Mars Science Laboratory
Software Interface Specification
Alpha Particle X-ray Spectrometer (APXS) Reduced Data Record (RDR) and RDR Archive Volume
Initial Release

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SIGNATURES

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CHANGE LOG

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TBD ITEMS

SECTION	DESCRIPTION

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ACRONYMS AND ABBREVIATIONS

APXS	Alpha Particle X-ray Spectrometer
ASCII	American Standard Code for Information Interchange
CODMAC	Committee on Data Management and Computation
CSV	Comma-Separated Value
EDR	Experiment Data Record
HTML	Hypertext Markup Language
JPL	Jet Propulsion Laboratory
MSL	Mars Science Laboratory
NSSDC	National Space Science Data Center
PDS	Planetary Data System
RDR	Reduced Data Record
RSP	RDR Summed X-ray Spectrum Product
RWP	RDR Elemental Oxide Abundance (Weight Percent) Product
SIS	Software Interface Specification
TBD	To Be Determined
URL	Universal Resource Locator

1. INTRODUCTION

1.1. Purpose and Scope

The propose of this data product and archive volume Software Interface Specification (SIS) is to provide users of the Alpha Particle X-ray Spectrometer (APXS) Reduced Data Record (RDR) data products with a detailed description of the two reduced product types. The first type of RDR product contains the sum of the sub X-ray spectra as a function of energy. The second type contains extracted oxide weight percents for a set of standard element oxides with statistical uncertainties. Both APXS reduced data product types are stored as ASCII text and have associated PDS labels.

This SIS is intended to provide enough information to enable users to read and use these reduced APXS products. The format of both product types are described in this document, along with the Planetary Data System (PDS) standards used to generate the PDS label. This document also describes the content and format of the archive volume where the APXS RDR data products will be archived. Example PDS labels are listed in Appendix A and example data products are given in Appendix B.

1.2. Applicable Documents

This data product and archive volume SIS is responsive to the following MSL documents:

1. Mars Exploration Program Data Management Plan, R. E. Arvidson, S. Slavney and S. Nelson, Rev. 3, March 20, 2002.
2. Mars Science Laboratory Archive Generation, Validation and Transfer Plan, J. Crisp, JPL D-35281, May 28, 2010.
3. MSL Alpha Particle X-ray Spectrometer (APXS) Experiment Data Record (EDR) Software Interface Specification, JPL D-69261, April 11, 2012.

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

4. Planetary Data System Archive Preparation Guide, Version 1.4, JPL D-31224, April 1, 2010.
5. Planetary Data System Standards Reference, Version 3.8, JPL D-7669, Part 2, February 27, 2009.
6. Planetary Science Data Dictionary Document, Version 1.87, July 2, 2012.

Finally, these publications have information about calibration of APXS data.

7. Alpha Particle X-Ray Spectrometer (APXS): Results from Gusev crater and calibration report, R. Gellert et al., J. Geophys. Res., 111, E02S05, doi:10.1029/2005JE002555, 2006.
8. Calibration of the Mars Science Laboratory Alpha Particle X-ray Spectrometer, J. L. Campbell et al., Space Sci. Rev., doi:10.1007/s11214-012-9873-5, 2012.

1.3. Relationships with Other Interfaces

The MSL APXS reduced products are generated from APXS EDR products by the APXS team with their own software tools. Changes to the EDR product format or content may affect the methods used by the APXS team to generate the reduced products. If the APXS team changes the content or structure of either of the reduced data product types, then this SIS and the PDS label will need to be revised.

2. DATA PRODUCT CHARACTERISTICS

2.1. Data Product Overview

There are two APXS RDR data products. The first is the summed X-ray spectrum in counts as a function of energy product, which is derived from the APXS EDR. The second is the standard elemental oxide abundance product, which is derived from the summed X-ray spectrum. Both products are stored as ASCII text in a Comma Separated Value (CSV) format. Each CSV file has an associated detached PDS label, also stored as ASCII.

2.2. Data Processing Level

PDS uses a data processing level based on the Committee On Data Management And Computation (CODMAC) numbering scheme to categorize the level of data reduction and processing for a data set. The APXS summed X-ray spectrum data product is considered to be CODMAC "Level 4" [Calibration and Resampled Data]. The elemental oxide abundance data product is considered to be CODMAC "Level 5" [Derived Data]. These data processing level values will appear the data set name and ID for this archive. See the PDS Standards Reference [Applicable Document 5] for a complete set of the CODMAC data processing levels.

2.3. File Naming Convention

File name formation rules for MSL APXS reduced data products follow a similar pattern to the APXS EDR products (see Applicable Document 3 section on Labeling and Identification for details of the MSL EDR file naming scheme) with a few changes. The naming convention is:

<instr><config><sclk><product><sol><site><drive>_<producer><version>.<ext>

where

instr	= 2 characters, AP for APXS
config	= 1 character, instrument configuration A or B
sclk	= 9 characters, spacecraft clock count at start of observation
product	= 3 characters, RSP for RDR spectrum, RWP for RDR weight percent
sol	= 4 characters, sol number (Martian day, where sol 0 is landing day)
site	= 3 characters, site number
drive	= 4 characters, drive position within site
producer	= 1 character, M for MIPL, P for Principal Investigator, A-L for Co-Investigators

version	= 1 character, version identifier starting at 1
ext	= 3 characters, CSV for comma-separated-value table, LBL for PDS label

Example file names for the APXS reduced data products are:

APA_400078349RSP00290040000_P1.CSV for the summed X-ray spectrum product,
APA_400078349RWP00290040000_P1.CSV for the elemental oxide abundance product.

Differences from the EDR product file name include the following. The product type field is changed from EDR to either RSP or RWP for the summed X-ray spectrum product and the elemental oxide abundance product, respectively. The multiple, contiguous underscore characters in the EDR file name have been collapsed to a single underscore. The producer field is changed to P for Principal Investigator. The file extension is CSV for the comma separated value format.

File names for the APXS RDR data products adhere to the PDS standard for file name length with a maximum of 36 characters for the name, followed by a dot and a 3 character extension.

2.4. Data Storage Conventions

The MSL APXS RDR data products and detached PDS labels are stored as ASCII text. Each line in these files is terminated with a two-character sequence of carriage return (<CR>, ASCII 13) and line feed (<LF>, ASCII 10) to comply with PDS standards [Applicable Document 5].

3. DETAILED DATA PRODUCT SPECIFICATION

3.1. PDS Label Description

Each MSL APXS RDR data product is accompanied by a detached PDS label, which is stored as ASCII text. The PDS label consists of lines of ASCII text in the form of "keyword = value" statements that provide descriptive information about the data file. The label is intended to be readable both by humans and by software. Details of the syntax and semantics of PDS labels can be found in the PDS Standards Reference [Applicable Document 5].

The structure of the RDR label largely parallels the label for the EDR product. Major differences between the EDR and RDR labels include the object definitions that describe the format and content of the data product structure. Some metadata keyword values are updated to be appropriate for the RDR product. Examples of updated keyword values include DATA_SET_ID, PRODUCT_ID, PRODUCT_CREATION_TIME, PRODUCER_FULL_NAME, etc. Refer to either the APXS EDR SIS [Applicable Document 3] or the PDS data dictionary [Applicable Document 6] for keyword definitions.

Appendix A lists an example PDS label for each of the two types of MSL APXS RDR products.

3.2. Data Format Description

Each APXS RDR data product is an ASCII text file in a comma separate value (CSV) format. Fields within a record are separated by commas. Fields can have variable length, which means

that the records can also have variable length. Any field that contains a comma must be enclosed in double quotes. Some non-numeric fields may also be enclosed in double quotes. The quotes are considered part of the field.

The summed X-ray spectrum (RSP) product is generated from the APXS EDR product by converting channel number to energy and summing together all buffers acquired at good temperatures. The RSP product consists of two fields, the first of which contains an energy value in eV and the second contains total counts for that energy channel. The count field value for first record is the counting time in seconds. The value for the last record is the overflow, that is, counts observed at that energy and higher. There is a header record at the start of the file that gives field headings for the two fields.

The elemental oxide abundance (RWP) product is derived from the summed X-ray spectrum (RSP) product. It contains abundance data for a set of standard oxides and elements. There are three fields in the product: the oxide or element name, the weight percent, and the standard error of the weight percent value. There are two header records in the file. The first header record provides a description of the target sample and the second header record gives the field headings.

Details on the methods used to generate the two RDR data products are given in Gellert et al.and Campbell et al. [Applicable Documents 7 and 8].

Appendix B lists an example data product for each of the two types of MSL APXS RDR products.

4. ARCHIVE VOLUME

The MSL APXS RDR products are archived on a single PDS volume at the PDS Geosciences Node. This section describes the contents of the archive volume, including directory names, directory contents, and file types.

4.1. Root Directory Contents

Files in the Root Directory of the volume include an overview of the archive, a description of the volume for the PDS Catalog, and a list of errata or comments about the archive. The following files are contained in the Root Directory.

File Name	File Contents
AAREADME.TXT	Volume introduction
ERRATA.TXT	Cumulative listing of comments and updates concerning for this volume
VOLDESC.CAT	Description of the contents of this volume for the PDS catalog

4.2. Data Directory Contents and Naming

The APXS data products are organized in subdirectories under the Data Directory. Each subdirectory contains derived data products and PDS labels for a given sol (Mars day) of the mission corresponding to the sol on which the raw data were acquired. The formation rule for subdirectory names is 'solxxxx' where xxxx is a sol number with leading zeros if needed. For example data acquired on sol 36 are stored in a directory named sol0036.

4.3. Index Directory Contents

Files in the Index Directory are provided to help the user locate products on this volume. The following files are contained in the Index Directory.

File Name	File Contents
INDXINFO.TXT	Description of the contents of this directory
INDEX.TAB	Table listing all data products on this volume
INDEX.LBL	PDS detached label that describes INDEX.TAB

The index table contains one row for each product on the archive volume.

4.4. Document Directory Contents

The Document Directory contains documentation to help the user understand and use the archive data. The following files are contained in the Document Directory.

File Name	File Contents
DOCINFO.TXT	Description of the contents of this directory
APXS_RDR_SIS.HTM	Data Product SIS as HTML
APXS_RDR_SIS.PDF	Data Product SIS as a PDF file
APXS_RDR_SIS.LBL	PDS detached label that describes both APXS_RDR_SIS.HTM and APXS_RDR_SIS.PDF
MSL_LDD.FUL, .LBL	MSL Local Data Dictionary and label
PDSDD.FUL, .LBL	PDS Data Dictionary and label

4.5. Catalog Directory Contents

The files in the Catalog Directory provide brief descriptions of the MSL mission, spacecraft, the APXS instrument, and the RDR data set for the PDS catalog. The files in this directory are coordinated with the PDS data engineer, who is responsible for loading them into the PDS catalog. The following files are found in the Catalog Directory.

File Name	File Contents
CATINFO.TXT	Description of the contents of this directory
APXS_INST.CAT	Description of the APXS instrument
APXS_PERSON.CAT	Contact information for Team and PDS personnel responsible for generating the archive
APXS_RDR_DS.CAT	Description of the RDR data set
APXS_REF.CAT	References mentioned in APXS*.CAT files
MSL_INSTHOST.CAT	Description of the MSL rover
MSL_MISSION.CAT	Description of the MSL mission
MSL_REF.CAT	References mentioned in MSL*.CAT files

4.6. Calib Directory Contents

The Calib Directory contains calibration files used to develop the calibration and reduction procedures for generating the APXS RDR data products. The calibration principle is to provide the APXS spectra for well characterized materials. All Spectra (RSP) taken with the flight instrument (PFM) before delivery in 2008 are published. These spectra were taken with EM sources for standard geological reference materials. One sample is the actual basaltic calibration target that is on board of the Curiosity rover and ultimately measured on Mars with the flight sources. Terrestrial analyses of these materials are given in the oxide weight percents (RWP). See Gellert et al. and Campbell et al. [Applicable Documents 7 and 8] for details of APXS calibration.

File Name	File Contents
CALINFO.TXT	Description of the contents of this directory
APXS*_CONCENTRATIONS*.CSV, .LBL	Oxide concentration data and PDS labels
APXS*_SPECTRUM*.CSV, .LBL	APXS calibration spectra and PDS labels

5. ARCHIVE VOLUME FILE FORMATS

This section describes file formats for the non-data files contained on the Archive Volume.

5.1. Text File Format

Files with the .TXT extension exist in several directories. Text files are ASCII files which may have attached or detached PDS labels. Lines in a text file have a variable length of characters and are terminated with a carriage return character (ASCII 13) and a line feed character (ASCII 10).

Some files in the Document directory may contain hypertext formatting (HTML) and figures that cannot be rendered as ASCII text. The hypertext file contains ASCII text plus hypertext markup language (HTML) commands that enable it to be viewed in a Web browser. The hypertext file may be accompanied by ancillary files such as images and style sheets that are incorporated into the document by the Web browser.

5.2. Tabular File Format

Tabular files (.TAB suffix) exist in the Index directory. Tabular files are ASCII files with fixed width records. All fields are separated by commas, and character fields are enclosed in double quotation marks ("). Character fields are padded with spaces to keep quotation marks in the same columns of successive records. Character fields are left justified, and numeric fields are right justified. The "start byte" and "bytes" values listed in the PDS label do not include the commas between fields or the quotation marks surrounding character fields. The last two bytes of each record contain the ASCII carriage return and line feed characters.

All tabular files are described by PDS labels, either embedded at the beginning of the file or detached. If detached, the PDS label file has the same name as the data file it describes, with the extension .LBL; for example, the file INDEX.TAB is accompanied by the detached label file INDEX.LBL in the same directory.

5.3. PDS Label Format

All data files in the archive have PDS labels, either embedded at the beginning of the file or detached in a separate file. A PDS label, whether embedded or detached from its associated file, consists of lines of ASCII text in the form of keyword = value statements that provide descriptive information about the file being described. Label records in detached labels end with a carriage return character (ASCII 13) and a line feed character (ASCII 10). It is recommended in the PDS standards that label records have lengths of less than or equal to 80 characters.

5.4. Catalog File Format

Catalog files (suffix .CAT) exist in the Root and Catalog directories. Like PDS labels, they are text files formatted as keyword = value statements. They contain descriptions of the data set, instrument, spacecraft, and mission, as well as personnel contact information and references to published literature. They are called Catalog Files because they are loaded into the PDS online catalog to make the information available to users searching for data.

6. ARCHIVE VOLUME GENERATION

6.1. Data Transfer and Volume Size

MSL APXS RDR data products are delivered to the PDS from the instrument team every 90 sols based on the schedule in the MSL archive plan [Applicable Document 2].

The number of products to be created during the mission is unknown due to the exploratory nature for science operations on the MSL mission. APXS measurements will be made when the MSL science team finds targets of interest. It is likely that several hundred measurements could be made by the APXS during the MSL primary mission.

6.2. Archive Volume Storage

APXS RDR data products are archived at the PDS Geosciences Node on a single archive volume. As new data products are delivered, they are added to the existing archive volume.

The MSL APXS RDR archive volume is stored on the Geosciences Node online repository and is accessible through the Node's web site and search services. The online archive is backed up on a regular basis to a secondary server and to tape. Once the archive is complete a copy will be sent to the PDS deep archive at the National Space Sciences Data Center (NSSDC) to a permanent backup copy.

6.3. Archive Volume Labeling and Identification

The data set ID for the APXS RDR archive is MSL-M-APXS-4/5-RDR-V1.0. The volume ID for the APXS RDR volume is MSLAPX_1001.

APPENDIX A – SAMPLE APXS RDR LABELS

A.1 Summed X-ray Spectrum Label

```
PDS_VERSION_ID                  = PDS3

RECORD_TYPE                     = STREAM
FILE_RECORDS                    = 1025

/* Pointers to Data Objects */
^HEADER                         = ("APA_400078349RSP00290040000_P1.CSV",1)
^SPREADSHEET                    = ("APA_400078349RSP00290040000_P1.CSV",2)

/* Identification Data Elements */
DATA_SET_ID                     = "MSL-M-APXS-4/5-RDR-V1.0"
PRODUCT_ID                      = "APA_400078349RSP00290040000_P1"
PRODUCT_VERSION_ID              = "V1.0"
PRODUCT_TYPE                    = APXS_RSP
PRODUCT_CREATION_TIME           = 2012-09-05T02:30:30.000
RELEASE_ID                      = "0001"
SOURCE_PRODUCT_ID               = "APA_400078349ESC00290040000_______M1"
PRODUCER_FULL_NAME              = "RALF GELLERT"
PRODUCER_INSTITUTION_NAME       = "UNIVERSITY OF GUELPH"

MISSION_NAME                    = "MARS SCIENCE LABORATORY"
MISSION_PHASE_NAME              = "PRIMARY SURFACE MISSION"
INSTRUMENT_HOST_NAME            = "MARS SCIENCE LABORATORY"
INSTRUMENT_HOST_ID              = MSL
INSTRUMENT_NAME                 = "ALPHA PARTICLE X-RAY SPECTROMETER"
INSTRUMENT_ID                   = APXS
INSTRUMENT_TYPE                 = SPECTROMETER

PLANET_DAY_NUMBER               = 29
MSL:LOCAL_MEAN_SOLAR_TIME_SOL   = "Sol-00029M15:31:26:021"
LOCAL_TRUE_SOLAR_TIME           = "16:08:46"
OBSERVATION_ID                  = UNK
COMMAND_SEQUENCE_NUMBER         = 7
MSL:REQUEST_ID                  = "0"
ROVER_MOTION_COUNTER            = (4,0,0,0,0,0,58,0,0,0)
ROVER_MOTION_COUNTER_NAME       = (SITE, DRIVE, POSE, ARM, CHIMRA, DRILL,
  RSM, HGA, DRT, IC)
SEQUENCE_ID                     = "apxs08145"
SEQUENCE_VERSION_ID             = "0"
MSL:ACTIVE_FLIGHT_STRING_ID     = A
SOLAR_LONGITUDE                 = 166.404
SPACECRAFT_CLOCK_CNT_PARTITION  = 1
SPACECRAFT_CLOCK_START_COUNT    = "0400077579.022"
SPACECRAFT_CLOCK_STOP_COUNT     = "0400078349.044"
START_TIME                      = 2012-09-05T00:42:14.180
STOP_TIME                       = 2012-249T02:30:10.535
TARGET_NAME                     = MARS
TARGET_TYPE                     = PLANET
EARTH_RECEIVED_START_TIME       = 2012-09-05T02:30:10.535

/* COORDINATE SYSTEM STATE: ROVER AT THE START */

GROUP                           = START_ROVER_COORDINATE_SYSTEM_PARMS
  COORDINATE_SYSTEM_NAME        = ROVER_FRAME
  COORDINATE_SYSTEM_INDEX       = (4,0,0,0,0,0,58,0,0,0)
  COORDINATE_SYSTEM_INDEX_NAME  = (SITE, DRIVE, POSE, ARM, CHIMRA, DRILL,
```

```
    RSM, HGA, DRT, IC)
  ORIGIN_OFFSET_VECTOR            = (0,0,0)
  ORIGIN_ROTATION_QUATERNION      = (0.0120958,0.0306292,-0.866243,0.498537)
  POSITIVE_AZIMUTH_DIRECTION      = CLOCKWISE
  POSITIVE_ELEVATION_DIRECTION    = UP
  REFERENCE_COORD_SYSTEM_NAME     = SITE_FRAME
  REFERENCE_COORD_SYSTEM_INDEX    = 4
END_GROUP                         = START_ROVER_COORDINATE_SYSTEM_PARMS

/* ARTICULATION DEVICE STATE: ROBOTIC ARM AT THE START */

GROUP                             = START_ARM_ARTICULATION_STATE_PARMS
  ARTICULATION_DEVICE_ID          = ARM
  ARTICULATION_DEVICE_NAME        = ROBOTIC_ARM
  ARTICULATION_DEVICE_ANGLE       = (1.57222<rad>, -0.277767<rad>,
    -2.81629<rad>, 3.12111<rad>, 0.593795<rad>)
  ARTICULATION_DEVICE_ANGLE_NAME  = ("JOINT 1 SHOULDER AZIMUTH", "JOINT 2
    SHOULDER ELEVATION", "JOINT 3 ELBOW-ENCODER", "JOINT 4 WRIST-ENCODER",
    "JOINT 5 TURRET-ENCODER")
END_GROUP                         = START_ARM_ARTICULATION_STATE_PARMS

/* COORDINATE SYSTEM STATE: ROVER AT THE END */

GROUP                             = ROVER_COORDINATE_SYSTEM_PARMS
  COORDINATE_SYSTEM_NAME          = ROVER_FRAME
  COORDINATE_SYSTEM_INDEX         = (4,0,0,0,0,0,58,0,0,0)
  COORDINATE_SYSTEM_INDEX_NAME    = (SITE, DRIVE, POSE, ARM, CHIMRA, DRILL,
    RSM, HGA, DRT, IC)
  ORIGIN_OFFSET_VECTOR            = (0,0,0)
  ORIGIN_ROTATION_QUATERNION      = (0.0120958,0.0306292,-0.866243,0.498537)
  POSITIVE_AZIMUTH_DIRECTION      = CLOCKWISE
  POSITIVE_ELEVATION_DIRECTION    = UP
  REFERENCE_COORD_SYSTEM_NAME     = SITE_FRAME
  REFERENCE_COORD_SYSTEM_INDEX    = 4
END_GROUP                         = ROVER_COORDINATE_SYSTEM_PARMS

/* ARTICULATION DEVICE STATE: ROBOTIC ARM AT THE END (DP CREATION) */

GROUP                             = ARM_ARTICULATION_STATE_PARMS
  ARTICULATION_DEVICE_ID          = ARM
  ARTICULATION_DEVICE_NAME        = ROBOTIC_ARM
  ARTICULATION_DEVICE_ANGLE       = (1.57222<rad>, -0.277767<rad>,
    -2.81629<rad>, 3.12111<rad>, 0.593795<rad>)
  ARTICULATION_DEVICE_ANGLE_NAME  = ("JOINT 1 SHOULDER AZIMUTH", "JOINT 2
    SHOULDER ELEVATION", "JOINT 3 ELBOW-ENCODER", "JOINT 4 WRIST-ENCODER",
    "JOINT 5 TURRET-ENCODER")
  CONTACT_SENSOR_STATE            = OPEN
  CONTACT_SENSOR_STATE_NAME       = "APXS SWITCH"
END_GROUP                         = ARM_ARTICULATION_STATE_PARMS

/* Data Object Definitions */

OBJECT                            = HEADER
  BYTES                           = UNK
  RECORDS                         = 1
  HEADER_TYPE                     = "SPREADSHEET"
  DESCRIPTION                     = "The first line in the file contains
    column headings."
END_OBJECT                        = HEADER

OBJECT                            = SPREADSHEET
  FIELDS                          = 2
```

```
  FIELD_DELIMITER                 = COMMA
  ROW_BYTES                       = 30              /* maximum length */
  ROWS                            = 1024

  OBJECT                          = FIELD
    FIELD_NUMBER                  = 1
    NAME                          = "X-RAY ENERGY"
    BYTES                         = 10              /* maximum length */
    DATA_TYPE                     = ASCII_INTEGER
    DESCRIPTION                   = "Each record in the file represents an
      X-ray channel. The X-RAY ENERGY field gives the energy in eV for that
      channel."
  END_OBJECT                      = FIELD

  OBJECT                          = FIELD
    FIELD_NUMBER                  = 2
    NAME                          = "COUNTS"
    BYTES                         = 10              /* maximum length */
    DATA_TYPE                     = ASCII_INTEGER
    DESCRIPTION                   = "Each record in the file represents an
      X-ray channel. The COUNTS field gives the counts for that channel,
      with two exceptions. The value for the first channel is total counting
      time in seconds. The value for the last channel is the overflow, the
      counts observed at that energy and higher."
  END_OBJECT                      = FIELD
END_OBJECT                        = SPREADSHEET

END
```

A.2 Elemental Oxide Abundance Label

```
PDS_VERSION_ID                    = PDS3

RECORD_TYPE                       = STREAM

FILE_RECORDS                      = 18

/* Pointers to Data Objects */
^HEADER                           = ("APA_400078349RWP00290040000_P1.CSV",1)
^SPREADSHEET                      = ("APA_400078349RWP00290040000_P1.CSV",3)

/* Identification Data Elements */
DATA_SET_ID                       = "MSL-M-APXS-4/5-RDR-V1.0"
PRODUCT_ID                        = "APA_400078349RWP00290040000_P1"
PRODUCT_VERSION_ID                = "V1.0"
PRODUCT_TYPE                      = APXS_RWP
PRODUCT_CREATION_TIME             = 2012-09-05T02:30:30.000
RELEASE_ID                        = "0001"
SOURCE_PRODUCT_ID                 = "APA_400078349ESC00290040000_______M1"
PRODUCER_FULL_NAME                = "RALF GELLERT"
PRODUCER_INSTITUTION_NAME         = "UNIVERSITY OF GUELPH"

MISSION_NAME                      = "MARS SCIENCE LABORATORY"
MISSION_PHASE_NAME                = "PRIMARY SURFACE MISSION"
INSTRUMENT_HOST_NAME              = "MARS SCIENCE LABORATORY"
INSTRUMENT_HOST_ID                = MSL
INSTRUMENT_NAME                   = "ALPHA PARTICLE X-RAY SPECTROMETER"
INSTRUMENT_ID                     = APXS
```

```
INSTRUMENT_TYPE                   = SPECTROMETER

PLANET_DAY_NUMBER                 = 29
MSL:LOCAL_MEAN_SOLAR_TIME_SOL     = "Sol-00029M15:31:26:021"
LOCAL_TRUE_SOLAR_TIME             = "16:08:46"
OBSERVATION_ID                    = UNK
COMMAND_SEQUENCE_NUMBER           = 7
MSL:REQUEST_ID                    = "0"
ROVER_MOTION_COUNTER              = (4,0,0,0,0,0,58,0,0,0)
ROVER_MOTION_COUNTER_NAME         = (SITE, DRIVE, POSE, ARM, CHIMRA, DRILL,
  RSM, HGA, DRT, IC)
SEQUENCE_ID                       = "apxs08145"
SEQUENCE_VERSION_ID               = "0"
MSL:ACTIVE_FLIGHT_STRING_ID       = A
SOLAR_LONGITUDE                   = 166.404
SPACECRAFT_CLOCK_CNT_PARTITION    = 1
SPACECRAFT_CLOCK_START_COUNT      = "0400077579.022"
SPACECRAFT_CLOCK_STOP_COUNT       = "0400078349.044"
START_TIME                        = 2012-09-05T00:42:14.180
STOP_TIME                         = 2012-249T02:30:10.535
TARGET_NAME                       = MARS
TARGET_TYPE                       = PLANET
EARTH_RECEIVED_START_TIME         = 2012-09-05T02:30:10.535
MSL:SAMPLE_NAME                   = "BEN standard"

/* COORDINATE SYSTEM STATE: ROVER AT THE START */

GROUP                             = START_ROVER_COORDINATE_SYSTEM_PARMS
  COORDINATE_SYSTEM_NAME          = ROVER_FRAME
  COORDINATE_SYSTEM_INDEX         = (4,0,0,0,0,0,58,0,0,0)
  COORDINATE_SYSTEM_INDEX_NAME    = (SITE, DRIVE, POSE, ARM, CHIMRA, DRILL,
    RSM, HGA, DRT, IC)
  ORIGIN_OFFSET_VECTOR            = (0,0,0)
  ORIGIN_ROTATION_QUATERNION      = (0.0120958,0.0306292,-0.866243,0.498537)
  POSITIVE_AZIMUTH_DIRECTION      = CLOCKWISE
  POSITIVE_ELEVATION_DIRECTION    = UP
  REFERENCE_COORD_SYSTEM_NAME     = SITE_FRAME
  REFERENCE_COORD_SYSTEM_INDEX    = 4
END_GROUP                         = START_ROVER_COORDINATE_SYSTEM_PARMS

/* ARTICULATION DEVICE STATE: ROBOTIC ARM AT THE START */

GROUP                             = START_ARM_ARTICULATION_STATE_PARMS
  ARTICULATION_DEVICE_ID          = ARM
  ARTICULATION_DEVICE_NAME        = ROBOTIC_ARM
  ARTICULATION_DEVICE_ANGLE       = (1.57222<rad>, -0.277767<rad>,
    -2.81629<rad>, 3.12111<rad>, 0.593795<rad>)
  ARTICULATION_DEVICE_ANGLE_NAME  = ("JOINT 1 SHOULDER AZIMUTH", "JOINT 2
    SHOULDER ELEVATION", "JOINT 3 ELBOW-ENCODER", "JOINT 4 WRIST-ENCODER",
    "JOINT 5 TURRET-ENCODER")
END_GROUP                         = START_ARM_ARTICULATION_STATE_PARMS

/* COORDINATE SYSTEM STATE: ROVER AT THE END */
```

```
GROUP                           = ROVER_COORDINATE_SYSTEM_PARMS
  COORDINATE_SYSTEM_NAME        = ROVER_FRAME
  COORDINATE_SYSTEM_INDEX       = (4,0,0,0,0,0,58,0,0,0)
  COORDINATE_SYSTEM_INDEX_NAME  = (SITE, DRIVE, POSE, ARM, CHIMRA, DRILL,
    RSM, HGA, DRT, IC)
  ORIGIN_OFFSET_VECTOR          = (0,0,0)
  ORIGIN_ROTATION_QUATERNION    = (0.0120958,0.0306292,-0.866243,0.498537)
  POSITIVE_AZIMUTH_DIRECTION    = CLOCKWISE
  POSITIVE_ELEVATION_DIRECTION  = UP
  REFERENCE_COORD_SYSTEM_NAME   = SITE_FRAME
  REFERENCE_COORD_SYSTEM_INDEX  = 4
END_GROUP                       = ROVER_COORDINATE_SYSTEM_PARMS

/* ARTICULATION DEVICE STATE: ROBOTIC ARM AT THE END (DP CREATION) */

GROUP                           = ARM_ARTICULATION_STATE_PARMS
  ARTICULATION_DEVICE_ID        = ARM
  ARTICULATION_DEVICE_NAME      = ROBOTIC_ARM
  ARTICULATION_DEVICE_ANGLE     = (1.57222<rad>, -0.277767<rad>,
    -2.81629<rad>, 3.12111<rad>, 0.593795<rad>)
  ARTICULATION_DEVICE_ANGLE_NAME  = ("JOINT 1 SHOULDER AZIMUTH", "JOINT 2
    SHOULDER ELEVATION", "JOINT 3 ELBOW-ENCODER", "JOINT 4 WRIST-ENCODER",
    "JOINT 5 TURRET-ENCODER")
  CONTACT_SENSOR_STATE          = OPEN
  CONTACT_SENSOR_STATE_NAME     = "APXS SWITCH"
END_GROUP                       = ARM_ARTICULATION_STATE_PARMS

/* Data Object Definitions */

OBJECT                          = HEADER
  BYTES                         = UNK
  RECORDS                       = 2
  HEADER_TYPE                   = "SPREADSHEET"
  DESCRIPTION                   = "The first line in the file gives the
    target name and a brief description. The second line gives the column
    headings."
END_OBJECT                      = HEADER

OBJECT                          = SPREADSHEET
  FIELDS                        = 3
  FIELD_DELIMITER               = COMMA
  ROW_BYTES                     = 70          /* maximum length */
  ROWS                          = 16

  OBJECT                        = FIELD
    FIELD_NUMBER                = 1
    NAME                        = "OXIDE"
    BYTES                       = 20          /* maximum length */
    DATA_TYPE                   = CHARACTER
    DESCRIPTION                 = "The OXIDE field gives the name of a
      standard element oxide."
  END_OBJECT                    = FIELD

  OBJECT                        = FIELD
```

```
    FIELD_NUMBER                = 2
    NAME                        = "WEIGHT PERCENT"
    BYTES                       = 20           /* maximum length */
    DATA_TYPE                   = ASCII_REAL
    DESCRIPTION                 = "The WEIGHT PERCENT field gives the
      computed weight percent of the oxide."
  END_OBJECT                    = FIELD

  OBJECT                        = FIELD
    FIELD_NUMBER                = 3
    NAME                        = "STANDARD ERROR"
    BYTES                       = 20           /* maximum length */
    DATA_TYPE                   = ASCII_REAL
    DESCRIPTION                 = "The STANDARD ERROR field gives the
      standard error from the weight percent calculation."
  END_OBJECT                    = FIELD

END_OBJECT                      = SPREADSHEET

END
```

APPENDIX B – SAMPLE APXS RDR DATA PRODUCTS

B.1 Summed X-ray Spectrum Product

```
"x-ray energy eV", "counts , first channel is counting time in seconds"
377,10801
404,0
431,0
458,0
485,0
512,0
539,0
565,0
592,2761
619,3352
646,3614
673,3759
700,3712
727,3756
754,3770
781,3693
808,3765
835,3816
862,4118
888,4699
915,5912
1131,18863
1158,27251
...
27862,39
27889,52
27916,122276
```

B.2 Elemental Oxide Abundance Product

```
"BEN standard, measured with APXS PFM and FEU source at ~0C in standard distance"
"oxide" ,  "weight percent" , "std error"
Na2O    ,  3.1810  ,     0.0423
MgO     , 13.1472  ,     0.0570
Al2O3   , 10.0731  ,     0.0526
SiO2    , 38.2945  ,     0.1093
P2O5    ,  1.0540  ,     0.0100
SO3     ,  0.0749  ,     0.0046
  Cl    ,  0.0200  ,     0.0044
K2O     ,  1.3853  ,     0.0132
CaO     , 13.8662  ,     0.0480
TiO2    ,  2.6022  ,     0.0159
Cr2O3   ,  0.0     ,     0.0000
MnO     ,  0.1937  ,     0.0039
Fe2O3T  , 11.5528  ,     0.0249
Ni     ,  0.0340  ,     0.0009
  Zn    ,  0.0120  ,     0.0005
  Br    ,  0.0000  ,     0.0002
```

B.3 Transformation Elemental to Oxide Abundance

Factors used to transform elemental abundance into oxide abundance. The element weight percent is divided by each given factor to get abundance for the given oxide.

Na2O	0.74191
MgO	0.60317
Al2O3	0.52913
SiO2	0.46743
P2O5	0.43642
SO3	0.40049
K2O	0.83016
CaO	0.71469
TiO2	0.59950
Cr2O3	0.68419
MnO	0.77446
Fe2O3	0.69944
FeO	0.77732