table 5-1 of this document. Notice that they are calculated using the equations in Table 5-2 and the constants in Table 5-3.

1.3 Plot the currents in Digital Numbers (DNs) versus time

1. Navigate to the raw data directory, data_raw/

2. In data_raw/, navigate to the same MOXIE run directory as before.

3. Open the CSV file, and plot IT and IB against SW_TIME. This time, the currents are not in Calibrated Units (CUs, A), but in the raw units of Digital Numbers (DNs).

1.4 Plotting other variables

1. Scan through the field names and descriptions for the derived data in Table 6-1 and for the calibrated data in Table 5-1.

2. If any field names or descriptions interest you, try adding them to your plots to see how they are related to the oxygen mass flow rate. You can try: pump RPM (RPMM1 in the calibrated data); heater temperatures (TT and TB in the calibrated data); or total energy consumption (E_TOT_W_HR in the derived data).

2 Introduction

1.5 Purpose and scope

The purpose of this Software Interface Specification (SIS) is to provide a detailed description of the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) raw, calibrated and derived data products.

This SIS is intended for two audiences. First, scientists and engineers analyzing the data products, both those associated with Mars 2020 and those in the general planetary science community. Second, software developers developing software used to generate and analyze the data products.

The raw, calibrated and derived data products described in this SIS adhere to version 4 of the Planetary Data System (PDS4). In version 3 of the PDS (PDS3), raw data products were called Experiment Data Records (EDRs) and calibrated and derived data products were called Reduced Data Records (RDRs). Therefore, within this SIS, “raw data product” can be interpreted as “EDR”, and “calibrated data product” and “derived data product” can be interpreted as “RDR”.

1.6 Contents

This SIS is divided into nine sections. Section 2 gives an overview of MOXIE. Section 3 describes the data products in general. Sections 4, 5 and 6 describe the raw, calibrated and derived data products in detail. Section 7 lists the standards used during generation of the data products. Section 8 describes software that can be used to analyze the data products. Section 9 contains references.

1.7 Applicable documents

This SIS responds to the following Mars 2020 documents:

- Mars 2020 Project: Archive Generation, Validation, and Transfer Plan. JPL D-95520.
- Flight Ground Interface Control Document (FGICD) Volume 1: Downlink. JPL D-95521.

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

- The PDS Data Provider’s Handbook - Guide to Archiving Planetary Data Using the PDS4 Standard.
- PDS Standards Reference. JPL D-7669.
- PDS4 Data Dictionary.

This SIS is meant to be consistent with the contract negotiated between the Mars 2020 Project and the MOXIE Principal Investigator (PI), in which data products and the associated documentation are explicitly defined as deliverable products.

1.8 Relationships to other interfaces

Changes to this SIS will affect the products, software, and/or documents listed in Table 2-1:

Table 2-1: Product and software interfaces to this SIS

Name	Type	Owner
MOXIE raw data products	Product	Instrument Data System (IDS)
m2020edrgen (telemproc)	Software	IDS
Common Software Services Subsystem (CS3) database schema	Product	CS3
Other MOXIE programs, products, and documents	Product; Software; Document	MOXIE science team

2 Instrument description

This section provides a general description of MOXIE. For a detailed description, refer to the pre-mission paper [1], which is included alongside this SIS in the MOXIE document collection.

2.1 Instrument system

The primary goals of MOXIE are to verify and validate Mars In-Situ Resource Utilization (ISRU) technology, and to enable potential future ISRU plants at the scale required for a human Mars mission.

MOXIE will produce oxygen from the carbon dioxide in Mars' atmosphere using Solid Oxide Electrolysis (SOXE). MOXIE's threshold requirements are to produce at least 6 g/hr of oxygen, of at least 98% purity, on at least 10 separate occasions. MOXIE's goal requirements are to produce at least 8 g/hr of oxygen, of at least 99.6% purity, on at least 20 separate occasions. These requirements have already been met on Earth.

On Mars, as well as repeating the threshold and goal requirements, MOXIE has the success criteria of running at day and night in all seasons, and during a dust storm if possible.

2.2 Instrument subsystems

A block diagram of MOXIE is shown in Figure 2-1, and the major component parts are drawn in Figure 2-2. MOXIE is comprised of three major subsystems: the Carbon dioxide Acquisition and Compression (CAC) subsystem, the SOXE subsystem, and the Process Monitoring and Control (PMC) subsystem. These subsystems are described in the following sections.

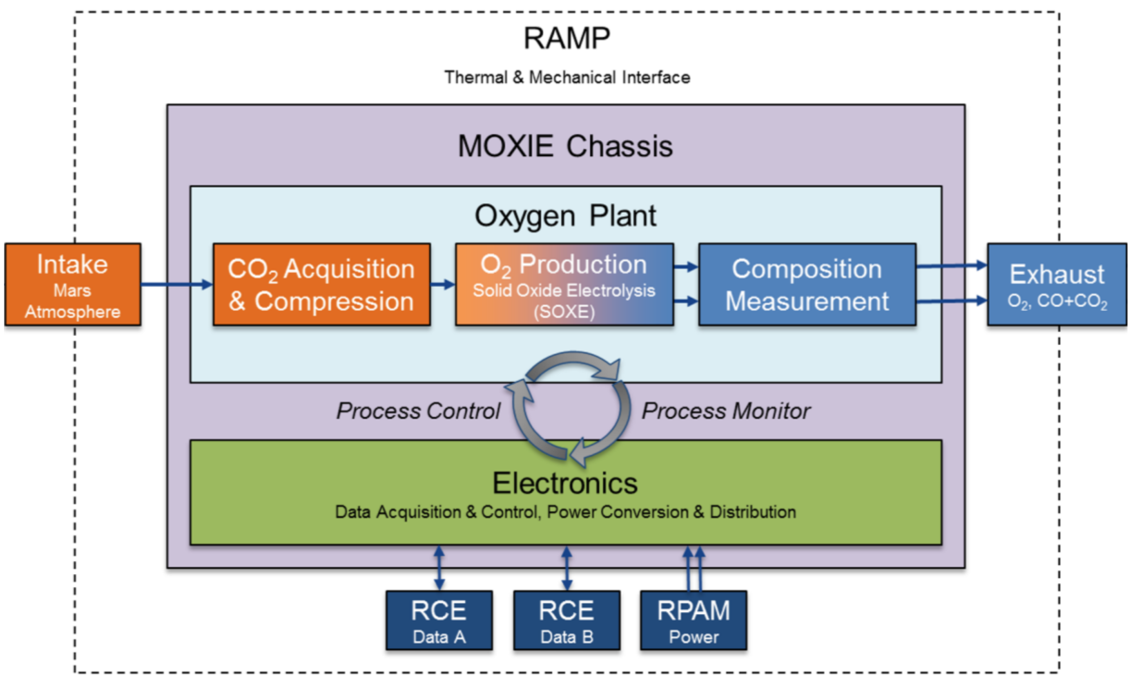

Figure 2-1: MOXIE block diagram

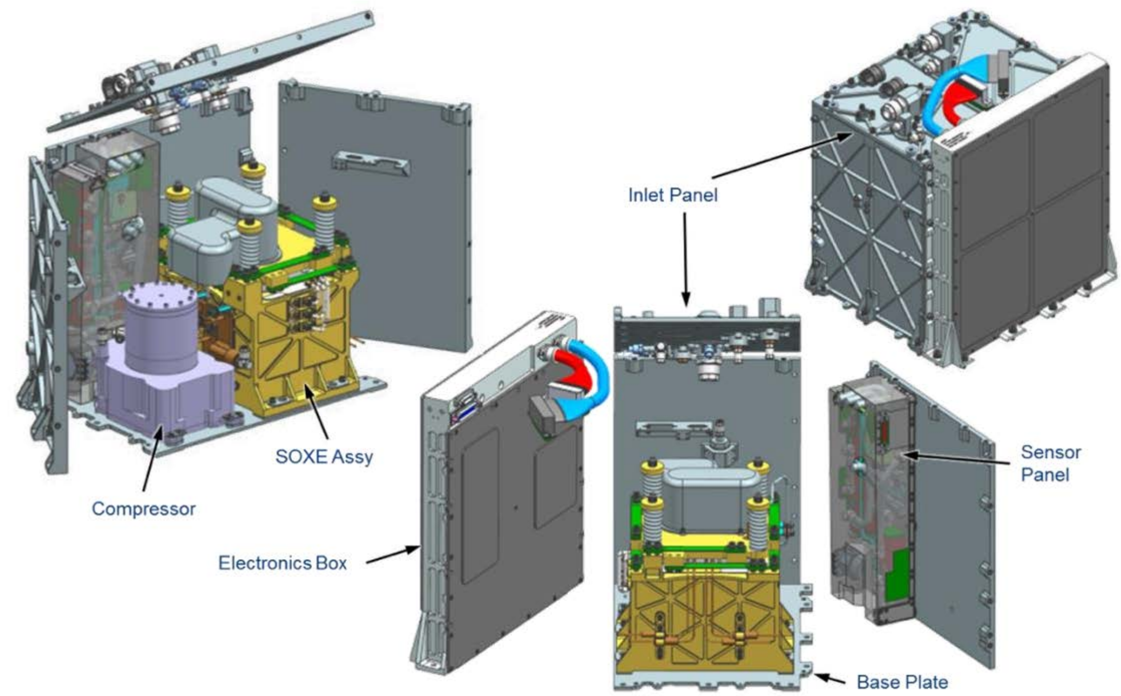

Figure 2-2: Exploded (left, center) and assembled (right) view of MOXIE, excluding components mounted externally on the rover chassis. The assembled MOXIE has dimensions of 24×24×31 cm. The major component parts are the scroll compressor (left, purple), SOXE assembly (gold, left and center), electronics box (center, right), base plate (center), inlet panel (center, right), and sensor panel (right)

2.2.1 Carbon dioxide Acquisition and Compression (CAC) subsystem

The primary function of the CAC subsystem is to acquire and compress carbon dioxide from the atmosphere of Mars.

The atmosphere is drawn in and compressed to approximately 1 bar by a scroll compressor (Air Squared, Inc., Broomfield, CO) operating at up to 3500 RPM. Downstream of the scroll compressor, a check valve is used to damp out pressure oscillations, a pair of pressure sensors on either side of an orifice is used to give an indication of flow rate, and a backflow gas cooler is used to prevent hot gases from damaging the check valve and backflowing into the compressor during shutdown.

Because Mars' atmosphere contains dust, the atmosphere is filtered before it enters the scroll compressor. A High-Efficiency Particulate Air (HEPA) filter is used.

2.2.2 Solid Oxide Electrolysis (SOXE) subsystem

The primary function of the SOXE subsystem is to produce oxygen by electrolysis of carbon dioxide. Carbon monoxide is produced as a waste product.

After exiting the backflow gas cooler, a heat exchanger heats the gas to approximately 800°C. Conversion of carbon dioxide to oxygen is achieved using a SOXE "stack" (Ceramatec, Inc., Salt Lake City, UT; now OxEon Energy, North Salt Lake, UT). The SOXE stack is mechanically configured as a stack of ten electrolytic cells, and electrically configured as a top and bottom half-stack of five cells each. Each electrolytic cell consists of a stabilized zirconia electrolyte located between porous nickel composite electrodes. The cells are separated by interconnects. One side of each interconnect directs the inlet gas across each cathode, carrying carbon monoxide, unreacted carbon dioxide, and residual atmospheric gases to the cathode exhaust. The other side of each interconnect directs the pure oxygen product away from each anode to the anode exhaust. Heat exchangers recover the heat from the outlet gases.

Depending on operating conditions, the SOXE stack converts between 30% and 50% of the incoming carbon dioxide to oxygen and carbon monoxide, resulting in an oxygen mass flow rate of up to 12 g/hr at 4 A.

As carbon dioxide is a mildly oxidizing gas, long-term operation can result in oxidation of the nickel catalyst in the cathodes. To prevent this, a few percent of the gas in the cathode exhaust is recirculated back to the scroll compressor inlet, so that the gas entering the SOXE stack contains a few percent carbon monoxide.

2.2.3 Process Monitoring and Control (PMC) subsystem

The primary functions of the PMC subsystem are to control the SOXE inlet mass flow rate, by either a compressor RPM or SOXE cathode pressure setpoint; the SOXE half-stack temperatures, by top and bottom heater temperature setpoints; the SOXE half-stack oxygen mass production rates, by top and bottom SOXE half-stack current setpoints; and to monitor MOXIE by recording data from MOXIE's sensors.

Most sensors and flow control devices are collected on a sensor panel mounted behind the scroll compressor and SOXE assembly. Exhaust gas heaters are vestigial from an earlier design that maintained full temperature control of the sensors. An electronics box is mounted on the side. The locations of MOXIE's pressure, temperature, and gas composition sensors are shown in Figure 2-3.

2.3 Instrument operations

Each MOXIE run is approximately three and a half hours long: two and a half hours for the SOXE to reach its operating temperature, followed by one hour of oxygen production.

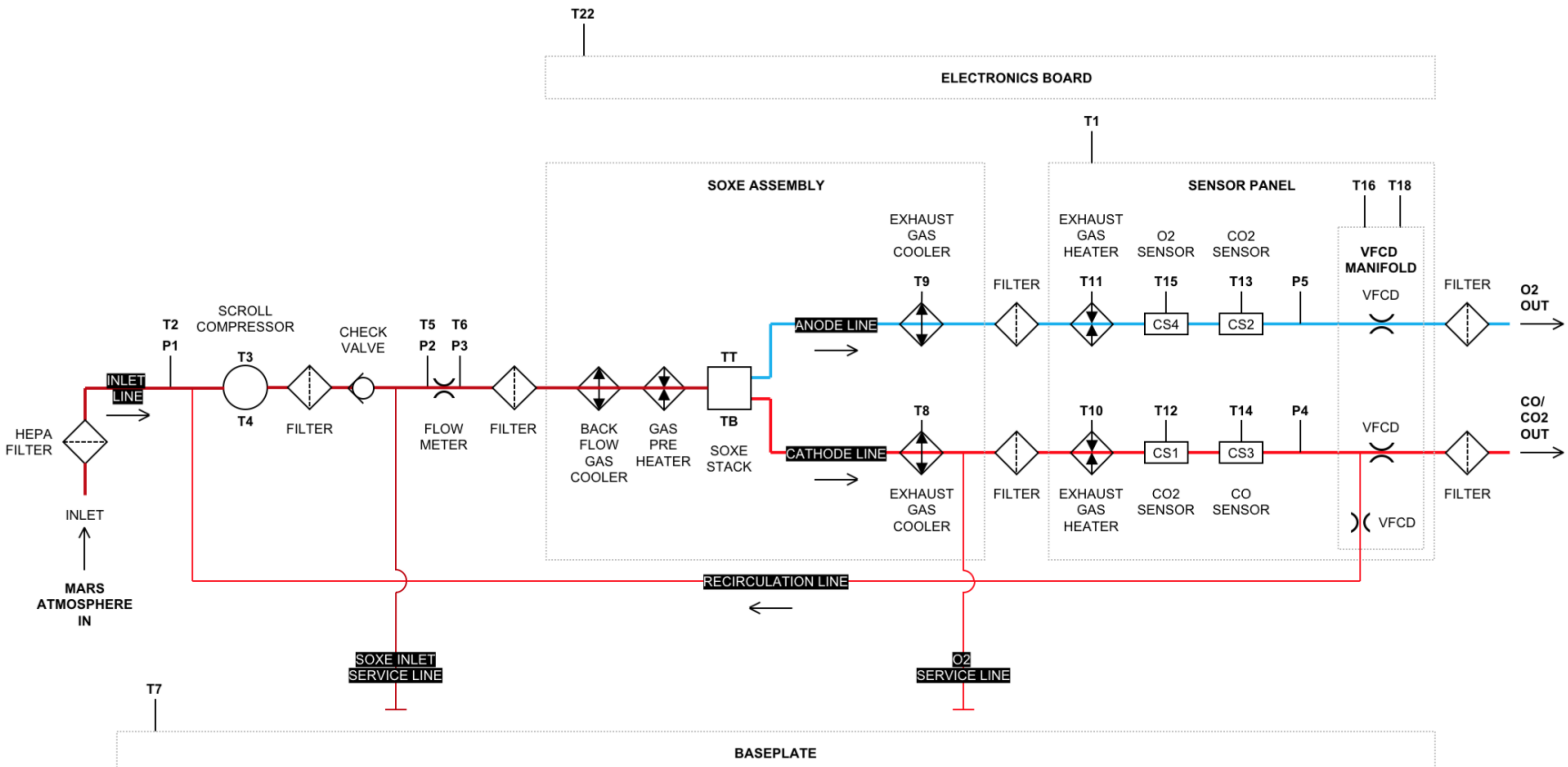

Figure 2-3: MOXIE sensor locations

3 Data product description: general

This section describes properties that are common to all three data products: raw, calibrated and derived. For properties specific to each data product, refer to Section 4 (raw), Section 5 (calibrated) and Section 6 (derived).

Each data product contains a data file (Section 3.1) and label file (Section 3.2).

3.1 Data file

3.1.1 Contents

Each data file contains time series of parameters sampled at 1 Hz.

The first row contains the field names for each parameter.

The time column (SW_TIME in the raw and calibrated data products, T in the derived data product) gives the time since the load of the Flight Software (FSW) after boot in seconds, starting at 0. The time column can be converted into spacecraft clock (SCLK), Local Mean Solar Time (LMST) or Local True Solar Time (LTST) by using the start time of the observation in the label file (Section 3.2.1.1).

3.1.2 Format

Each data file is in Comma-Separated Variable (CSV) format.

The fundamental structure of a MOXIE data table (.csv) file is the Parsable_Byte_Stream class: a stream of bytes that can be parsed using standardized rules. A simple ASCII text file – the MOXIE CSV table – consists of a stream of character data: one or more records delimited by a standard set of characters (the carriage-return line-feed pair). This is called the Delimiter Separated Value Format:

```
aaa,bbb,ccc<CR><LF>
zzz,yyy,xxx<CR><LF>
```

More specifically, a MOXIE .csv file is characterized by the Table_Delimited class, which inherits attributes from the Parsable_Byte_Stream class, and adds several more. The attribute <field_delimiter> must be defined in the Table_Delimited class.

The Table_Delimited class has one Record_Delimited class, which describes the structure of all records in the delimited table.

Although the individual fields may vary in size from one record to the next, the number of fields, their names, and their data types remain the same from line to line. Each field in the table is described by one Field_Delimited class. Field definitions are in the same order as the physical appearance of the fields in the record. Attribute <maximum_field_length> gives the maximum number of bytes in a field. Field delimiters and bracketing double quotes around character strings (if any) are not included in the count.

3.2 Label file

3.2.1 Contents

Each label file contains metadata. In addition to the standard PDS4 metadata, MOXIE label files contain Mars 2020- and MOXIE-specific metadata.

Mars 2020-specific metadata (Section 3.2.1.1) contains general information about the timing of the MOXIE run.

MOXIE-specific metadata (Section 3.2.1.2) is divided into two types: experiment configuration metadata and ancillary metadata. Experiment configuration metadata contains a record of the run uplinked to and executed by MOXIE that resulted in the downlinked data. Ancillary metadata contains references to data from other instruments relevant to MOXIE: the Mars Environmental Dynamics Analyzer (MEDA), SuperCam and Entry, Descent and Landing camera (EDLcam).

3.2.1.1 Mars 2020 parameters

Mars 2020-specific metadata is specified in each label file as follows. Values are examples only.

```
<Product_Observational>
  ⋮
  <Mission_Area>
    <mars2020:Mars2020_Parameters>
      <mars2020:Observation_Information>
        <mars2020:release_number>0001</mars2020:release_number>
        <mars2020:mission_phase_name>Surface Mission</mars2020:mission_phase_name>
        <mars2020:spacecraft_clock_start>0668149966</mars2020:spacecraft_…_start>
        <mars2020:spacecraft_clock_stop>0668163690</mars2020:spacecraft_…_stop>
        <mars2020:spacecraft_clock_partition>1</mars2020:spacecraft_…_partition>
        <mars2020:start_sol_number>00014</mars2020:start_sol_number>
        <mars2020:stop_sol_number>00014</mars2020:stop_sol_number>
        <mars2020:start_local_mean_solar_time>00014M03:30:00</mars2020:start_…_time>
        <mars2020:stop_local_mean_solar_time>000014M07:12:36</mars2020:stop_…_time>
        <mars2020:start_local_true_solar_time>00014M02:56:39</mars2020:start_…_time>
        <mars2020:stop_local_true_solar_time>00014M06:39:19</mars2020:stop_…_time>
        <mars2020:start_solar_longitude unit="deg">012.370</mars2020:start_…_longitude>
        <mars2020:stop_solar_longitude unit="deg">012.446</mars2020:stop_…_longitude>
        <mars2020:start_mars_year>36</mars2020:start_mars_year>
        <mars2020:stop_mars_year>36</mars2020:stop_mars_year>
      </mars2020:Observation_Information>
    </mars2020:Mars2020_Parameters>
    ⋮
  </Mission_Area>
  ⋮
</Product_Observational>
```

In the following description, the “mars2020:” namespace has been omitted from each XML object name for brevity.

The <Observation_Information> object contains 11 objects that describe the release number, mission phase, and then the start and stop times of the data in SCLK, sol number, LMST, LTST, solar longitude, and Mars Year (MY).

3.2.1.2 MOXIE parameters

MOXIE is commanded using an experiment configuration which consists of four tables: the Run Control Table (RCT), Algorithm Parameter Table (APT), Safety Parameter Table (SPT), and Run Parameter Table (RPT).

The experiment configuration is specified in each label file as follows. Values are examples only.

```
<Product_Observational>
  ⋮
  <Mission_Area>
    ⋮
    <mars2020:MOXIE_Parameters>
      <mars2020:Experiment_Configuration>
        <mars2020:Experiment_Configuration_Metadata>
          <mars2020:run_id>000</mars2020:run_id>
          <mars2020:experiment_name>example_run</mars2020:experiment_name>
          <mars2020:major_version_number>01</mars2020:major_version_number>
          <mars2020:minor_version_number>0</mars2020:minor_version_number>
          <mars2020:primary_objective>Make 6 g/hr O2 … </mars2020:primary_objective>
          <mars2020:secondary_objective>None</mars2020:secondary_objective>
        </mars2020:Experiment_Configuration_Metadata>
        ⋮
      </mars2020:Experiment_Configuration>
      ⋮
    </mars2020:MOXIE_Parameters>
  </Mission_Area>
  ⋮
</Product_Observational>
```

In the following description, the “mars2020:” namespace has been omitted from each XML object name for brevity.

The <Experiment_Configuration> object contains five objects: <Experiment_Configuration_Metadata>, <Run_Control_Table>, <Algorithm_Parameter_Table>, <Safety_Parameter_Table> and <Run_Parameter_Table>.

The <Run_Control_Table_Metadata> object contains the attributes <id>, <name>, <major_version_number>, <minor_version_number>, <primary_objective> and <secondary_objective>.

<id> is a unique identifier for the experiment configuration.

<experiment_name> is a short name for the experiment configuration.

<major_version_number> is an experiment configuration version number that was incremented when major changes were made to the experiment configuration.

<minor_version_number> is an experiment configuration version number that was incremented when minor changes were made to the experiment configuration.

<primary_objective> is the primary objective of the experiment configuration. The primary objective determines the steps written in the RCT.

<secondary_objective> is the secondary objective of the experiment configuration. The secondary objective does not determine the steps written in the RCT, but is achieved as a byproduct of the RCT steps written.

3.2.1.2.1 Run Control Table (RCT)

The RCT is the most important configuration file. Each row in the RCT is one step in the run, with an associated duration in seconds. At the start of each step, control loop setpoints, operational limits, and enable bits are set to the values specified for the duration of that step. The RCT includes a comments field that provides a brief description of the purpose of each step.

The control loop setpoints are: either scroll compressor RPM or SOXE cathode pressure, which are used to set the SOXE inlet mass flow rate; SOXE top and bottom half-stack currents, which are used to set the oxygen mass production rate; and SOXE top and bottom half-stack temperatures, which are normally set such that the interior of each SOXE half-stack is at the optimal temperature for oxygen production, approximately 800°C.

The operational limits apply to: the top and bottom SOXE half-stack temperatures; the SOXE cathode pressure; and the ratio of the top and bottom SOXE half-stack currents to the SOXE cathode pressure. Operational limits are so named because they can be changed from RCT step to RCT step. If any parameter exceeds its operational limit for longer than that operational limit's associated persistence time, a fault is declared and MOXIE aborts the run.

The enable bits apply to gas composition sensors CS1, CS2, and CS3; gas composition sensor CS4; the scroll compressor motor; and the top and bottom SOXE half-stacks.

The RCT written by the person commanding MOXIE is called the "Experiment Intent" (EI) RCT. The EI RCT is normally written in physical units, called Calibrated Units (CUs). Occasionally, the person commanding MOXIE will use a combination of physical units and Digital Numbers (DNs). However, before any RCT can be run on MOXIE, it must be converted to only DNs.

RCT field names, calibrated units, and descriptions are given in Table 3-1.

Table 3-1: Run Control Table (RCT) field names and descriptions

Name	Description	Calibrated unit
STEP_NUMBER	Step number	N/A
STEP_DURATION	Step duration	s
ZTT_SP	SOXE top half-stack temperature control loop setpoint	°C
ZTB_SP	SOXE bottom half-stack temperature control loop setpoint	°C
ZP4_SP	SOXE cathode pressure control loop setpoint	bar
ZP4_OS	SOXE cathode pressure control loop scroll compressor RPM offset	RPM
ZIT_SP	SOXE top half-stack current control loop setpoint	A

Name	Description	Calibrated unit
ZIT_OS	SOXE top half-stack current control loop voltage offset	V
ZIB_SP	SOXE bottom half-stack current control loop setpoint	A
ZIB_OS	SOXE bottom half-stack current control loop voltage offset	V
OL_TT_H	SOXE top half-stack temperature upper operational limit	°C
OL_TT_L	SOXE top half-stack temperature lower operational limit	°C
OL_TB_H	SOXE bottom half-stack temperature upper operational limit	°C
OL_TB_L	SOXE bottom half-stack temperature lower operational limit	°C
OL_P4_H	SOXE cathode pressure upper operational limit	bar
OL_P4_L	SOXE cathode pressure lower operational limit	bar
OL_XITP4_H	Ratio of SOXE top half-stack current to SOXE cathode pressure upper operational limit	A/bar
OL_XITP4_L	Ratio of SOXE top half-stack current to SOXE cathode pressure lower operational limit	A/bar
OL_XIBP4_H	Ratio of SOXE bottom half-stack current to SOXE cathode pressure upper operational limit	A/bar
OL_XIBP4_L	Ratio of SOXE bottom half-stack current to SOXE cathode pressure lower operational limit	A/bar
HS_en	SOXE heater enable bit	N/A
CS123_en	Gas composition sensors CS1, CS2, and CS3 enable bit	N/A
CS4_en	Gas composition sensor CS4 enable bit	N/A
M1_en	Scroll compressor motor enable bit	N/A
VT_en	SOXE top half-stack power supply enable bit	N/A
VB_en	SOXE bottom half-stack power supply enable bit	N/A
Comments	Comments	N/A

The RCT is specified in the label file as follows. Ellipses (…) indicate where values have been omitted or shortened for brevity; numeric values are examples only.

```
<Product_Observational>
  ⋮
  <Mission_Area>
    ⋮
    <mars2020:MOXIE_Parameters>
      <mars2020:Experiment_Configuration>
        ⋮
        <mars2020:Run_Control_Table>
          <mars2020:Run_Control_Table_Metadata>
            <mars2020:file_name_experiment_intent>…</mars2020:file_…_intent>
            <mars2020:file_name_digital_numbers>…</mars2020:file_name_digital_numbers>
          </mars2020:Run_Control_Table_Metadata>
          <mars2020:Run_Control_Table_Fields>
            <mars2020:Run_Control_Table_Field>
              <mars2020:name>ZTT_SP</mars2020:Name>
              <mars2020:description>SOXE … setpoint</mars2020:description>
              <mars2020:unit>degree Celsius</mars2020:unit>
            </mars2020:Run_Control_Table_Field>
            ⋮
          </mars2020:Run_Control_Table_Fields>
          <mars2020:Run_Control_Table_Values>
            <mars2020:Run_Control_Table_Step>
              <mars2020:step_number>0</mars2020:step_number>
              <mars2020:step_duration>60</mars2020:step_duration>
              <mars2020:ztt_sp_calibrated>800</mars2020:ztt_sp_calibrated>
              <mars2020:ztt_sp_digital_number>1234</mars2020:ztt_sp_digital_number>
              ⋮
            </mars2020:Run_Control_Table_Step>
            ⋮
          </mars2020:Run_Control_Table_Values>
        </mars2020:Run_Control_Table>
        ⋮
      </mars2020:Experiment_Configuration>
      ⋮
    </mars2020:MOXIE_Parameters>
  </Mission_Area>
  ⋮
</Product_Observational>
```

In the following description, the "mars2020:" namespace has been omitted from each XML object name for brevity.

The <Run_Control_Table> object contains three objects: <Run_Control_Table_Metadata>, <Run_Control_Table_Fields>, and <Run_Control_Table_Values>.

The <Run_Control_Table_Metadata> object contains the attributes <file_name_experiment_intent> and <file_name_digital_numbers>.

<file_name_experiment_intent> is the name of the EI RCT CSV file that contained the Experiment Intent (EI): the CSV file that was written by the person commanding MOXIE. The EI is specified in either CUs only, or both CUs and DNs.

<file_name_digital_numbers> is the name of the RCT CSV file produced by converting file_name_experiment_intent into DNs only.

The <Run_Control_Table_Fields> object lists and describes the fields in the RCT (Table 3-1). It contains several <Run_Control_Table_Field> objects. Each <Run_Control_Table_Field> object contains the attributes <name>, <description>, and <unit>.

<name> is the name of the RCT field as listed in the first column of Table 3-1.

<description> is the description of the RCT field as listed in the second column of Table 3-1.

<unit> is the unit of the RCT field in physical (calibrated) units, if applicable, as listed in the third column of Table 3-1.

The <Run_Control_Table_Values> object lists and describes each RCT step. It contains several <Run_Control_Table_Step> objects. Each <Run_Control_Table_Step> object contains attributes that describe the value of each RCT field at that RCT step.

If a field uses a CU-to-DN conversion, then both CU and DN values are included using attributes ending in "_calibrated" and "_digital_number". Examples are shown above for <ztt_sp_calibrated> and <ztt_sp_digital_number>. If a field does not use a CU-to-DN conversion, then the value is included using an attribute with the same name as the field. Examples are shown above for <step_number> and <step_duration>.

3.2.1.2.2 Algorithm Parameter Table (APT)

The APT contains settings for the control loops: proportional gains, integral gains, and output limits, and persistence times for the operational limits in the RCT.

APT field names and their descriptions are given in Table 3-2.

Table 3-2: Algorithm Parameter Table (APT) field names and descriptions

Name	Description	Calibrated unit
Persistence_en	Persistence time enable flag	N/A
ZTT_P	SOXE top half-stack temperature control loop proportional gain	V/°C
ZTB_P	SOXE bottom half-stack temperature control loop proportional gain	V/°C
ZTT_I	SOXE top half-stack heater temperature control loop integral gain	V/(°C s)
ZTB_I	SOXE bottom half-stack heater temperature control loop integral gain	V/(°C s)
ZP4_P	SOXE cathode pressure control loop proportional gain	RPM/bar
ZP4_I	SOXE cathode pressure control loop integral gain	RPM/(bar s)

Name	Description	Calibrated unit
ZP4_L	SOXE cathode pressure control loop scroll compressor RPM output lower limit	RPM
ZP4_H	SOXE cathode pressure control loop scroll compressor RPM output upper limit	RPM
ZIT_P	SOXE top half-stack current control loop proportional gain	V/A
ZIB_P	SOXE bottom half-stack current control loop proportional gain	V/A
ZIT_I	SOXE top half-stack current control loop integral gain	V/(A s)
ZIB_I	SOXE bottom half-stack current control loop integral gain	V/(A s)
ZIT_L	SOXE top half-stack current control loop voltage output lower limit	V
ZIB_L	SOXE bottom half-stack current control loop voltage output lower limit	V
ZIT_H	SOXE top half-stack current control loop voltage output upper limit	V
ZIB_H	SOXE bottom half-stack current control loop voltage output upper limit	V
HT_VTL_H	SOXE top half-stack heater temperature control loop heater Pulse Width Modulation (PWM) duty cycle upper limit when SOXE top half-stack power supply is off	%
HT_VTH_H	SOXE top half-stack heater temperature control loop heater PWM duty cycle upper limit when SOXE top half-stack power supply is on	%
HB_VBL_H	SOXE bottom half-stack heater temperature control loop heater PWM duty cycle upper limit when SOXE bottom half-stack power supply is off	%
HB_VBH_H	SOXE bottom half-stack heater temperature control loop heater PWM duty cycle upper limit when SOXE bottom half-stack power supply is on	%
OL_TT_T	SOXE top half-stack temperature operational limit persistence time	s

Name	Description	Calibrated unit
OL_TB_T	SOXE bottom half-stack temperature operational limit persistence time	s
OL_P4_T	SOXE cathode pressure operational limit persistence time	s
OL_XITP4_T	Ratio of SOXE top half-stack current to SOXE cathode pressure operational limit persistence time	s
OL_XIBP4_T	Ratio of SOXE bottom half-stack current to SOXE cathode pressure operational limit persistence time	s

The APT is specified in the label file as follows. Ellipses (…) indicate where values have been omitted or shortened for brevity; numeric values are examples only.

```
<Product_Observational>
  ⋮
  <Mission_Area>
    ⋮
    <mars2020:MOXIE_Parameters>
      <mars2020:Experiment_Configuration>
        ⋮
        <mars2020:Algorithm_Parameter_Table>
          <mars2020:Algorithm_Parameter_Table_Metadata>
            <mars2020:file_name_experiment_intent>…</mars2020:file_…_intent>
            <mars2020:file_name_digital_numbers>…</mars2020:file_name_digital_numbers>
          </mars2020:Algorithm_Parameter_Table_Metadata>
          <mars2020:Algorithm_Parameter_Table_Fields>
            <mars2020:Algorithm_Parameter_Table_Field>
              <mars2020:name>Persistence_en</mars2020:name>
              <mars2020:description>Persistence time enable flag</mars2020:description>
              <mars2020:unit></mars2020:unit>
            </mars2020:Algorithm_Parameter_Table_Field>
            ⋮
          </mars2020:Algorithm_Parameter_Table_Fields>
          <mars2020:Algorithm_Parameter_Table_Values>
            <mars2020:persistence_en>1</mars2020:Persistence_en>
            <mars2020:ztt_p>0.001</mars2020:ztt_p>
            ⋮
          </mars2020:Algorithm_Parameter_Table_Values>
        </mars2020:Algorithm_Parameter_Table>
        ⋮
      </mars2020:Experiment_Configuration>
      ⋮
    </mars2020:MOXIE_Parameters>
  </Mission_Area>
  ⋮
</Product_Observational>
```

In the following description, the “mars2020:” namespace has been omitted from each XML object name for brevity.

The <Algorithm_Parameter_Table> object has three objects: <Algorithm_Parameter_Table_Metadata>, <Algorithm_Parameter_Table_Fields> and <Algorithm_Parameter_Table_Values>.

The <Algorithm_Parameter_Table_Metadata> object has attributes <file_name_experiment_intent> and <file_name_digital_numbers>.

<file_name_experiment_intent> is the name of the EI APT CSV file that contained the Experiment Intent (EI): the CSV file that was written by the person commanding MOXIE. The EI is specified in either CUs only, or both CUs and DNs.

<file_name_digital_numbers> is the name of the APT CSV file produced by converting file_name_experiment_intent into DNs only.

The <Algorithm_Parameter_Table_Fields> object lists and describes the fields in the APT, as listed in Table 3-2. It contains several <Algorithm_Parameter_Table_Field> objects. Each <Algorithm_Parameter_Table_Field> object contains the attributes <name>, <description>, and <unit>.

<name> is the name of the APT field as listed in the first column of Table 3-2.

<description> is the description of the APT field as listed in the second column of Table 3-2.

<unit> is the unit of the APT field in physical units, if applicable, as listed in the third column of Table 3-2.

The <Algorithm_Parameter_Table_Values> object describes the value of each APT field.

If a field uses a CU-to-DN conversion, then both CU and DN values are included using attributes ending in “_calibrated” and “_digital_number”. If a field does not use a CU-to-DN conversion, then the value is included in an attribute with the same name as the field. Examples are shown above for <Persistence_en> and <ZTT_P>.

3.2.1.2.3 Safety Parameter Table (SPT)

The SPT defines Safety Limits (SLs) that apply for the entirety of each run: limits that cannot be changed from RCT step to RCT step. If any parameter exceeds its SL for longer than that safety limit’s associated persistence time, a fault is declared and MOXIE aborts the run.

SPT field names and their descriptions are given in Table 3-3.

Table 3-3: Safety Parameter Table (SPT) field names and descriptions

Name	Description	Calibrated unit
Persistence_en	Persistence time enable flag	N/A
SL_P2_H	Pressure between check valve and flow sensor upper safety limit	bar

Name	Description	Calibrated unit
SL_P3_H	Pressure between flow sensor and SOXE upper safety limit	bar
SL_P4_H	Pressure at CO/CO_2 VFCD inlet (SOXE cathode pressure) upper safety limit	bar
SL_P5_H	Pressure at O_2 VFCD inlet (SOXE anode pressure) upper safety limit	bar
SL_VT_H	SOXE top half-stack voltage upper safety limit	V
SL_VB_H	SOXE bottom half-stack voltage upper safety limit	V
SL_V28VM_L	Main 28 V power supply lower voltage safety limit	V
SL_V28VM_H	Main 28 V power supply upper voltage safety limit	V
SL_V28VS_L	SOXE heaters 28 V power supply lower voltage safety limit	V
SL_V28VS_H	SOXE heaters 28 V power supply upper voltage safety limit	V
SL_IT_H	SOXE top half-stack current upper safety limit	A
SL_IB_H	SOXE bottom half-stack current upper safety limit	A
SL_TT_H	SOXE top half-stack temperature upper safety limit	°C
SL_TB_H	SOXE bottom half-stack temperature upper safety limit	°C
SL_T3_H	Temperature at compressor housing upper safety limit	°C
SL_T4_H	Temperature at compressor motor upper safety limit	°C
SL_T1_H	Temperature at sensor panel upper safety limit	°C
SL_T22_H	Temperature at electronics control board upper safety limit	°C
SL_T7_L	Temperature at baseplate lower safety limit	°C
SL_T7_H	Temperature at baseplate upper safety limit	°C
SL_P2_T	Pressure between check valve and flow sensor safety limit persistence time	s
SL_P3_T	Pressure between flow sensor and SOXE safety limit persistence time	s
SL_P4_T	Pressure at CO/CO_2 VFCD inlet (SOXE cathode pressure) safety limit persistence time	s

Name	Description	Calibrated unit
SL_P5_T	Pressure at O_2 VFCD inlet (SOXE anode pressure) safety limit persistence time	s
SL_VT_T	SOXE top half-stack voltage safety limit persistence time	s
SL_VB_T	SOXE bottom half-stack voltage safety limit persistence time	s
SL_V28VM_T	Main 28 V power supply voltage safety limit persistence time	s
SL_V28VS_T	SOXE heaters 28 V power supply voltage safety limit persistence time	s
SL_IT_T	SOXE top half-stack current safety limit persistence time	s
SL_IB_T	SOXE bottom half-stack current safety limit persistence time	s
SL_TT_T	SOXE top half-stack temperature safety limit persistence time	s
SL_TB_T	SOXE bottom half-stack temperature safety limit persistence time	s
SL_T3_T	Temperature at compressor housing safety limit persistence time	s
SL_T4_T	Temperature at compressor motor safety limit persistence time	s
SL_T1_T	Temperature at sensor panel safety limit persistence time	s
SL_T22_T	Temperature at electronics control board safety limit persistence time	s
SL_T7_T	Temperature at baseplate safety limit persistence time	s

The SPT is specified in the label file as follows. Ellipses (…) indicate where values have been omitted or shortened for brevity; numeric values are examples only.

```
<Product_Observational>
  ⋮
  <Mission_Area>
    ⋮
    <mars2020:MOXIE_Parameters>
      <mars2020:Experiment_Configuration>
```

```
        ⋮
        <mars2020:Safety_Parameter_Table>
          <mars2020:Safety_Parameter_Table_Metadata>
            <mars2020:file_name_experiment_intent>…</mars2020:file_…_intent>
            <mars2020:file_name_digital_numbers>…</mars2020:file_name_digital_numbers>
          </mars2020:Safety_Parameter_Table_Metadata>
          <mars2020:Safety_Parameter_Table_Fields>
            <mars2020:Safety_Parameter_Table_Field>
              <mars2020:name>Persistence_en</mars2020:name>
              <mars2020:description>Persistence time enable flag</mars2020:description>
              <mars2020:unit></mars2020:unit>
            </mars2020:Safety_Parameter_Table_Field>
            ⋮
          </mars2020:Safety_Parameter_Table_Fields>
          <mars2020:Safety_Parameter_Table_Values>
            <mars2020:persistence_en>1</mars2020:persistence_en>
            <mars2020:sl_p2_h_calibrated>1.2</mars2020:sl_p2_h_calibrated>
            <mars2020:sl_p2_h_digital_number>1234</mars2020:sl_p2_h_digital_number>
            ⋮
          </mars2020:Safety_Parameter_Table_Values>
        </mars2020:Safety_Parameter_Table>
        ⋮
      </mars2020:Experiment_Configuration>
      ⋮
    </mars2020:MOXIE_Parameters>
  </Mission_Area>
  ⋮
</Product_Observational>
```

In the following description, the “mars2020:” namespace has been omitted from each XML object name for brevity.

The <Safety_Parameter_Table> object contains three objects: <Safety_Parameter_Table_Metadata>, <Safety_Parameter_Table_Fields>, and <Safety_Parameter_Table_Values>.

The <Safety_Parameter_Table_Metadata> object contains attributes <file_name_experiment_intent> and <file_name_digital_numbers>.

<file_name_experiment_intent> is the name of the EI SPT CSV file that contained the Experiment Intent (EI): the CSV file that was written by the person commanding MOXIE. The EI is specified in either CUs only, or both CUs and DNs.

<file_name_digital_numbers> is the name of the SPT CSV file produced by converting file_name_experiment_intent into DNs only.

The <Safety_Parameter_Table_Fields> object lists and describes the fields in the SPT, as listed in Table 3-3. It contains several <Safety_Parameter_Table_Field> objects. Each <Safety_Parameter_Table_Field> object contains the attributes <name>, <description>, and <unit>.

<name> is the name of the SPT field as listed in the first column of Table 3-3.

<description> is the description of the SPT field as listed in the second column of Table 3-3.

<unit> is the unit of the SPT field in physical units, if applicable, as listed in the third column of Table 3-3.

The <Safety_Parameter_Table_Values> object describes the value of each SPT field.

If a field uses a CU-to-DN conversion, then both CU and DN values are included using attributes ending in "_calibrated" and "_digital_number". Examples are shown above for <sl_p2_h_calibrated> and <sl_p2_h_digital_number>. If a field does not use a CU-to-DN conversion, then the value is included in an attribute with the same name as the field. An example is shown above for <persistence_en>.

3.2.1.2.4 Run Parameter Table (RPT)

The RPT contains Temperature Limits (TLs) and Current Limits (CLs) for the gas composition sensors. If a TL or CL is exceeded for longer than that limit's associated persistence time, the gas composition sensors are disabled for the remainder of the run.

RPT field names and their descriptions are given in Table 3-4.

Table 3-4: Run Parameter Table (RPT) field names and descriptions

Name	Description	Calibrated unit
Persistence_en	Persistence time enable flag	N/A
TL_ICS1234_H	Gas composition sensors CS1, CS2, CS3 and CS4 upper temperature limit	°C
CL_ICS123_H	Gas composition sensors CS1, CS2 and CS3 upper current limit	A
CL_ICS4_H	Gas composition sensor CS4 upper current limit	A
TL_ICS1234_T	Gas composition sensors CS1, CS2, CS3 and CS4 temperature limit persistence time	s
CL_ICS123_T	Gas composition sensors CS1, CS2 and CS3 current limit persistence time	s
CL_ICS4_T	Gas composition sensor CS4 current limit persistence time	s

The RPT is specified in the label file as follows. Ellipses (…) indicate where values have been omitted or shortened for brevity; numeric values are examples only.

```
<Product_Observational>
  ⋮
  <Mission_Area>
    ⋮
    <mars2020:MOXIE_Parameters>
      <mars2020:Experiment_Configuration>
        ⋮
```

```
          <mars2020:Run_Parameter_Table>
            <mars2020:Run_Parameter_Table_Metadata>
              <mars2020:file_name_experiment_intent>…</mars2020:file_…_intent>
              <mars2020:file_name_digital_numbers>…</mars2020:file_name_digital_numbers>
            </mars2020:Run_Parameter_Table_Metadata>
            <mars2020:Run_Parameter_Table_Fields>
              <mars2020:Run_Parameter_Table_Field>
                <mars2020:name>Persistence_en</mars2020:name>
                <mars2020:description>Persistence time enable flag</mars2020:description>
                <mars2020:unit></mars2020:unit>
              </mars2020:Run_Parameter_Table_Field>
              ⋮
            </mars2020:Run_Parameter_Table_Fields>
            <mars2020:Run_Parameter_Table_Values>
              <mars2020:persistence_en>1</mars2020:persistence_en>
              ⋮
              <mars2020:cl_ics123_h_calibrated>1</mars2020:cl_…_unit>
              <mars2020:cl_ics123_h_digital_number>123</mars2020:cl_…_number>
              ⋮
            </mars2020:Run_Parameter_Table_Values>
          </mars2020:Run_Parameter_Table>
          ⋮
        </mars2020:Experiment_Configuration>
        ⋮
      </mars2020:MOXIE_Parameters>
    </Mission_Area>
    ⋮
</Product_Observational>
```

In the following description, the "mars2020:" namespace has been omitted from each XML object name for brevity.

The <Run_Parameter_Table> object has three objects: <Run_Parameter_Table_Metadata>, <Run_Parameter_Table_Fields> and <Run_Parameter_Table_Values>.

The <Run_Parameter_Table_Metadata> object has attributes <file_name_experiment_intent> and <file_name_digital_numbers>.

<file_name_experiment_intent> is the name of the EI RPT CSV file that contained the Experiment Intent (EI): the CSV file that was written by the person commanding MOXIE. The EI is specified in either CUs only, or both CUs and DNs.

<file_name_digital_numbers> is the name of the RPT CSV file produced by converting file_name_experiment_intent into DNs only.

The <Run_Parameter_Table_Fields> object lists and describes the fields in the RPT, as listed in Table 3-4. It contains several <Run_Parameter_Table_Field> objects. Each <Run_Parameter_Table_Field> object contains the attributes <name>, <description>, and <unit>.

<name> is the name of the RPT field as listed in the first column of Table 3-4.

<description> is the description of the RPT field as listed in the second column of Table 3-4.

<unit> is the unit of the RPT field in physical units, if applicable, as listed in the third column of Table 3-4.

The <Run_Parameter_Table_Values> object describes the value of each RPT field.

If a field uses a CU-to-DN conversion, then both CU and DN values are included using attributes ending in "_calibrated" and "_digital_number". Examples are shown above for <cl_ics123_h_calibrated> and <cl_ics123_h_digital_number>. If a field does not use a CU-to-DN conversion, then the value is included in an attribute with the same name as the field. An example is shown above for <persistence_en>.

3.2.1.2.5 Data from other instruments and rover

During a MOXIE run, data from three other instruments are recorded: the Mars Environmental Dynamics Analyzer (MEDA), SuperCam, and Entry, Descent and Landing camera (EDLcam). In addition, several rover parameters are relevant to MOXIE operation, for example, Rover Avionics Mounting Panel (RAMP) temperature.

MEDA records atmospheric pressure, surface temperature, relative humidity, upward and downward radiative fluxes in several solar and infrared bands, and atmospheric temperature, wind speed, and 3D wind direction at ~1.5 m, at 1 Hz. During MOXIE runs, MEDA will record a subset of the above (atmospheric pressure, temperature, optical depth, wind speed, and 3D wind direction at ~1.5 m, at 1 Hz) from 3 minutes before the start of oxygen production until 3 minutes after the end of oxygen production. In addition, MEDA's Radiation and Dust Sensor-Skycam (RDS)-Skycam is also scheduled to acquire two images of the sky each sol to retrieve optical depth, a measure of atmospheric column dust content.

The SuperCam and EDLcam microphones are intended to record audio from one minute before to five minutes after the start of scroll compressor operation; from one minute before to two minutes after any change in scroll compressor RPM commanded via the RCT; and from one minute before to one minute after the end of scroll compressor operation.

References to data from other instruments and the rover are specified in the label file as follows. Ellipses (…) indicate where values have been omitted or shortened for brevity.

```
<Product_Observational>
  ⋮
  <Mission_Area>
    ⋮
    <mars2020:MOXIE_Parameters>
      ⋮
      <mars2020:Ancillary_Data>
        <mars2020:Ancillary_Data_MEDA>
          <lid_reference>…</lid_reference>
          <reference_type>data_to_ancillary_data</reference_type>
        </mars2020:Ancillary_Data_MEDA>
        <mars2020:Ancillary_Data_Supercam>
          <lid_reference>…</lid_reference>
          <reference_type>data_to_ancillary_data</reference_type>
        </mars2020:Ancillary_Data_Supercam>
        <mars2020:Ancillary_Data_EDLcam>
          <lid_reference>…</lid_reference>
```

```
          <reference_type>data_to_ancillary_data</reference_type>
        </mars2020:Ancillary_Data_EDLcam
        <mars2020:Ancillary_Data_Rover>
          <lid_reference>…</lid_reference>
          <reference_type>data_to_ancillary_data</reference_type>
        </mars2020:Ancillary_Data_Rover>
      </mars2020:Ancillary_Data>
    </mars2020:MOXIE_Parameters>
  </Mission_Area>
  ⋮
</Product_Observational>
```

3.2.2 Format

Each label file is in eXtensible Markup Language (XML) format.

MOXIE data products have detached PDS4 labels stored as ASCII and are denoted by the .xml extension. A PDS4 label is object-oriented and describes the objects in the data file. The PDS4 label contains attributes for product identification and for table object definitions. The label also contains descriptive information needed to interpret or process the data objects in the file.

PDS4 labels are written in eXtensible Markup Language (xml). PDS4 label statements have the form of:

```
<attribute>value</attribute>
```

4 Data product description: raw

The raw data product consists of two files: one data file in CSV format (Section 4.1), and one PDS4 label file in XML format (Section 4.2).

The raw data product generation process is shown in Figure 4-1:

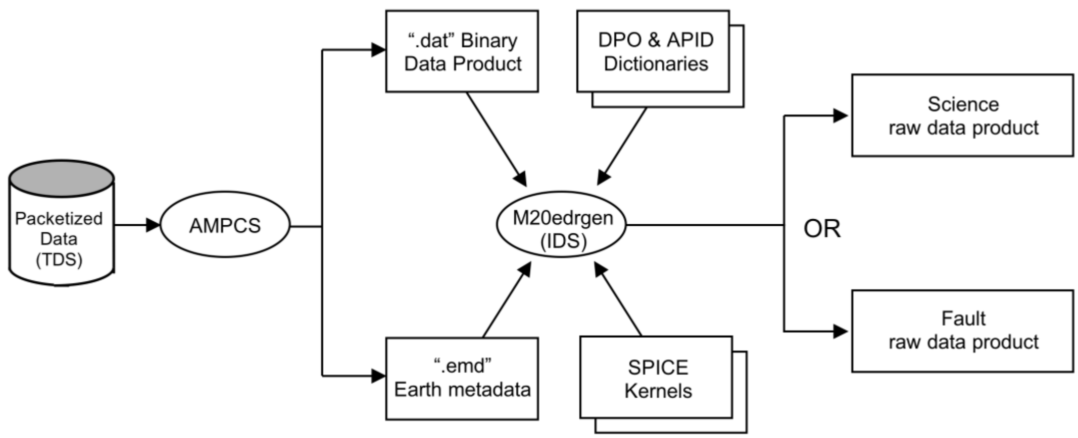

Figure 4-1: Raw data product generation process

If the MOXIE run is nominal (no faults declared), a MoxiScidataFrame data product is produced on board the rover. If the MOXIE run is off-nominal (one or more faults declared), a MoxieFault data product is produced on board the rover. The MoxiScidataFrame and MoxieFault data products are used to produce science and fault raw data products respectively.

Packetized instrument data received from the spacecraft is stored on JPL's Telemetry Delivery System (TDS) in the form of Standard Format Data Units (SFDUs). The Advanced Multi-Mission Operations System (AMMOS) Mission data Processing and Control Subsystem (AMPCS) depacketizes the instrument telemetry data. During depacketization, the SFDU wrapping is removed and the data is restructured to build a binary data product file (.dat) comprised of one or more Data Product Objects (DPOs) and an Earth metadata file (.emd). AMPCS writes the data product file and the Earth metadata file to the Operations Cloud Store (OCS).

IDS's raw data product generation software, m20edrgen, generates the raw data product from: the binary data product file (.dat); the Earth metadata file (.emd); DPO dictionary; Application ID (APID) dictionary provided by the Mars 2020 Flight Software; and Spacecraft, Planet, Instrument, Camera matrix, Events (SPICE) kernels provided by the Navigation and Ancillary Information Facility (NAIF). The raw data product is generated within 60 seconds of the IDS pipeline system receiving a Java Message System (JMS) message that describes the OCS location of the binary data product file (.dat) and Earth metadata file (.emd). The raw data product is placed into IDS's File Exchange Interface (FEI) for electronic distribution to the MOXIE science team.

Raw data products will only be reprocessed if packets in the original downlink are not received. Missing packets will be identified as "partial datasets" and reported so that retransmission can be requested. Before retransmission, missing data will be filled with zeroes. The data will be reprocessed only after all partial datasets are retransmitted and received on the ground. In these cases, the raw data product version number will be incremented, to avoid overwriting previous versions.

4.1 Data file

MOXIE generates two types of raw data file depending upon whether standard telemetry records or extended telemetry records are used. Standard telemetry records contain the main parameters needed for most science and engineering analysis. Extended telemetry records contain the same parameters as standard telemetry records, as well as additional parameters for detailed engineering analysis.

Science raw data products normally use standard telemetry records, unless extended telemetry records were specifically requested at uplink. Fault raw data products always use extended telemetry records.

4.1.1 Field names, descriptions, and units

Field names and descriptions in standard telemetry records are listed in Table 4-1. The additional field names and descriptions in extended telemetry records are listed in Table 4-2, which starts on page 42.

Whereas fields with a units of “None”, “s” or “DN” can be interpreted, fields with a unit of “N/A” require additional manipulation (see Section 5.1.2) before interpretation.

Table 4-1: Data file field names and descriptions in the standard telemetry record

Name	Description	Unit
SW_MODE	Software mode (0 = IDLE; 1 = RUN; 2 = BOOT; 2 will not be telemetered)	None
SW_FAULT_COUNT	Number of faults since last count	None
SW_LAST_FAULT	Most recent fault	None
SW_TIME	Incremented time since the load of FSW after boot	s
SW_RCT_STEP	Current RCT step number	None
TT_HC	SOXE top half-stack temperature measured by high bias current	DN
TT_LC	SOXE top half-stack temperature measured by low bias current	DN
T1	Temperature at sensor panel	DN
T2	Temperature at P1 sensor	DN
T3	Temperature at compressor housing	DN
T4	Temperature at compressor motor	DN
TB_HC	SOXE bottom half-stack temperature measured by high bias current	DN
TB_LC	SOXE bottom half-stack temperature measured by low bias current	DN

Name	Description	Unit
T7	Temperature at baseplate	DN
T8	Temperature at CO/CO_2 heat exchanger on Rover Avionics Mounting Panel (RAMP)	DN
T9	Temperature at O_2 heat exchanger on RAMP	DN
T10	Temperature at CO/CO_2 heat exchanger on sensor panel	DN
T11	Temperature at O_2 heat exchanger on sensor panel	DN
T12	Temperature at CS1 sensor (CO_2 sensor in cathode line)	DN
T13	Temperature at CS2 sensor (CO_2 sensor in anode line)	DN
T14	Temperature at CS3 sensor (CO sensor in cathode line)	DN
T15	Temperature at CS4 sensor (O_2 sensor in anode line)	DN
T16	Temperature at P4 Viscous Flow Control Device (VFCD) manifold	DN
T17	Not used	DN
T18	Temperature at VFCD on CO/CO_2 outlet	DN
T19	Not used	DN
T20	Not used	DN
TCAL0	Temperature calibration	DN
T22	Temperature at electronics control board	DN
T23	Not used	DN
T24	Not used	DN
TCAL1_HC	Calibration resistor for temperature sensor measurements at high bias current	DN
TCAL1_LC	Calibration resistor for temperature sensor measurements at low bias current	DN
P1	Pressure at HEPA filter exit	DN
P2	Pressure between check valve and flow sensor	DN
P3	Pressure between flow sensor and SOXE	DN

Name	Description	Unit
P4	Pressure at CO/CO_2 VFCD inlet (SOXE cathode pressure)	DN
P5	Pressure at O_2 VFCD inlet (SOXE anode pressure)	DN
P6	Not used	DN
PCAL1	Calibration resistor for low end of pressure transducer range	DN
PCAL2	Calibration resistor for high end of pressure transducer range	DN
VT	Voltage at terminal that supplies voltage to top SOXE half-stack	DN
VB	Voltage at terminal that supplies voltage to bottom SOXE half-stack	DN
V28VM	Main 28 V power supply voltage	DN
V28VS	SOXE heaters 28 V power supply voltage	DN
V5V	Electronics 5 V power supply voltage	DN
IT	Current through top SOXE half-stack	DN
IB	Current through bottom SOXE half-stack	DN
IHT	Current through top SOXE half-stack heater	DN
IHB	Current through bottom SOXE half-stack heater	DN
IM1	Current to scroll compressor motor	DN
I28VM	Current to main 28 V power supply	DN
I28VS	Current to SOXE heaters 28 V power supply	DN
I5V	Current in electronics 5 V bus	DN
ICS123	Sum of currents for CS1 (CO_2 sensor in cathode line), CS2 (CO_2 sensor in anode line), and CS3 (CO sensor in cathode line)	DN
ICS4	Current for CS4 (O_2 sensor in anode line)	DN
IR_M_PRE1	CS1 (CO_2 sensor in cathode line) IR intensity signal from measurement channel 1	N/A
REF_M1	CS1 (CO_2 sensor in cathode line) IR intensity signal from reference channel 1	N/A

Name	Description	Unit
IR_M1	CS1 (CO_2 sensor in cathode line) relation between measurement and reference channel	N/A
T_M1	CS1 (CO_2 sensor in cathode line) relative sensor temperature x 0.1°C (not absolute)	N/A
IR_KORR1	CS1 (CO_2 sensor in cathode line) IR_m signal temperature corrected at zero	N/A
MOD1	CS1 (CO_2 sensor in cathode line) modulation - non linearized concentration signal	N/A
SYS_STATUS1	CS1 (CO_2 sensor in cathode line) status bits	N/A
KONZ1	CS1 (CO_2 sensor in cathode line) gas concentration signal	N/A
MOD_KORR1	CS1 (CO_2 sensor in cathode line) modulation corrected by temperature	N/A
I_STR1	CS1 (CO_2 sensor in cathode line) supply current for the IR source × 0.01 mA	N/A
NUM_EIN1	CS1 (CO_2 sensor in cathode line) buffer for number of power on	N/A
IR_M_PRE2	CS2 (CO_2 sensor in anode line) IR intensity signal from measurement channel 2	N/A
REF_M2	CS2 (CO_2 sensor in anode line) IR intensity signal from reference channel 2	N/A
IR_M2	CS2 (CO_2 sensor in anode line) relation between measurement and reference channel	N/A
T_M2	CS2 (CO_2 sensor in anode line) relative sensor temperature x 0.1°C (not absolute)	N/A
IR_KORR2	CS2 (CO_2 sensor in anode line) IR_m signal temperature corrected at zero	N/A
MOD2	CS2 (CO_2 sensor in anode line) modulation - non linearized concentration signal	N/A
SYS_STATUS2	CS2 (CO_2 sensor in anode line) status bits	N/A
KONZ2	CS2 (CO_2 sensor in anode line) gas concentration signal	N/A
MOD_KORR2	CS2 (CO_2 sensor in anode line) modulation corrected by temperature	N/A

Name	Description	Unit
I_STR2	CS2 (CO_2 sensor in anode line) supply current for the IR source × 0.01 mA	N/A
NUM_EIN2	CS2 (CO_2 sensor in anode line) buffer for number of power on	N/A
IR_M_PRE3	CS3 (CO sensor in cathode line) IR intensity signal from measurement channel 3	N/A
REF_M3	CS3 (CO sensor in cathode line) IR intensity signal from reference channel 3	N/A
IR_M3	CS3 (CO sensor in cathode line) relation between measurement and reference channel	N/A
T_M3	CS3 (CO sensor in cathode line) relative sensor temperature x 0.1°C (not absolute)	N/A
IR_KORR3	CS3 (CO sensor in cathode line) IR_m signal temperature corrected at zero	N/A
MOD3	CS3 (CO sensor in cathode line) modulation - non linearized concentration signal	N/A
SYS_STATUS3	CS3 (CO sensor in cathode line) status bits	N/A
KONZ3	CS3 (CO sensor in cathode line) gas concentration signal	N/A
MOD_KORR3	CS3 (CO sensor in cathode line) modulation corrected by temperature	N/A
I_STR3	CS3 (CO sensor in cathode line) supply current for the IR source × 0.01 mA	N/A
NUM_EIN3	CS3 (CO sensor in cathode line) buffer for number of power on	N/A
CS4_DATA1	CS4_DATA1 through CS4_DATA20 contain raw data from CS4 (O_2 sensor in anode line). These fields must be manipulated as described in Section 5.1.2.2 before interpretation.	N/A
CS4_DATA2		N/A
CS4_DATA3		N/A
CS4_DATA4		N/A
CS4_DATA5		N/A
CS4_DATA6		N/A
CS4_DATA7		N/A
CS4_DATA8		N/A

Name	Description	Unit
CS4_DATA9		N/A
CS4_DATA10		N/A
CS4_DATA11		N/A
CS4_DATA12		N/A
CS4_DATA13		N/A
CS4_DATA14		N/A
CS4_DATA15		N/A
CS4_DATA16		N/A
CS4_DATA17		N/A
CS4_DATA18		N/A
CS4_DATA19		N/A
CS4_DATA20		N/A
RPMM1	Scroll compressor RPM measured from motor driver	DN
XITP4	Calculated ratio of SOXE top half-stack current to SOXE cathode pressure	DN
XIBP4	Calculated ratio of SOXE bottom half-stack current to SOXE cathode pressure	DN
HT_OUT	Top SOXE half-stack heater commanded Pulse Width Modulation (PWM) duty cycle	DN
HB_OUT	Bottom SOXE half-stack heater commanded PWM duty cycle	DN
M1_OUT	Commanded scroll compressor RPM	DN
VT_OUT	Commanded top SOXE half-stack voltage	DN
VB_OUT	Commanded bottom SOXE half-stack voltage	DN
HS_en	SOXE heaters enable (1 = enabled; 0 = disabled)	None
CS123_en	CS123 enable (1 = enabled; 0 = disabled)	None
CS4_en	CS4 enable (1 = enabled; 0 = disabled)	None
M1_en	Scroll compressor motor enable bit (1 = enabled; 0 = disabled)	None
VT_en	SOXE top power supply enable bit (1 = enabled; 0 = disabled)	None

Name	Description	Unit
VB_en	SOXE bottom power supply enable bit (1 = enabled; 0 = disabled)	None

Table 4-2: Additional data file field names and descriptions in the extended telemetry record

Name	Description	Unit
MEMORY_SLOT	Software current memory slot	None
RESET_TYPE	Software reset type	None
INTERRUPT_COUNT	Software interrupt count	None
SW_VERSION	Software version number	None
FPGA_VERSION	Field Programmable Gate Array (FPGA) firmware version number	None
BOARD_ID	Control board serial number	None
DEBUG_INPUT	Debug input	None
SIDE_SELECT	Side select (A or B)	None
ZTT_SP	SOXE top half-stack temperature control loop setpoint	DN
ZTB_SP	SOXE bottom half-stack temperature control loop setpoint	DN
ZP4_SP	SOXE cathode pressure control loop setpoint	DN
ZIT_SP	SOXE top half-stack current control loop setpoint	DN
ZIB_SP	SOXE bottom half-stack current control loop setpoint	DN
ZP4_OS	SOXE cathode pressure control loop scroll compressor RPM offset	DN
ZIT_OS	SOXE top half-stack current control loop voltage offset	DN
ZIB_OS	SOXE bottom half-stack current control loop voltage offset	DN
OL_TT_H	SOXE top half-stack temperature upper operational limit	DN
OL_TT_L	SOXE top half-stack temperature lower operational limit	DN
OL_TT_T	SOXE top half-stack temperature operational limit persistence time	s

Name	Description	Unit
OL_TB_H	SOXE bottom half-stack temperature upper operational limit	DN
OL_TB_L	SOXE bottom half-stack temperature lower operational limit	DN
OL_TB_T	SOXE bottom half-stack temperature operational limit persistence time	s
OL_P4_H	SOXE cathode pressure upper operational limit	DN
OL_P4_L	SOXE cathode pressure lower operational limit	DN
OL_P4_T	SOXE cathode pressure operational limit persistence time	s
OL_XITP4_H	Ratio of SOXE top half-stack current to SOXE cathode pressure upper operational limit	DN
OL_XITP4_L	Ratio of SOXE top half-stack current to SOXE cathode pressure lower operational limit	DN
OL_XITP4_T	Ratio of SOXE top half-stack current to SOXE cathode pressure operational limit persistence time	s
OL_XIBP4_H	Ratio of SOXE bottom half-stack current to SOXE cathode pressure upper operational limit	DN
OL_XIBP4_L	Ratio of SOXE bottom half-stack current to SOXE cathode pressure lower operational limit	DN
OL_XIBP4_T	Ratio of SOXE bottom half-stack current to SOXE cathode pressure operational limit persistence time	s
SL_P2_H	Pressure between check valve and flow sensor upper safety limit	DN
SL_P2_T	Pressure between check valve and flow sensor upper safety limit persistence time	s
SL_P3_H	Pressure between flow sensor and SOXE inlet upper safety limit	DN
SL_P3_T	Pressure between flow sensor and SOXE inlet upper safety limit persistence time	s
SL_P4_H	Pressure at CO/CO_2VFCD inlet (SOXE cathode pressure) upper safety limit	DN
SL_P4_T	Pressure at CO/CO_2 VFCD inlet (SOXE cathode pressure) upper safety limit persistence time	s

Name	Description	Unit
SL_P5_H	Pressure at O_2 VFCD inlet (SOXE anode pressure) upper safety limit	DN
SL_P5_T	Pressure at O_2 VFCD inlet (SOXE anode pressure) upper safety limit persistence time	s
SL_VT_H	SOXE top half-stack voltage upper safety limit	DN
SL_VT_T	SOXE top half-stack voltage upper safety limit persistence time	s
SL_VB_H	SOXE bottom half-stack voltage upper safety limit	DN
SL_VB_T	SOXE bottom half-stack voltage upper safety limit persistence time	s
SL_IT_H	SOXE top half-stack current upper safety limit	DN
SL_IT_T	SOXE top half-stack current upper safety limit persistence time	s
SL_IB_H	SOXE bottom half-stack current upper safety limit	DN
SL_IB_T	SOXE bottom half-stack current upper safety limit persistence time	s
SL_TT_H	SOXE top half-stack temperature upper safety limit	DN
SL_TT_T	SOXE top half-stack temperature upper safety limit persistence time	s
SL_TB_H	SOXE bottom half-stack temperature upper safety limit	DN
SL_TB_T	SOXE bottom half-stack temperature upper safety limit persistence time	s
SL_T3_H	Temperature at compressor housing upper safety limit	DN
SL_T3_T	Temperature at compressor housing upper safety limit persistence time	s
SL_T4_H	Temperature at compressor motor upper safety limit	DN
SL_T4_T	Temperature at compressor motor upper safety limit persistence time	s
SL_T1_H	Temperature at sensor panel upper safety limit	DN
SL_T1_T	Temperature at sensor panel upper safety limit persistence time	s
SL_T22_H	Temperature at electronics control board upper safety limit	DN

Name	Description	Unit
SL_T22_T	Temperature at electronics control board upper safety limit persistence time	s
SL_T7_L	Temperature at baseplate lower safety limit	DN
SL_T7_H	Temperature at baseplate upper safety limit	DN
SL_T7_T	Temperature at baseplate safety limit persistence time	s
SL_V28VM_L	Main 28 V power supply voltage lower safety limit	DN
SL_V28VM_H	Main 28 V power supply voltage upper safety limit	DN
SL_V28VM_T	Main 28 V power supply voltage safety limit persistence time	s
SL_V28VS_L	SOXE heaters 28 V power supply voltage lower safety limit	DN
SL_V28VS_H	SOXE heaters 28 V power supply voltage upper safety limit	DN
SL_V28VS_T	SOXE heaters 28 V power supply voltage safety limit persistence time	s
ZTT_P	SOXE top half-stack temperature control loop proportional gain	DN
ZTT_I	SOXE top half-stack temperature control loop integral gain	DN
HT_VTL_H	SOXE top half-stack temperature control loop heater PWM duty cycle upper limit when SOXE top half-stack power supply is off	DN
HT_VTH_H	SOXE top half-stack temperature control loop heater PWM duty cycle upper limit when SOXE top half-stack power supply is on	DN
ZTB_P	SOXE bottom half-stack temperature control loop proportional gain	DN
ZTB_I	SOXE bottom half-stack temperature control loop integral gain	DN
HB_VBL_H	SOXE bottom half-stack temperature control loop heater PWM duty cycle upper limit when SOXE bottom half-stack power supply is off	DN
HB_VBH_H	SOXE bottom half-stack temperature control loop heater PWM duty cycle upper limit when SOXE bottom half-stack power supply is on	DN

Name	Description	Unit
ZP4_P	SOXE cathode pressure control loop proportional gain	DN
ZP4_I	SOXE cathode pressure control loop integral gain	DN
ZP4_H	SOXE cathode pressure control loop scroll compressor RPM output upper limit	DN
ZP4_L	SOXE cathode pressure control loop scroll compressor RPM output lower limit	DN
ZIT_P	SOXE top half-stack current control loop proportional gain	DN
ZIT_I	SOXE top half-stack current control loop integral gain	DN
ZIT_H	SOXE top half-stack current control loop voltage output upper limit	DN
ZIT_L	SOXE top half-stack current control loop voltage output lower limit	DN
ZIB_P	SOXE bottom half-stack current control loop proportional gain	DN
ZIB_I	SOXE bottom half-stack current control loop integral gain	DN
ZIB_H	SOXE bottom half-stack current control loop voltage output upper limit	DN
ZIB_L	SOXE bottom half-stack current control loop voltage output lower limit	DN
TL_ICS1234_H	Gas composition sensors CS1, CS2, CS3 and CS4 upper temperature limit	DN
TL_ICS1234_T	Gas composition sensors CS1, CS2, CS3 and CS4 upper temperature limit persistence time	s
CL_ICS123_H	Gas composition sensors CS1, CS2 and CS3 upper current limit	DN
CL_ICS123_T	Gas composition sensors CS1, CS2 and CS3 upper current limit persistence time	s
CL_ICS4_H	Gas composition sensor CS4 upper current limit	DN
CL_ICS4_T	Gas composition sensor CS4 upper current limit persistence time	s
I28VS_OC	Overcurrent protection detected on SOXE heaters 28 V power supply	None

Name	Description	Unit
I28VM_OC	Overcurrent protection detected on main 28 V power supply	None

4.2 Label file

The raw data product label file contains no additional metadata above and beyond the metadata common to raw, calibrated and derived data products described in Section 3.2.

However, there are two types of label files associated with every MOXIE raw data product, one for PDS archive (described in this document) and the other for mission operations.

The mission operations label file is used internally by the MOXIE project's GDS and also the IDS software. It is a detached label file in ODL format and is denoted by the .lbl extension. The PDS4 label file is generated from the ODL label during production to ensure consistency between them.

5 Data product description: calibrated

The calibrated data product consists of two files: one data file in CSV format (Section 5.1), and one PDS4 label file in XML format (Section 5.2).

5.1 Data file

MOXIE calibrated data products use standard telemetry records. Standard telemetry records contain the main parameters needed for most science and engineering analysis.

5.1.1 Field names, descriptions, and units

Field names, descriptions and units for the calibrated data product are listed in Table 5-1. Refer to Table 5-2 for the equations used to convert the raw data product values in DN into the calibrated data product values in CU.

Table 5-1: Data file field names and descriptions in the calibrated data product

Name	Description	Unit	DN-to-CU conversion
SW_MODE	Software mode (0 = IDLE; 1 = RUN; 2 = BOOT; 2 will not be telemetered)	None	None
SW_FAULT_COUNT	Number of faults since last count	None	None
SW_LAST_FAULT	Most recent fault	None	None
SW_TIME	Incremented time since the load of FSW after boot	s	None
SW_RCT_STEP	Current Run Control Table (RCT) step number	None	None
T1	Temperature at sensor panel	°C	Table 5-2
T2	Temperature at P1 sensor	°C	Table 5-2
T3	Temperature at compressor housing	°C	Table 5-2
T4	Temperature at compressor motor	°C	Table 5-2
TT	Temperature at SOXE top half-stack heater carrier	°C	Table 5-2
TB	Temperature at SOXE bottom half-stack heater carrier	°C	Table 5-2
T7	Temperature at baseplate	°C	Table 5-2
T8	Temperature at CO/CO_2 heat exchanger on Rover Avionics Mounting Panel (RAMP)	°C	Table 5-2

Name	Description	Unit	DN-to-CU conversion
T9	Temperature at O_2 heat exchanger on RAMP	°C	Table 5-2
T10	Temperature at CO/CO_2 heat exchanger on sensor panel	°C	Table 5-2
T11	Temperature at O_2 heat exchanger on sensor panel	°C	Table 5-2
T12	Temperature at CS1 sensor (CO_2 sensor in cathode line)	°C	Table 5-2
T13	Temperature at CS2 sensor (CO_2 sensor in anode line)	°C	Table 5-2
T14	Temperature at CS3 sensor (CO sensor in cathode line)	°C	Table 5-2
T15	Temperature at CS4 sensor (O_2sensor in anode line)	°C	Table 5-2
T16	Temperature at P4 Viscous Flow Control Device (VFCD) manifold	°C	Table 5-2
T18	Temperature at VFCD on CO/CO_2 outlet	°C	Table 5-2
TCAL0	Temperature calibration	°C	Table 5-2
T22	Temperature at electronics control board	°C	Table 5-2
P1	Pressure at HEPA filter exit	bar	Table 5-2
P2	Pressure between check valve and flow sensor	bar	Table 5-2
P3	Pressure between flow sensor and SOXE	bar	Table 5-2
P4	Pressure at CO/CO_2 VFCD inlet (SOXE cathode pressure)	bar	Table 5-2
P5	Pressure at O_2 VFCD inlet (SOXE anode pressure)	bar	Table 5-2
PCAL1	Calibration resistor for low end of pressure transducer range	bar	Table 5-2
PCAL2	Calibration resistor for high end of pressure transducer range	bar	Table 5-2

Name	Description	Unit	DN-to-CU conversion
VT	Voltage at terminal that supplies voltage to top SOXE half-stack	V	Table 5-2
VB	Voltage at terminal that supplies voltage to bottom SOXE half-stack	V	Table 5-2
V28VM	Main 28 V power supply voltage	V	Table 5-2
V28VS	SOXE heaters 28 V power supply voltage	V	Table 5-2
V5V	Electronics 5 V power supply voltage	V	Table 5-2
IT	Current through top SOXE half-stack	A	Table 5-2
IB	Current through bottom SOXE half-stack	A	Table 5-2
IHT	Current through top SOXE half-stack heater	A	Table 5-2
IHB	Current through bottom SOXE half-stack heater	A	Table 5-2
IM1	Current to scroll compressor motor	A	Table 5-2
I28VM	Current to main 28 V power supply	A	Table 5-2
I28VS	Current to SOXE heaters 28 V power supply	A	Table 5-2
I5V	Current in electronics 5 V bus	A	Table 5-2
ICS123	Sum of currents for CS1 (CO_2 sensor in cathode line), CS2 (CO_2 sensor in anode line), and CS3 (CO sensor in cathode line)	A	Table 5-2
ICS4	Current for CS4 (O_2 sensor in anode line)	A	Table 5-2
PCO2_C	Partial pressure of carbon dioxide in SOXE cathode outlet (*uncorrected from total pressure of 1 bar and temperature of 22°C)	bar*	Section 5.1.2.1 then Table 5-2
PCO_C	Partial pressure of carbon monoxide in SOXE cathode outlet (*uncorrected from total pressure of 1 bar and temperature of 22°C)	bar*	Section 5.1.2.1 then Table 5-2

Name	Description	Unit	DN-to-CU conversion
PCO2_A	Partial pressure of carbon dioxide in SOXE anode outlet (*uncorrected from total pressure of 1 bar and temperature of 22°C)	bar*	Section 5.1.2.1 then Table 5-2
PO2_A	Partial pressure of oxygen in SOXE anode outlet (*uncorrected from temperature of 25°C)	bar*	Section 5.1.2.2 then Table 5-2
RPMM1	Scroll compressor RPM measured from motor driver	RPM	Table 5-2
XITP4	Calculated ratio of SOXE top half-stack current to SOXE cathode pressure	None	Table 5-2
XIBP4	Calculated ratio of SOXE bottom half-stack current to SOXE cathode pressure	None	Table 5-2
HT_OUT	Top SOXE half-stack heater commanded Pulse Width Modulation (PWM) duty cycle	None	Table 5-2
HB_OUT	Bottom SOXE half-stack heater commanded PWM duty cycle	None	Table 5-2
M1_OUT	Commanded scroll compressor RPM	RPM	Table 5-2
VT_OUT	Commanded top SOXE half-stack voltage	V	Table 5-2
VB_OUT	Commanded bottom SOXE half-stack voltage	V	Table 5-2
HS_en	SOXE heaters enable (1 = enabled; 0 = disabled)	None	None
CS123_en	CS123 enable (1 = enabled; 0 = disabled)	None	None
CS4_en	CS4 enable (1 = enabled; 0 = disabled)	None	None
M1_en	Scroll compressor motor enable bit (1 = enabled; 0 = disabled)	None	None
VT_en	SOXE top power supply enable bit (1 = enabled; 0 = disabled)	None	None

Name	Description	Unit	DN-to-CU conversion
VB_en	SOXE bottom power supply enable bit (1 = enabled; 0 = disabled)	None	None

5.1.2 Pre-DN-to-CU processing for gas composition sensor data

The gas composition sensors require additional processing before the DN-to-CU equations are applied.

5.1.2.1 CS1-CS3

1. Convert the “KONZ” DN value from decimal to hex. (For example, for CS1, use “KONZ1”).
2. Split the hex value into four bytes.
3. Reverse the order of the four bytes.
3. Convert each byte from hex to an ASCII character.
4. Convert each ASCII character from hex to decimal.
5. Apply the relevant DN-to-CU equation in Table 5-2.

5.1.2.2 CS4

1. Convert each of “CS4_DATA1” through “CS4_DATA20” from one 32-bit (4-byte) integer into four 8-bit (1-byte) integers.
2. Convert each 8-bit (1-byte) integer into an ASCII character.
3. Discard the first five ASCII characters (“`RAL1_`”), where “_” represents space.
4. Split the remaining ASCII string into the 13 calibrated data product fields, using space as the delimiter.
5. Extract the fourth field.
5. Apply the DN-to-CU equation in Table 5-2.

5.2 Label file

In addition to the metadata common to raw, calibrated and derived data products described in Section 3.2, the calibrated data product label file contains the DN-to-CU equations and constants conversions used to produce the calibrated data file.

5.2.1 Digital Number to Calibrated Unit (DN-to-CU) equations

The equations used to convert DN to CU are listed in Table 5-2. DN represents the value of the listed parameter in DN in the raw data product. Lowercase symbols (for example, aa) represent constants which are defined in Table 5-3. References to other parameters (for example, $\mathrm{TCAL1\_HC}$) always represent the value of those parameters in DN in the raw data product.

Table 5-2 DN-to-CU equations

Name	DN-to-CU equation
T1	$\mathrm{CU} = aa(ab\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + ac(ad\mathrm{DN}/\mathrm{TCAL1\_HC}) + ae$
T2	$\mathrm{CU} = af(ag\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + ah(ai\mathrm{DN}/\mathrm{TCAL1\_HC}) + aj$
T3	$\mathrm{CU} = ak(al\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + am(an\mathrm{DN}/\mathrm{TCAL1\_HC}) + ao$
T4	$\mathrm{CU} = ap(aq\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + ar(as\mathrm{DN}/\mathrm{TCAL1\_HC}) + at$
TT	$\mathrm{CU} = au(av(aw/ax)(\mathrm{TT\_HC} - \mathrm{TT\_LC})/(\mathrm{TCAL1\_HC} - \mathrm{TCAL1\_LC}))^2 + ay(az(ba/bb)(\mathrm{TT\_HC} - \mathrm{TT\_LC})/(\mathrm{TCAL1\_HC} - \mathrm{TCAL1\_LC})) + bc$
TB	$\mathrm{CU} = bd(be(bf/bg)(\mathrm{TB\_HC} - \mathrm{TB\_LC})/(\mathrm{TCAL1\_HC} - \mathrm{TCAL1\_LC}))^2 + bh(bi(bj/bk)(\mathrm{TB\_HC} - \mathrm{TB\_LC})/(\mathrm{TCAL1\_HC} - \mathrm{TCAL1\_LC})) + bl$
T7	$\mathrm{CU} = bm(bn\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + bo(bp\mathrm{DN}/\mathrm{TCAL1\_HC}) + bq$
T8	$\mathrm{CU} = br(bs\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + bt(bu\mathrm{DN}/\mathrm{TCAL1\_HC}) + bv$
T9	$\mathrm{CU} = bw(bx\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + by(bz\mathrm{DN}/\mathrm{TCAL1\_HC}) + ca$
T10	$\mathrm{CU} = cb(cc\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + cd(ce\mathrm{DN}/\mathrm{TCAL1\_HC}) + cf$
T11	$\mathrm{CU} = cg(ch\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + ci(cj\mathrm{DN}/\mathrm{TCAL1\_HC}) + ck$
T12	$\mathrm{CU} = cl(cm\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + cn(co\mathrm{DN}/\mathrm{TCAL1\_HC}) + cp$
T13	$\mathrm{CU} = cq(cr\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + cs(ct\mathrm{DN}/\mathrm{TCAL1\_HC}) + cu$
T14	$\mathrm{CU} = cv(cw\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + cx(cy\mathrm{DN}/\mathrm{TCAL1\_HC}) + cz$
T15	$\mathrm{CU} = da(db\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + dc(dd\mathrm{DN}/\mathrm{TCAL1\_HC}) + de$
T16	$\mathrm{CU} = df(dg\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + dh(di\mathrm{DN}/\mathrm{TCAL1\_HC}) + dj$
T18	$\mathrm{CU} = dk(dl\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + dm(dn\mathrm{DN}/\mathrm{TCAL1\_HC}) + do$
TCAL0	$\mathrm{CU} = dp(dq\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + dr(ds\mathrm{DN}/\mathrm{TCAL1\_HC}) + dt$
T22	$\mathrm{CU} = du(dv\mathrm{DN}/\mathrm{TCAL1\_HC})^2 + dw(dx\mathrm{DN}/\mathrm{TCAL1\_HC}) + dy$
P1	$\mathrm{CU} = dz\mathrm{DN} + ea$
P2	$\mathrm{CU} = eb\mathrm{DN} + ec$
P3	$\mathrm{CU} = ed\mathrm{DN} + ee$
P4	$\mathrm{CU} = ef\mathrm{DN} + eg$
P5	$\mathrm{CU} = eh\mathrm{DN} + ei$
PCAL1	$\mathrm{CU} = \mathrm{DN}/ej$
PCAL2	$\mathrm{CU} = \mathrm{DN}/ek$

Name	DN-to-CU equation
VT	$\mathrm{CU} = el\mathrm{DN}/em$
VB	$\mathrm{CU} = en\mathrm{DN}/eo$
V28VM	$\mathrm{CU} = ep\mathrm{DN}/eq$
V28VS	$\mathrm{CU} = er\mathrm{DN}/es$
V5V	$\mathrm{CU} = et\mathrm{DN}/eu$
IT	$\mathrm{CU} = ev\mathrm{DN}/ew$
IB	$\mathrm{CU} = ex\mathrm{DN}/ey$
IHT	$\mathrm{CU} = ez\mathrm{DN}/fa$
IHB	$\mathrm{CU} = fb\mathrm{DN}/fc$
IM1	$\mathrm{CU} = fd\mathrm{DN}/fe$
I28VM	$\mathrm{CU} = ff\mathrm{DN}/fg$
I28VS	$\mathrm{CU} = fh\mathrm{DN}/fi$
I5V	$\mathrm{CU} = fj\mathrm{DN}/fk$
ICS123	$\mathrm{CU} = fl\mathrm{DN}/fm$
ICS4	$\mathrm{CU} = fn\mathrm{DN}/fo$
PCO2_C	$\mathrm{CU} = fp\mathrm{DN}$
PCO_C	$\mathrm{CU} = fq\mathrm{DN}$
PCO2_A	$\mathrm{CU} = fr\mathrm{DN}$
PO2_A	$\mathrm{CU} = fs\mathrm{DN}$
RPMM1	$\mathrm{CU} = ft\mathrm{DN}/fu$
XITP4	$\mathrm{CU} = \mathrm{DN}/fv$
XIBP4	$\mathrm{CU} = \mathrm{DN}/fw$
HT_OUT	$\mathrm{CU} = \mathrm{DN}/fx$
HB_OUT	$\mathrm{CU} = \mathrm{DN}/fy$
M1_OUT	$\mathrm{CU} = fz\mathrm{DN} + ga$
VT_OUT	$\mathrm{CU} = gb\mathrm{DN} + gc$
VB_OUT	$\mathrm{CU} = gd\mathrm{DN} + ge$

DN-to-CU equations are specified in the label file as follows. Ellipses (…) indicate where values have been omitted or shortened for brevity; numeric values are examples only.

```
<Product_Observational>
  ⋮
  <Mission_Area>
    ⋮
    <mars2020:MOXIE_Parameters>
      <mars2020:Digital_Number_To_Calibrated_Unit_Conversions>
        <mars2020:file_name_calibration_table>…</mars2020:file_name_calibration_table>
        <mars2020:file_name_standard_telemetry_record>…</mars2020:file_…_record>
        <mars2020:file_name_extended_telemetry_record>…</mars2020:file_…_record>
        <mars2020:Digital_Number_To_Calibrated_Unit_Equations>
          <mars2020:Digital_Number_To_Calibrated_Unit_Equation>
            <mars2020:parameter>T1</mars2020:parameter>
            <mars2020:equation>CU = aa*(ab*DN/TCAL1_HC)^2 + … + ae</mars2020:equation>
          </mars2020:Digital_Number_To_Calibrated_Unit_Equation>
          ⋮
        </mars2020:Digital_Number_To_Calibrated_Unit_Equations>
        ⋮
      </mars2020:Digital_Number_To_Calibrated_Unit_Conversions>
      ⋮
    </mars2020:MOXIE_Parameters>
  </Mission_Area>
  ⋮
</Product_Observational>
```

In the following description, the “mars2020:” namespace has been omitted from each XML object name for brevity.

The <Digital_Number_To_Calibrated_Unit_Conversions> object contains two objects: <Digital_Number_To_Calibrated_Unit_Equations> and <Digital_Number_To_Calibrated_Unit_Constants>, and the attributes <file_name_calibration_table>, <file_name_standard_telemetry_record> and <file_name_extended_telemetry_record>.

<file_name_calibration_table> is the name of the YAML Ain’t Markup Language (YAML) file that contains the DN-to-CU equations and constants listed in Table 5-2 and Table 5-3. This file is used by the software that converts the raw data product in DN to the calibrated data product in CU. Therefore, the version number of the calibration file YAML file can be considered to be the version number of the DN-to-CU equations. As calibrations are updated, the version number of this file is incremented.

<file_name_standard_telemetry_record> is the name of the YAML file used by software to link the fields in the standard telemetry record to the equations in <file_name_calibration_table>.

<file_name_extended_telemetry_record> is the name of the YAML file used by software to link the fields in the extended telemetry record to the equations in <file_name_calibration_table>.

The <Digital_Number_To_Calibrated_Unit_Equations> object contains several <Digital_Number_To_Calibrated_Unit_Equation> objects. Each <Digital_Number_To_Calibrated_Unit_Equation> object contains the attributes <parameter> and <equation>.

<parameter> is the name of the field as listed in the first column of Table 5-1.

<equation> is the equation as listed in the second column of Table 5-2.

5.2.2 Digital Number to Calibrated Unit (DN-to-CU) constants

Table 5-3 DN-CU constants

Second letter of t symbol	a	b	c	d	e	f	g	
a	1.300E-05	1.000E+03	-2.502E+02	1.300E-05	-4.004E-02	3.461E+03	-1.398E+02	a
b	1.000E+03	4.194E-01	1.300E-05	1.000E+03	5.151E-04	5.000E+00	2.386E-03	b
c	2.370E-01	-2.288E+02	1.000E+03	2.370E-01	-1.585E-01	3.461E+03	1.733E+00	c
d	1.000E+03	2.543E-04	2.370E-01	1.000E+03	5.168E-04	5.000E+00	2.386E-03	d
e	-2.502E+02	4.194E-01	1.000E+03	-2.502E+02	-1.305E-01	1.817E+03	1.733E+00	e
f	1.300E-05	1.000E+03	-2.502E+02	1.300E-05	5.148E-04	5.000E+00	-	f
g	1.000E+03	4.194E-01	1.300E-05	1.000E+03	-1.415E-01	1.810E+03	-	g
h	2.370E-01	7.619E-01	1.000E+03	2.370E-01	5.163E-04	5.000E+00	-	h
i	1.000E+03	4.194E-01	2.370E-01	1.000E+03	-1.715E-01	1.810E+03	-	i
j	-2.502E+02	1.000E+03	1.000E+03	-2.502E+02	1.934E+03	5.970E+00	-	j
k	1.300E-05	4.194E-01	-2.502E+02	1.300E-05	1.934E+03	4.096E+03	-	k
l	1.000E+03	-2.134E+02	1.300E-05	1.000E+03	1.175E+03	2.315E+00	-	l
m	2.370E-01	1.300E-05	1.000E+03	2.370E-01	4.628E+05	4.096E+03	-	m
n	1.000E+03	1.000E+03	2.370E-01	1.000E+03	1.175E+03	2.882E+00	-	n
o	-2.502E+02	2.370E-01	1.000E+03	-2.502E+02	4.628E+05	4.096E+03	-	o
p	1.300E-05	1.000E+03	-2.502E+02	1.300E-05	4.435E+01	1.000E-04	-	p
q	1.000E+03	-2.502E+02	1.300E-05	1.000E+03	4.096E+03	1.000E-04	-	q
r	2.370E-01	1.300E-05	1.000E+03	2.370E-01	4.435E+01	1.000E-05	-	r
s	1.000E+03	1.000E+03	2.370E-01	1.000E+03	4.096E+03	1.000E-06	-	s
t	-2.502E+02	2.370E-01	1.000E+03	-2.502E+02	7.235E+00	6.000E+01	-	t
u	2.423E-04	1.000E+03	-2.502E+02	1.300E-05	4.096E+03	3.600E+01	-	u
v	4.194E-01	-2.502E+02	1.300E-05	1.000E+03	5.970E+00	8.000E+00	-	v
w	1.000E+03	1.300E-05	1.000E+03	2.370E-01	4.096E+03	8.000E+00	-	w
x	4.194E-01	1.000E+03	2.370E-01	1.000E+03	5.970E+00	6.400E+01	-	x
y	8.108E-01	2.370E-01	1.000E+03	-2.502E+02	4.096E+03	6.400E+01	-	y
z	4.194E-01	1.000E+03	-2.502E+02	1.043E-04	5.000E+00	4.293E+00	-	z
	a	b	c	d	e	f	g	
	First letter of symbol							

DN-to-CU constants are specified in the label file as follows. Ellipses (…) indicate where values have been omitted or shortened for brevity; numeric values are examples only.

```
<Product_Observational>
  ⋮
  <Mission_Area>
    ⋮
    <mars2020:MOXIE_Parameters>
      <mars2020:Digital_Number_To_Calibrated_Unit_Conversions>
        <mars2020:file_name_calibration_table>…</mars2020:file_name_calibration_table>
        ⋮
        <mars2020:Digital_Number_To_Calibrated_Unit_Constants>
          <mars2020:Digital_Number_To_Calibrated_Unit_Constant>
            <mars2020:symbol>aa</mars2020:symbol>
            <mars2020:value>1.300E-05</mars2020:value>
          </mars2020:Digital_Number_To_Calibrated_Unit_Constant>
          ⋮
        </mars2020:Digital_Number_To_Calibrated_Unit_Constants>
      </mars2020:Digital_Number_To_Calibrated_Unit_Conversions>
      ⋮
    </mars2020:MOXIE_Parameters>
  </Mission_Area>
  ⋮
</Product_Observational>
```

In the following description, the “mars2020:” namespace has been omitted from each XML object name for brevity.

The <Digital_Number_To_Calibrated_Unit_Conversions> and <Digital_Number_To_Calibrated_Unit_Equations> objects are described in Section 5.2.1 above.

The <Digital_Number_To_Calibrated_Unit_Constants> object contains several <Digital_Number_To_Calibrated_Unit_Constant> objects. Each <Digital_Number_To_Calibrated_Unit_Constant> object contains the attributes <symbol> and <value>.

<symbol> is the symbol of the constant, for example “aa”.

<value> is the value of the constant as listed in Table 5-3, for example “1.300E-05”.

6 Data product description: derived

The derived data product consists of two files: one data file in CSV format (Section 6.1), and one PDS4 label file in XML format (Section 6.1.2).

6.1 Data file

MOXIE derived data products do not use telemetry record field names. Instead, a variety of derived quantities are calculated from calibrated, and other derived, data product fields.

6.1.1 Field names, descriptions, and units

Field names, descriptions and units for the derived data product are listed in Table 6-1. Refer to the listed subsection of Section 6.1.3 for the equations used to derive each quantity. If there are multiple ways of calculating the same derived quantity, the preferred way is indicated by an asterisk (*).

Table 6-1: Derived data product field names and descriptions

Name	Description	Unit	Derivation in Section
T	Time	s	6.1.3.1
F_S_P4_G_HR*	SOXE inlet mass flow rate derived using P4	g/hr	6.1.3.2
F_S_P4_SCCM	SOXE inlet mass flow rate derived using P4	sccm	6.1.3.3
F_S_RPM_G_HR	SOXE inlet mass flow rate derived using scroll compressor RPM	g/hr	6.1.3.4
F_S_RPM_SCCM	SOXE inlet mass flow rate derived using scroll compressor RPM	sccm	6.1.3.5
F_S_FM_G_HR	SOXE inlet mass flow rate derived using flowmeter	g/hr	6.1.3.6
F_S_FM_SCCM	SOXE inlet mass flow rate derived using flowmeter	sccm	6.1.3.7
F_S_CS_G_HR	SOXE inlet mass flow rate derived using gas composition sensors	g/hr	6.1.3.8
F_S_CS_SCCM	SOXE inlet mass flow rate derived using gas composition sensors	sccm	6.1.3.9
VF_S_RPM_CM3_S	SOXE inlet volumetric flow rate derived using scroll compressor RPM	cm^3/s	6.1.3.10
F_O2_I_G_HR*	Oxygen mass production rate derived using SOXE current	g/hr	6.1.3.11

Name	Description	Unit	Derivation in Section
F_O2_I_SCCM	Oxygen mass production rate derived using SOXE current	sccm	6.1.3.12
F_O2_P5_G_HR	Oxygen mass production rate derived using P5	g/hr	6.1.3.13
F_O2_P5_SCCM	Oxygen mass production rate derived using P5	sccm	6.1.3.14
F_O2_CS_G_HR	Oxygen mass production rate derived using gas composition sensor	g/hr	6.1.3.15
F_O2_CS_SCCM	Oxygen mass production rate derived using gas composition sensor	sccm	6.1.3.16
X_O2_CS*	Oxygen purity (mole fraction) derived using gas composition sensors	None	6.1.3.17
X_O2_P	Oxygen purity (mole fraction) derived from pressures	None	6.1.3.18
U_CO2_1_I_P4*	CO_2 utilization, single pass, derived from current and P4	None	6.1.3.19
U_CO2_1_CS	CO_2 utilization, single pass, derived from gas composition sensors	None	6.1.3.20
U_CO2_O_I_P4*	CO_2 utilization, overall, derived from current and P4	None	6.1.3.21
U_CO2_O_CS	CO_2 utilization, overall, derived from gas composition sensors	None	6.1.3.22
X_CO2_IN	Mole fraction of carbon dioxide at SOXE inlet	None	6.1.3.23
X_CO_IN	Mole fraction of carbon monoxide at SOXE inlet	None	6.1.3.24
X_CO2_OUT	Mole fraction of carbon dioxide at SOXE cathode outlet	None	6.1.3.25
X_CO_OUT	Mole fraction of carbon monoxide at SOXE cathode outlet	None	6.1.3.26

Name	Description	Unit	Derivation in Section
V_N_CO_IN	Nernst potential for the reaction $2CO_2 \rightarrow O_2 + 2CO$ at SOXE cathode inlet	V	6.1.3.27
V_N_CO_AVG	Integral average Nernst potential for the reaction $2CO_2 \rightarrow O_2 + 2CO$	V	6.1.3.28
V_N_CO_OUT	Nernst potential for the reaction $2CO_2 \rightarrow O_2 + 2CO$ at SOXE cathode outlet	V	6.1.3.29
V_N_C_OUT	Nernst potential for the reaction $2CO \rightarrow O_2 + 2C$ at SOXE cathode outlet	V	6.1.3.30
V_OC_OP	SOXE open circuit voltage derived from operation	V	6.1.3.31
V_OC_SD	SOXE open circuit voltage derived at shutdown	V	6.1.3.32
AASR_T	SOXE top half-stack apparent area specific resistance	Ω cm^2	6.1.3.33
AASR_B	SOXE bottom half-stack apparent area specific resistance	Ω cm^2	6.1.3.34
CCASR_T	SOXE top half-stack conversion-corrected area specific resistance	Ω cm^2	6.1.3.35
CCASR_B	SOXE bottom half-stack conversion-corrected area specific resistance	Ω cm^2	6.1.3.36
TCCASR_T	SOXE top half-stack temperature- and conversion-corrected area specific resistance	Ω cm^2	6.1.3.37
TCCASR_B	SOXE bottom half-stack temperature- and conversion-corrected area specific resistance	Ω cm^2	6.1.3.38
ETA_SC_V	Scroll compressor volumetric efficiency	None	6.1.3.39
ETA_SC_T	Scroll compressor thermodynamic efficiency	None	6.1.3.40
P_TOT_W	Total power	W	6.1.3.41

Name	Description	Unit	Derivation in Section
P_MAIN_W	Power draw from main power supply	W	6.1.3.42
P_SOXE_W	Power draw from SOXE power supply	W	6.1.3.43
P_SC_W	Scroll compressor power	W	6.1.3.44
E_TOT_W_HR	Cumulative energy consumption	Wh	6.1.3.45

6.1.2 Equations for interim quantities

Interim quantities are quantities that appear often in the equations for derived quantities. For convenience, they are grouped together here and described below.

6.1.2.1 T_{VFCD}

T_{VFCD} is the temperature of the VFCDs in °C:

$$T_{\mathrm{VFCD}} = \frac{\mathrm{T16} + \mathrm{T18}}{2}$$

where $\mathrm{T16}$ is the temperature at the P4 VFCD manifold in °C from the calibrated data product, and $\mathrm{T18}$ is the temperature at the VFCD on the CO/CO_2 outlet in °C from the calibrated data product.

6.1.2.2 F_t

F_{t} is the VFCD temperature correction factor (dimensionless) [2]:

$$F_{\mathrm{t}} = \sqrt{\frac{530}{1.6T_{\mathrm{VFCD}} + 492}}$$

where T_{VFCD} is the temperature of the VFCDs in °C (Section 6.1.2.1).

6.1.2.3 M1CO2

$\mathrm{M1CO2}$ is the mass flow rate of carbon dioxide at the MOXIE inlet in g/hr:

$$\mathrm{M1CO2} = 0.955[\mathrm{F\_S\_P4\_G\_HR} - 0.064(\mathrm{F\_S\_P4\_G\_HR} - \mathrm{F\_O2\_I\_G\_HR})]$$

where $\mathrm{F\_S\_P4\_G\_HR}$ is the SOXE inlet mass flow rate derived using P4 in g/hr (Section 6.1.3.2), and $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11).

6.1.2.4 MCCO2

$\mathrm{MCCO2}$ is the mass flow rate of carbon dioxide at the SOXE inlet in g/hr:

$$\mathrm{MCCO2} = 0.8993\mathrm{F\_S\_P4\_G\_HR} + 0.0557\mathrm{F\_O2\_I\_G\_HR} + \mathrm{MRCO2}$$

where $\mathrm{F\_S\_P4\_G\_HR}$ is the SOXE inlet mass flow rate derived using P4 in g/hr (Section 6.1.3.2), $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11), and $\mathrm{MRCO2}$ is the mass flow rate of carbon dioxide in the recirculation line in g/hr (Section 6.1.2.5).

6.1.2.5 MCCO

MCCO is the mass flow rate of carbon monoxide at the SOXE inlet in g/hr:

$$\mathrm{MCCO} = \mathrm{MRCO}$$

where MRCO is the mass flow rate of carbon monoxide in the recirculation line in g/hr (Section 6.1.2.9).

6.1.2.6 MSCO2

$\mathrm{MSCO2}$ is the mass flow rate of carbon dioxide at the SOXE cathode outlet in g/hr:

$$\mathrm{MSCO2} = 0.945\mathrm{F\_S\_P4\_G\_HR} - 2.854\mathrm{F\_O2\_I\_G\_HR}$$

where $\mathrm{F\_S\_P4\_G\_HR}$ is the SOXE inlet mass flow rate derived using P4 in g/hr (Section 6.1.3.2) and $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11).

6.1.2.7 MSCO

MSCO is the mass flow rate of carbon monoxide at the SOXE cathode outlet in g/hr:

$$\mathrm{MSCO} = 1.75\mathrm{F\_O2\_I\_G\_HR} + \mathrm{MRCO}$$

where $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11) and MRCO is the mass flow rate of carbon monoxide in the recirculation line in g/hr (Section 6.1.2.9).

6.1.2.8 MRCO2

$\mathrm{MRCO2}$ is the mass flow rate of carbon dioxide in the recirculation line in g/hr:

$$\mathrm{MRCO2} = 0.0551\mathrm{F\_S\_P4\_G\_HR} - 0.1664\mathrm{F\_O2\_I\_G\_HR}$$

where $\mathrm{F\_S\_P4\_G\_HR}$ is the SOXE inlet mass flow rate derived using P4 in g/hr (Section 6.1.3.2) and $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11).

6.1.2.9 MRCO

MRCO is the mass flow rate of carbon monoxide in the recirculation line in g/hr:

$$\mathrm{MRCO} = 0.1083\mathrm{F\_O2\_I\_G\_HR}$$

where $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11).

6.1.2.10 *x*

x is the RPM offset:

$$x = \frac{\mathrm{RPMM1} - 3000}{500}$$

where $\mathrm{RPMM1}$ is the scroll compressor RPM from the calibrated data product.

6.1.3 Equations for derived quantities

This section contains the equations for the quantities in the derived data product (Table 6-1).

6.1.3.1 T

T is the time elapsed since the start of the data in s:

$$\mathrm{T} = \mathrm{SW\_TIME}$$

where $\mathrm{SW\_TIME}$ is the incremented time since the load of FSW after boot in s from the calibrated data product.

6.1.3.2 F_S_P4_G_HR*

$\mathrm{F\_S\_P4\_G\_HR}$ is the SOXE inlet mass flow rate derived using P4 in g/hr:

$$\mathrm{F\_S\_P4\_G\_HR} = \frac{750\mathrm{P4} - C_2}{C_1}$$

where $\mathrm{P4}$ is the pressure at the CO/CO_2 VFCD inlet (SOXE cathode pressure) in bar from the calibrated data product, C_2 is:

$$C_2 = -31 + \frac{5(F_\mathrm{t} - 0.96)}{0.15} - 3.3(\mathrm{F\_S\_O2\_I\_G\_HR} - 6)$$

and C_1 is:

$$C_1 = 8.03 - \frac{1.08(F_\mathrm{t} - 0.96)}{0.15} - 0.05\left(\frac{\mathrm{F\_S\_O2\_I\_G\_HR}}{6}\right)$$

where in both C_2 and C_1, F_t is the VFCD temperature correction factor (Section 6.1.2.2) and $\mathrm{F\_S\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11).

6.1.3.3 F_S_P4_SCCM

$\mathrm{F\_S\_P4\_SCCM}$ is the SOXE inlet mass flow rate derived using P4 in standard cubic centimeters per minute (sccm):

$$\mathrm{F\_S\_P4\_SCCM} = \frac{RT^\theta}{M_\mathrm{CO2}P^\theta}\frac{\mathrm{F\_S\_P4\_G\_HR}}{60}$$

where R is the universal gas constant, 8.315×10^6 (cm^3 Pa)/(K mol), T^θ is the standard temperature, 273.15 K (0°C), M_CO2 is the molar mass of CO_2, 44 g/mol, P^θ is the standard pressure, 101325 Pa (1 atm) and $\mathrm{F\_S\_P4\_G\_HR}$ is the SOXE inlet mass flow rate derived using P4 in g/hr (Section 6.1.3.2).

6.1.3.4 F_S_RPM_G_HR

$\mathrm{F\_S\_RPM\_G\_HR}$ is the SOXE inlet mass flow rate derived using scroll compressor RPM in g/hr:

$$\mathrm{F\_S\_RPM\_G\_HR} = \frac{1.2071\left[\frac{\mathrm{RPMM1}}{\mathrm{T2}+273}\right][750\mathrm{PM} - 0.14]}{1 + 1.291\left[\frac{\mathrm{RPMM1}}{\mathrm{T2}+273}\right]\left[9.35\times10^{-4}(750\mathrm{PM} - 0.14) + 8.742\times10^{-4}\left(\frac{\mathrm{TM}}{750\mathrm{PM}}\right)\right]}$$

where $\mathrm{RPMM1}$ is the scroll compressor RPM from the calibrated data product, $\mathrm{T2}$ is the temperature at the P1 sensor in °C from the calibrated data product, PM is Mars atmospheric pressure in bar as measured by MEDA and TM is Mars atmospheric temperature in K as measured by MEDA.

If PM and TM are not available from MEDA, predicted values are used. If predicted values are not available, default values of PM = 0.00715 bar and TM = 215 K are assumed in the calculation of $\mathrm{F\_S\_RPM\_G\_HR}$. These values are the hourly mean of the pressure and temperature at the landing site over one Mars year found using the Mars Climate Database [3, 4].

6.1.3.5 F_S_RPM_SCCM

$\mathrm{F\_S\_RPM\_SCCM}$ is the SOXE inlet mass flow rate derived using scroll compressor RPM in sccm:

$$\mathrm{F\_S\_RPM\_SCCM} = \frac{RT^{\theta}}{M_{\mathrm{CO2}}P^{\theta}} \frac{\mathrm{F\_S\_RPM\_G\_HR}}{60}$$

where R is the universal gas constant, 8.315×10^6 (cm^3 Pa)/(K mol), T^{θ} is the standard temperature, 273.15 K (0°C), M_{CO2} is the molar mass of CO_2, 44 g/mol, P^{θ} is the standard pressure, 101325 Pa (1 atm) and $\mathrm{F\_S\_RPM\_G\_HR}$ is the SOXE inlet mass flow rate derived using scroll compressor RPM in g/hr (Section 6.1.3.4).

6.1.3.6 F_S_FM_G_HR

$\mathrm{F\_S\_FM\_G\_HR}$ is the SOXE inlet mass flow rate derived using the flowmeter in g/hr:

$$\mathrm{F\_S\_FM\_G\_HR} = \frac{2(4110)F_{\mathrm{t}}M_{\mathrm{CO2}}\left(\frac{10}{3600}\right)\sqrt{750\mathrm{P3}(750\mathrm{P2} - 750\mathrm{P3})}}{1775}$$

where F_{t} is the VFCD temperature correction factor (Section 6.1.2.2), M_{CO2} is the molar mass of CO_2, 44 g/mol, $\mathrm{P3}$ is the pressure between the flow sensor and SOXE in bar from the calibrated data product and $\mathrm{P2}$ is the pressure between the check valve and the flow sensor in bar from the calibrated data product. $\mathrm{P2}$ and $\mathrm{P3}$ are first smoothed using the Savitsky-Golay method [5] to reduce oscillations caused by the scroll compressor.

6.1.3.7 F_S_FM_SCCM

$\mathrm{F\_S\_FM\_SCCM}$ is the SOXE inlet mass flow rate derived using the flowmeter in sccm:

$$\mathrm{F\_S\_FM\_SCCM} = \frac{RT^{\theta}}{M_{\mathrm{CO2}}P^{\theta}} \frac{\mathrm{F\_S\_FM\_G\_HR}}{60}$$

where R is the universal gas constant, 8.315×10^6 (cm^3 Pa)/(K mol), T^{θ} is the standard temperature, 273.15 K (0°C), M_{CO2} is the molar mass of CO_2, 44 g/mol, P^{θ} is the standard pressure, 101325 Pa (1 atm) and $\mathrm{F\_S\_FM\_G\_HR}$ is the SOXE inlet mass flow rate derived using the flowmeter in g/hr (Section 6.1.3.6).

6.1.3.8 F_S_CS_G_HR

$\mathrm{F\_S\_CS\_G\_HR}$ is the SOXE inlet mass flow rate derived using the gas composition sensors in g/hr:

$$\mathrm{F\_S\_CS\_G\_HR} = \frac{750\mathrm{P4\_CS} - C_2}{C_1}$$

where $\mathrm{P4\_CS}$ is the pressure at CO/CO_2 VFCD inlet (SOXE cathode pressure) derived from composition sensor readings and C_2 and C_1 are as defined in Section 6.1.3.2.

6.1.3.9 F_S_CS_SCCM

$\mathrm{F\_S\_CS\_SCCM}$ is the SOXE inlet mass flow rate derived using the gas composition sensors in sccm:

$$\mathrm{F\_S\_CS\_SCCM} = \frac{RT^{\theta}}{M_{\mathrm{CO2}}P^{\theta}} \frac{\mathrm{F\_S\_CS\_G\_HR}}{60}$$

where R is the universal gas constant, 8.315×10^6 (cm^3 Pa)/(K mol), T^{θ} is the standard temperature, 273.15 K (0°C), M_{CO2} is the molar mass of CO_2, 44 g/mol, P^{θ} is the standard pressure, 101325 Pa (1 atm) and $\mathrm{F\_S\_CS\_G\_HR}$ is the SOXE inlet mass flow rate derived using the gas composition sensors in g/hr (Section 6.1.3.8).

6.1.3.10 VF_S_RPM_CM3_S

$\mathrm{VF\_S\_RPM\_CM3\_S}$ is the SOXE inlet volumetric flow rate derived using scroll compressor RPM in cm^3/s:

$$\mathrm{VF\_S\_RPM\_CM3\_S} = \frac{30.1\mathrm{RPMM1}}{60}$$

where $\mathrm{RPMM1}$ is the scroll compressor RPM from the calibrated data product.

6.1.3.11 F_O2_I_G_HR*

$\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr:

$$\mathrm{F\_O2\_I\_G\_HR} = \frac{1}{0.335}\left(\frac{\mathrm{IT} + \mathrm{IB}}{2}\right)$$

where IT is the current through the top SOXE half-stack in A from the calibrated data product, and IB is the current through the bottom SOXE half-stack in A from the calibrated data product.

6.1.3.12 F_O2_I_SCCM

$\mathrm{F\_O2\_I\_SCCM}$ is the oxygen mass production rate derived using the SOXE current in sccm:

$$\mathrm{F\_O2\_I\_SCCM} = \frac{RT^{\theta}}{M_{\mathrm{O2}}P^{\theta}} \frac{\mathrm{F\_O2\_I\_G\_HR}}{60}$$

where R is the universal gas constant, 8.315×10^6 (cm^3 Pa)/(K mol), T^{θ} is the standard temperature, 273.15 K (0°C), M_{O2} is the molar mass of O_2, 32 g/mol, P^{θ} is the standard pressure, 101325 Pa (1 atm) and $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11).

6.1.3.13 F_O2_P5_G_HR

$\mathrm{F\_O2\_P5\_G\_HR}$ is the oxygen mass production rate derived using $\mathrm{P5}$ in g/hr:

$$\mathrm{F\_O2\_P5\_G\_HR} = 0.00268 M_{\mathrm{O2}} \left[\frac{4970 F_{\mathrm{t}}(750\mathrm{P5})}{34308}\right]$$

where M_{O2} is the molar mass of O_2, 32 g/mol, F_{t} is the VFCD temperature correction factor (Section 6.1.2.2) and $\mathrm{P5}$ is the pressure at the O_2 VFCD inlet (SOXE anode pressure) in bar from the calibrated data product.

6.1.3.14 F_O2_P5_SCCM

$\mathrm{F\_O2\_P5\_SCCM}$ is the oxygen mass production rate derived using $\mathrm{P5}$ in sccm:

$$\mathrm{F\_O2\_P5\_SCCM} = \frac{RT^{\theta}}{M_{\mathrm{O2}} P^{\theta}} \frac{\mathrm{F\_O2\_P5\_G\_HR}}{60}$$

where R is the universal gas constant, 8.315×10^6 (cm^3 Pa)/(K mol), T^{θ} is the standard temperature, 273.15 K (0°C), M_{O2} is the molar mass of O_2, 32 g/mol, P^{θ} is the standard pressure, 101325 Pa (1 atm) and $\mathrm{F\_S\_O2\_P5\_G\_HR}$ is the oxygen mass production rate derived using $\mathrm{P5}$ in g/hr (Section 6.1.3.13).

6.1.3.15 F_O2_CS_G_HR

$\mathrm{F\_O2\_CS\_G\_HR}$ is the oxygen mass production rate derived using the gas composition sensors in g/hr.

6.1.3.16 F_O2_CS_SCCM

$\mathrm{F\_O2\_CS\_SCCM}$ is the oxygen mass production rate derived using the gas composition sensor in sccm:

$$\mathrm{F\_O2\_CS\_SCCM} = \frac{RT^{\theta}}{M_{\mathrm{O2}} P^{\theta}} \frac{\mathrm{F\_O2\_CS\_G\_HR}}{60}$$

where R is the universal gas constant, 8.315×10^6 (cm^3 Pa)/(K mol), T^{θ} is the standard temperature, 273.15 K (0°C), M_{O2} is the molar mass of O_2, 32 g/mol, P^{θ} is the standard pressure, 101325 Pa (1 atm) and $\mathrm{F\_S\_O2\_CS\_G\_HR}$ is the oxygen mass production rate derived using the gas composition sensor in g/hr (Section 6.1.3.15).

6.1.3.17 X_O2_CS*

$\mathrm{X\_O2\_CS}$ is the oxygen purity (mole fraction) derived using the gas composition sensors (dimensionless).

6.1.3.18 X_O2_P

$\mathrm{X\_O2\_P}$ is the oxygen purity (mole fraction) derived using pressure measurements (dimensionless):

$$\mathrm{X\_O2\_P} = \frac{\mathrm{P5}}{\mathrm{P5} + 22.4\mathrm{PCO\_A}\left(\frac{\mathrm{T13}+273}{22+273}\right)}$$

where $\mathrm{P5}$ is the pressure at the O_2 VFCD inlet (SOXE anode pressure) in bar from the calibrated data product, $\mathrm{PCO\_A}$ is the partial pressure of carbon dioxide in the anode line in bar (assuming room temperature) from the calibrated data product and $\mathrm{T13}$ is the temperature at the CS2 sensor (CO_2 sensor in anode line) in °C from the calibrated data product.

6.1.3.19 U_CO2_1_I_P4*

$\mathrm{U\_CO2\_1\_I\_P4}$ is the CO_2 utilization, single pass, derived from the SOXE current and $\mathrm{P4}$ (dimensionless):

$$\mathrm{U\_CO2\_1\_I\_P4} = \frac{44\mathrm{F\_O2\_I\_G\_HR}}{16\mathrm{M1CO2}}$$

where $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11) and $\mathrm{M1CO2}$ is the mass flow rate of carbon dioxide entering MOXIE in g/hr (Section 6.1.2.3).

6.1.3.20 U_CO2_1_CS

$\mathrm{U\_CO2\_1\_CS}$ is the CO_2 utilization, single pass, derived from the gas composition sensors (dimensionless).

6.1.3.21 U_CO2_O_I_P4*

$\mathrm{U\_CO2\_O\_I\_P4}$ is the CO_2 utilization, overall, derived from the SOXE current and $\mathrm{P4}$ (dimensionless):

$$\mathrm{U\_CO2\_O\_I\_P4} = \frac{44\mathrm{F\_O2\_I\_G\_HR}}{16\mathrm{MCCO2}}$$

where $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11) and $\mathrm{MCCO2}$ is the mass flow rate of carbon dioxide entering the scroll compressor in g/hr (Section 6.1.2.4).

6.1.3.22 U_CO2_O_CS

$\mathrm{U\_CO2\_O\_CS}$ is the CO_2 utilization, overall, derived from the gas composition sensors (dimensionless).

6.1.3.23 X_CO2_IN

$\mathrm{X\_CO2\_IN}$ is the mole fraction of carbon dioxide at the SOXE inlet (dimensionless):

$$\mathrm{X\_CO2\_IN} = \frac{\left(\frac{\mathrm{MCCO2}}{44}\right)}{\left(\frac{\mathrm{MCCO}}{28} + \frac{\mathrm{MCCO2}}{44}\right)}$$

where $\mathrm{MCCO2}$ is the mass flow rate of carbon dioxide at the SOXE inlet in g/hr (Section 6.1.2.4) and MCCO is the mass flow rate of carbon monoxide at the SOXE inlet in g/hr (Section 6.1.2.5).

6.1.3.24 X_CO_IN

$\mathrm{XCO\_IN}$ is the mole fraction of carbon monoxide at the SOXE inlet (dimensionless):

$$\mathrm{X\_CO\_IN} = \frac{\left(\frac{\mathrm{MCCO}}{28}\right)}{\left(\frac{\mathrm{MCCO}}{28} + \frac{\mathrm{MCCO2}}{44}\right)}$$

where MCCO is the mass flow rate of carbon monoxide at the SOXE inlet in g/hr (Section 6.1.2.5) and $\mathrm{MCCO2}$ is the mass flow rate of carbon dioxide at the SOXE inlet in g/hr (Section 6.1.2.4).

6.1.3.25 X_CO2_OUT

$\mathrm{X\_CO2\_OUT}$ is the mole fraction of carbon dioxide at the SOXE cathode outlet (dimensionless):

$$\mathrm{X\_CO2\_OUT} = \frac{0.02148[\mathrm{F\_S\_P4\_G\_HR} - 0.064(\mathrm{F\_S\_P4\_G\_HR} - \mathrm{F\_O2\_I\_G\_HR})] - 0.0649\mathrm{F\_O2\_I\_G\_HR}}{0.02289[\mathrm{F\_S\_P4\_G\_HR} - 0.064(\mathrm{F\_S\_P4\_G\_HR} - \mathrm{F\_O2\_I\_G\_HR})] + 0.00146\mathrm{F\_O2\_I\_G\_HR}}$$

where $\mathrm{F\_S\_P4\_G\_HR}$ is the SOXE inlet mass flow rate derived using P4 in g/hr (Section 6.1.3.2) and $\mathrm{F\_O2\_I\_G\_HR}$ is the oxygen mass production rate derived using the SOXE current in g/hr (Section 6.1.3.11).

6.1.3.26 X_CO_OUT

$\mathrm{X\_CO\_OUT}$ is the mole fraction of carbon monoxide at the SOXE cathode outlet (dimensionless):

$$\mathrm{X\_CO\_OUT} = \frac{\left(\frac{\mathrm{MSCO}}{28}\right)}{\left(\frac{\mathrm{MSCO}}{28} + \frac{\mathrm{MSCO2}}{44}\right)}$$

where MSCO is the mass flow rate of carbon monoxide at the SOXE cathode outlet in g/hr (Section 6.1.2.7) and $\mathrm{MSCO2}$ is the mass flow rate of carbon dioxide at the SOXE cathode outlet in g/hr (Section 6.1.2.6).

6.1.3.27 V_N_CO_IN

V_N_CO_IN is the Nernst potential for the reaction $2CO_2 \rightarrow O_2 + 2CO$ at the SOXE inlet in V:

$$\mathrm{V\_N\_CO\_IN} = 0.9809 + 0.02312 \ln\left[\frac{(0.2/100)\mathrm{P3}(\mathrm{X\_CO\_IN})^2\mathrm{P3}^2}{(\mathrm{X\_CO2\_IN})^2\mathrm{P3}^2}\right]$$

where P3 is the pressure between the flow sensor and SOXE in bar from the calibrated data product, X_CO_IN is the mole fraction of carbon monoxide at the SOXE inlet (6.1.3.24) and X_CO2_IN is the mole fraction of carbon dioxide at the SOXE inlet (6.1.3.23).

6.1.3.28 V_N_CO_AVG

V_N_CO_AVG is the integral average Nernst potential for the reaction $2CO_2 \rightarrow O_2 + 2CO$ in V:

$$\mathrm{V\_N\_O\_AVG} = K_1[K_2 + 0.02312(K_3 + K_4 - K_5 - K_6)]$$

where:

$$K_1 = \frac{1}{\mathrm{X\_CO\_OUT} - \mathrm{X\_CO\_IN}}$$

$$K_2 = 0.9809[\mathrm{X\_CO\_OUT} - \mathrm{X\_CO\_IN}]$$

$$K_3 = \ln\left(\frac{(\mathrm{X\_CO\_OUT})^2\mathrm{P5}}{[\mathrm{X\_CO\_OUT} - 1]^2}\right)\mathrm{X\_CO\_OUT}$$

$$K_4 = 2\ln[1 - \mathrm{X\_CO\_OUT}]$$

$$K_5 = \ln\left(\frac{(\mathrm{X\_CO\_IN})^2\mathrm{P5}}{[1 - \mathrm{X\_CO\_IN}]^2}\right)\mathrm{X\_CO\_IN}$$

$$K_6 = 2\ln[1 - \mathrm{X\_CO\_IN}]$$

where in all of K_1 through K_6, X_CO_OUT is the mole fraction of carbon dioxide at the SOXE cathode outlet (Section 6.1.3.23), X_CO_IN is the mole fraction of carbon monoxide at the SOXE inlet (Section 6.1.3.25) and P5 is the pressure at the O_2 VFCD inlet (SOXE anode pressure) in bar from the calibrated data product.

6.1.3.29 V_N_CO_OUT

V_N_CO_OUT is the Nernst potential for the reaction $2CO_2 \rightarrow O_2 + 2CO$ at the SOXE outlet in V:

$$\mathrm{V\_N\_CO\_OUT} = 0.9809 + 0.02312 \ln \left[\frac{(\mathrm{X\_CO\_OUT})^2 \left(\frac{750\mathrm{P4} + 10}{750}\right)^2 \mathrm{P5}}{(\mathrm{X\_CO2\_OUT})^2 \left(\frac{750\mathrm{P4} + 10}{750}\right)^2} \right]$$

where $\mathrm{X\_CO\_OUT}$ is the mole fraction of carbon monoxide at the SOXE cathode outlet (Section 6.1.3.25), $\mathrm{P4}$ is the pressure at the CO/CO_2 VFCD inlet (SOXE cathode pressure) in bar from the calibrated data product, $\mathrm{P5}$ is the pressure at the O_2 VFCD inlet (SOXE anode pressure) in bar from the calibrated data product and $\mathrm{X\_CO2\_OUT}$ is the mole fraction of carbon dioxide at the SOXE cathode outlet (Section 6.1.3.25).

6.1.3.30 V_N_C_OUT

$\mathrm{V\_N\_C}$ is the Nernst potential for the reaction 2CO → O_2 + 2C at the SOXE outlet in V:

$$\mathrm{V\_N\_C} = 1.0713 + 0.04623 \ln \left[\frac{\sqrt{\mathrm{P5}}}{\left(\frac{750\mathrm{P4} + 10}{750}\right) \mathrm{X\_CO\_OUT}} \right]$$

where $\mathrm{P5}$ is the pressure at the O_2 VFCD inlet (SOXE anode pressure) in bar from the calibrated data product, $\mathrm{P4}$ is the pressure at the CO/CO_2 VFCD inlet (SOXE cathode pressure) in bar from the calibrated data product and $\mathrm{X\_CO\_OUT}$ is the mole fraction of carbon monoxide at the SOXE cathode outlet (Section 6.1.3.25).

6.1.3.31 V_OC_OP

$\mathrm{V\_OC\_OP}$ is the estimated SOXE open circuit voltage per cell derived from operation (I-V measurements) in V.

6.1.3.32 V_OC_SD

$\mathrm{V\_OC\_SD}$ is the SOXE open-circuit voltage per cell derived at shutdown in V.

6.1.3.33 AASR_T

$\mathrm{AASR\_T}$ is the mean apparent Area Specific Resistance (ASR) per cell of the top SOXE half-stack in in Ω cm^2:

$$\mathrm{AASR\_T} = \frac{\mathrm{VT}/5 - 0.9809}{\mathrm{IT}/22.7}$$

where VT is the voltage across the top SOXE half-stack in V from the calibrated data product and IT is the current through the top SOXE half-stack in A from the calibrated data product.

6.1.3.34 AASR_B

$\mathrm{AASR\_B}$ is the mean apparent ASR per cell of the bottom SOXE half-stack in Ω cm^2:

$$\mathrm{AASR\_B} = \frac{\mathrm{VB}/5 - 0.9809}{\mathrm{IB}/22.7}$$

where VB is the voltage across the bottom SOXE half-stack in V from the calibrated data product and IB is the current through the bottom SOXE half-stack in A from the calibrated data product.

6.1.3.35 CCASR_T

$\mathrm{CCASR\_T}$ is the mean conversion-corrected ASR per cell of the top SOXE half-stack in Ω cm^2:

$$\mathrm{CCASR\_T} = \frac{\mathrm{VT}/5 - \mathrm{V\_N\_O\_AVG}\ - 0.02155}{\mathrm{IT}/22.7}$$

where VT is the voltage across the top SOXE half-stack in V from the calibrated data product, $\mathrm{V\_N\_O\_AVG}$ is the integral average Nernst potential for the reaction $2CO_2 \rightarrow O_2 + 2CO$ in V (Section 6.1.3.28) and IT is the current through the top SOXE half-stack in A from the calibrated data product.

6.1.3.36 CCASR_B

$\mathrm{CCASR\_B}$ is the mean conversion-corrected ASR per cell of the bottom SOXE half-stack in Ω cm^2:

$$\mathrm{CCASR\_B} = \frac{\mathrm{VB}/5 - \mathrm{V\_N\_O\_AVG}\ - 0.02155}{\mathrm{IB}/22.7}$$

where VB is the voltage across the bottom SOXE half-stack in V from the calibrated data product, $\mathrm{V\_N\_O\_AVG}$ is the integral average Nernst potential for the reaction $2CO_2 \rightarrow O_2 + 2CO$ in V (Section 6.1.3.28) and IB is the current through the bottom SOXE half-stack in A from the calibrated data product.

6.1.3.37 TCCASR_T

$\mathrm{TCCASR\_T}$ is the mean temperature- and conversion-corrected ASR per cell of the top SOXE half-stack in Ω cm^2:

$$\mathrm{TCCASR\_T} = \frac{\mathrm{CCASR\_T}}{10300\,\exp(-82556/1073R)}$$

where $\mathrm{CCASR\_T}$ is the mean conversion-corrected ASR per cell of the top SOXE half-stack in Ω cm^2 (Section 6.1.3.35) and R is the universal gas constant, 8.3145 J mol^{-1} K^{-1}.

6.1.3.38 TCCASR_B

$\mathrm{TCCASR\_B}$ is the mean temperature- and conversion-corrected ASR per cell of the bottom SOXE half-stack in Ω cm^2:

$$\mathrm{TCCASR\_B} = \frac{\mathrm{CCASR\_B}}{10300\exp(-82556/1073R)}$$

where $\mathrm{CCASR\_B}$ is the mean conversion-corrected ASR per cell of the bottom SOXE half-stack in Ω cm^2 (Section 6.1.3.36) and R is the universal gas constant, 8.3145 J mol^{-1} K^{-1}.

6.1.3.39 ETA_SC_V

$\mathrm{ETA\_SC\_V}$ is the scroll compressor volumetric efficiency (dimensionless):

$$\mathrm{ETA\_SC\_V} = 0.944 - 0.000113\mathrm{P2}$$

where $\mathrm{P2}$ is the pressure between the check valve and the flow sensor in bar from the calibrated data product.

6.1.3.40 ETA_SC_T

$\mathrm{ETA\_SC\_T}$ is the scroll compressor thermodynamic efficiency, assuming isothermal compression (dimensionless):

$$\mathrm{ETA\_SC\_T} = \frac{0.1\left[5.19\ln\left(\frac{30.1}{5.19}\right)\mathrm{P1} + 5.19\mathrm{P2}\right]\left[\frac{\mathrm{RPMM1}}{60}\right]}{(1.336 + 0.286x)\mathrm{F\_S\_P4\_G\_HR} + (20 - 7.63x)}$$

where $\mathrm{P1}$ is the pressure at the HEPA filter exit in bar from the calibrated data product, $\mathrm{P2}$ is the pressure between the check valve and the flow sensor in bar from the calibrated data product, $\mathrm{RPMM1}$ is the scroll compressor RPM from the calibrated data product, x is the RPM offset (Section 6.1.2.10) and $\mathrm{F\_S\_P4\_G\_HR}$ is the SOXE inlet mass flow rate derived using P4 in g/hr (Section 6.1.3.2).

6.1.3.41 P_TOT_W

$\mathrm{P\_TOT\_W}$ is the instantaneous total power in W:

$$\mathrm{P\_TOT\_W} \ = \mathrm{P\_MAIN\_W} + \mathrm{P\_SOXE\_W} + \mathrm{P\_SC\_W}$$

where $\mathrm{P\_MAIN\_W}$ is the instantaneous power drawn from the main 28 V power supply in W (Section 6.1.3.42), $\mathrm{P\_SOXE\_W}$ is the instantaneous power drawn from the SOXE 28 V power supply in W (Section 6.1.3.43) and $\mathrm{P\_SC\_W}$ is the instantaneous scroll compressor power in W (Section 6.1.3.44).

6.1.3.42 P_MAIN_W

$\mathrm{P\_MAIN\_W}$ is the instantaneous power drawn from the main 28 V power supply in W:

$$\mathrm{P\_MAIN} = (\mathrm{I28VM})(\mathrm{V28VM})$$

where $\mathrm{I28VM}$ is the current to the main 28 V power supply in A from the calibrated data product and $\mathrm{V28VM}$ is the main 28 V power supply voltage in V from the calibrated data product.

6.1.3.43 P_SOXE_W

$\mathrm{P\_SOXE\_W}$ is the instantaneous power drawn from the SOXE 28 V power supply in W:

$$\mathrm{P\_SOXE} = (\mathrm{I28VS})(\mathrm{V28VS})$$

where $\mathrm{I28VS}$ is the current to the SOXE 28 V power supply in A from the calibrated data product and $\mathrm{V28VS}$ is the SOXE 28 V power supply voltage in V from the calibrated data product.

6.1.3.44 P_SC_W

$\mathrm{P\_SC\_W}$ is the instantaneous scroll compressor power in W:

$$\mathrm{P\_SC\_W} = (1.336 + 0.286x)\mathrm{F\_S\_P4\_G\_HR} + (20 - 7.63x)$$

where x is the RPM offset (Section 6.1.2.10) and $\mathrm{F\_S\_P4\_G\_HR}$ is the SOXE inlet mass flow rate derived using P4 in g/hr (Section 6.1.3.2).

6.1.3.45 E_TOT_W_HR

$\mathrm{E\_TOT\_W\_HR}$ is the cumulative energy consumption in Wh:

$$\mathrm{E\_TOT\_W\_HR}(T = t) = \frac{\sum_{i=0}^{t} \mathrm{P\_TOT\_W}(T = i)}{3600}$$

where $\mathrm{P\_TOT\_W}$ is the instantaneous total power in W (Section 6.1.3.41).

6.2 Label file

The derived data product label file contains no additional metadata above and beyond the metadata common to raw, calibrated and derived data products described in Section 3.2.

7 Standards used

This section describes the standards used in the generation of the data products.

7.1 File naming standard

The file naming standard has been chosen for uniqueness and to provide metadata.

File names must be unique unto themselves, without including the file system's directory path. This protects against overwriting files as they are copied or moved within the file system and external to the file system.

File names are comprised of metadata fields that make file bookkeeping and sorting intuitive to the human user. Even though autonomous file processing will be managed via databases, there will always be human-in-the-loop that puts a premium on filename intuition. Secondly, metadata fields are appropriately selected based on their value to ground processing tools, as it is less CPU-intensive to extract information from the filename than from the label. Note that some metadata in the filename is also in the data product label.

The metadata fields have been selected based on lessons learned from previous missions. In general, the metadata fields are arranged to achieve readability. An effort is made to alternate integer fields with ASCII character fields to optimize differentiation of field boundaries for the human user.

Each data product can be uniquely identified by incorporating the following metadata fields in the filename: instrument ID, SCLK or coordinated universal time (UTC), product type identifier, and version number.

The data product file naming standard is shown in Figure 7-1.

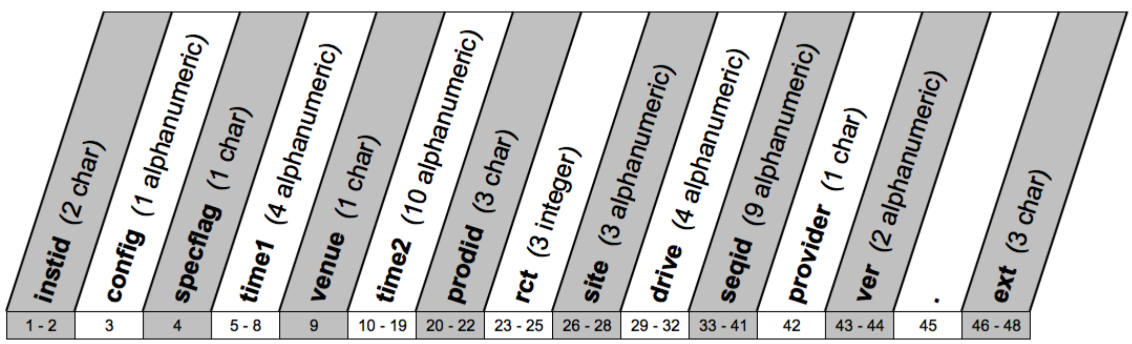

Figure 7-1: Data product file naming standard

Each metadata field is described below:

instid

Instrument ID (two characters). The Mars 2020 science or engineering payload instrument that acquired the data. The first character is the primary instrument identifier. The second character is the instrument state, or if no state, simply the secondary instrument identifier. For MOXIE data products, this metadata field is always "OX".

config

Instrument configuration (one alphanumeric character). An operational attribute of the instrument that assists in characterizing the data. For MOXIE data products, this metadata field is not specified, therefore an underscore ("_") is used.

specflag

Special processing flag (one character). This metadata field is not applicable to MOXIE data products, therefore an underscore ("_") is used.

time1

Primary timestamp (four alphanumeric characters). The four-integer sol (Mars solar day) of the first (i.e., lowest clock time) acquired instrument data.

venue

Venue type (one character). The data processing context or activity. For MOXIE data products from the Flight Model (FM) on Mars, an underscore is used "_".

time2

Secondary timestamp (ten alphanumeric characters). The ten-integer SCLK (seconds). Which specific SCLK count (start or end) is used depends on the instrument, but nominally it is the starting count of the first (i.e., lowest clock time) acquired instrument data.

prodid

Product type identifier (three characters). For MOXIE data products, this metadata field is "EDR"; for calibrated data products, "RDR"; and for derived data products, "DDR".

rct

Run Control Table (three numbers). For MOXIE data products, the unique RCT identifier used to generate the data product.

site

Site location count (three alphanumeric characters). Site location count from the Rover Motion Counter (RMC) for the frame wherein the data was collected. The valid site location counts, in their progression, are shown in Table 7-1 (non-hex).

Table 7-1: Site location count values and corresponding site ranges

Values	Site range
"000", "001", …, "999"	000 thru 999
"A00", "A01", …, "A99"	1000 thru 1099
"B00", "B01", …, "B99"	1100 thru 1199
⋮	
"Z00", "Z01", …, "Z99"	3500 thru 3599
"AA0", "AA1", …, "AA9"	3600 thru 3609

Values	Site range
"AB0", "AB1", …, "AB9"	3610 thru 3619
⋮	
"AZ0", "AZ1", …, "AZ9"	3850 thru 3859
"BA0", "BA1", …, "BA9"	3860 thru 3869
"BB0", "BB1", …, "BB9"	3870 thru 3879
⋮	
"ZZ0", "ZZ1", …, "ZZ9"	10350 thru 10359
"AAA", "AAB", …, "AAZ"	10360 thru 10385
"ABA", "ABB", …, "ABZ"	10386 thru 10411
⋮	
"ZZA", "ZZB", …, "ZZZ"	27910 thru 27935
"0AA", "0AB", …, "0AZ"	27936 thru 27961
"0BA", "0BB", …, "0BZ"	27962 thru 27987
⋮	
"7CA", "7CB", …, "7CZ"	32720 thru 32745
"7DA", "7DB", …, "7DV"	32746 thru 32767
"_ _ _" (3 underscores)	Value is out of range

drive

Drive (position-within-site) location count from the RMC, which may be the last drive before stationary data collection. The valid drive values, and their progression, are shown in Table 7-2 (non-hex).

Table 7-2: Drive location count values and corresponding drive ranges

Values	Drive range
"0000", "0001", …, "9999"	0000 thru 9999
"A000", "A001", …, "A999"	10000 thru 10999
⋮	
"Z000", "Z001", …, "Z999"	35000 thru 35999
"AA00", "AA01", …, "AA99"	36000 thru 36099

Values	Drive range
⋮	
“AZ00”, “AZ01”, …, “AZ99”	38500 thru 38599
“BA00”, “BA01”, …, “BA99”	38600 thru 38699
⋮	
“LJ00”, “LJ01”, …, “LJ35”	65500 thru 65535
“_ _ _ _” (4 underscores)	Value is out of range

seqid

Sequence, activity or component identifier from command process (nine alphanumeric characters). If sequence ID, seqid is composed of a four-character subfield and a five-digit numeric subfield representing the six-bit “category” and 14-bit numeric components of the commanded sequence ID, respectively.

provider

Product provider ID (one character). Identifies the institution that generated the data product. For MOXIE raw data products, provider is “J” for IDS at JPL, and for MOXIE calibrated and derived data products, provider is “P” for PI.

ver

Version identifier (two alphanumeric characters). The version number increments by one whenever an otherwise-identical filename would be produced. The valid values, in their progression that excludes “0” altogether, are shown in Table 7-3 (non-hex). Note that not every version need exist, e.g. versions 1, 2 and 4 may exist, but not version 3. In general, the highest-numbered version represents the “best” version of that product. This field increments independently of all fields, including the special processing field.

Table 7-3: Version identifier values and associated version ranges

Values	Version range
“01”, “02”, …, “99”	1 thru 99
“A0”, “A1”, …, “A9”	100 thru 109
“AA”, “AB”, …, “AZ”	110 thru 135
“B0”, “B1”, …, “B9”	136 thru 145
“BA”, “BB”, …, “BZ”	146 thru 171
“C0”, “C1”, …, “C9”	172 thru 181
“CA”, “CB”, …, “CZ”	182 thru 207

ext

Product type extension (two to three characters). For MOXIE data products, this is “CSV” for the CSV data file, and “XML” for the XML label file.

7.2 PDS standards

MOXIE data products, as with all other Mars 2020 data products, are subject to PDS peer review.

Validation of MOXIE data products during production will be performed according to specifications in the Mars 2020 Archive Plan and of the MOXIE science team. The MOXIE science team will validate the science content of the data products, and the PDS Atmospheres Node will validate the products for compliance with PDS standards (PDS Standards Reference, JPL D-7669) and for conformance with the design specified in this SIS.

Validation of the Mars 2020 data products will fall into two primary categories: automated and manual. Automated validation will be performed on every data product produced for the mission. Manual validation will only be performed on a subset.

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

Manual validation of the data will be performed both as spot-checking of data throughout the life of the mission, and comprehensive validation of a subset of the data (for example, a couple of days’ worth of data). A human will view these products. The MOXIE science team will validate the science content of the data products, and the corresponding PDS Atmospheres node will validate the products for compliance with PDS standards and for conformance with the design specified in this SIS.

7.3 Time standards

The MOXIE PDS4 label uses attributes containing time values. Each time value standard is defined according to the attribute description within the standard PDS data dictionaries.

7.4 Coordinate frame standards

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

8 Applicable software

8.1 Applicable utility programs

The MOXIE data products can be viewed by any software capable of viewing ASCII CSV and XML files.

8.2 Applicable PDS software tools

PDS-labeled data can be viewed with PDS4 Viewer, developed by the PDS Small Bodies Node and available for a variety of computer platforms from the PDS web site, http://pds.nasa.gov/tools/tool-registry. There is no charge for PDS4 viewer.

9 References

[1] Hecht, M. H., et al., 2020. Mars Oxygen In-Situ Resource Utilization Experiment. *Space Science Reviews*, submitted.

[2] The Lee Company, 2020. https://www.theleeco.com/engineering/lohm-laws-working-with-gases/how-to-calculate-flow-resistance-for-gases/.

[3] Forget, F., et al., 1999. Improved general circulation models of the Martian atmosphere from the surface to above 80 km. *Journal of Geophysical Research: Planets*, 104, 24155-24175.

[4] Millour, E., et al., 2015. The Mars Climate Database (MCD version 5.2). European Planetary Science Congress, 27 September-2 October, Nantes, France.

[5] Savitsky, A., and Golay, M. J. E., 1964. Smoothing and differentiation of data by simplified least squares procedures. *Analytical Chemistry*, 36, 8, 1627-1639.