2008 Lunar Reconnaissance Orbiter

LUNAR EXPLORATION NEUTRON DETECTOR EDR NASA LEVEL 0 SOFTWARE INTERFACE SPECIFICATION

April 22, 2010

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DOCUMENT CHANGE LOG

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Sections Affected</th>
</tr>
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<tr>
<td>5/1/06</td>
<td>Initial draft</td>
<td>All</td>
</tr>
<tr>
<td>6/25/07</td>
<td>Corrected name of first reference doc</td>
<td>1.3</td>
</tr>
<tr>
<td>6/25/07</td>
<td>Added more information about the instrument</td>
<td>2.1</td>
</tr>
<tr>
<td>6/25/07</td>
<td>Corrected reference of Table 5-1 in DMAP to Appendix 4</td>
<td>2.3.3</td>
</tr>
<tr>
<td>6/25/07</td>
<td>Added section 2.4.4</td>
<td>2.4.4</td>
</tr>
<tr>
<td>6/25/07</td>
<td>Removed wording about messages</td>
<td>3.2</td>
</tr>
<tr>
<td>4/21/08</td>
<td>Reworded section 2.1</td>
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<tr>
<td>5/5/2008</td>
<td>End-to-End validation test revisions</td>
<td>1.1, 1.3, 1.4, 2.3, 2.4, 3.3</td>
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<tr>
<td>7/14/2008</td>
<td>Additional updates from end-to-end testing.</td>
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<tr>
<td>4/22/10</td>
<td>Fixed the definitions of the three SC spectra</td>
<td>Table 1</td>
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TBD ITEMS

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
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ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CODMAC</td>
<td>Committee on Data Management and Computation</td>
</tr>
<tr>
<td>EDR</td>
<td>Experiment Data Record</td>
</tr>
<tr>
<td>IKI</td>
<td>Institute for Space Research</td>
</tr>
<tr>
<td>JPL</td>
<td>Jet Propulsion Laboratory</td>
</tr>
<tr>
<td>LEND</td>
<td>Lunar Exploration Neutron Detector</td>
</tr>
<tr>
<td>LRO</td>
<td>Lunar Reconnaissance Orbiter</td>
</tr>
<tr>
<td>MSB</td>
<td>Most Significant Byte</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>PDS</td>
<td>Planetary Data System</td>
</tr>
<tr>
<td>PI</td>
<td>Principal Investigator</td>
</tr>
<tr>
<td>SIS</td>
<td>Software Interface Specification</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Determined</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

1.1 Purpose and Scope

The purpose of this Data Product SIS is to provide users of the Lunar Exploration Neutron Detector (LEND) Experimental Data Record (EDR) (NASA Level 0) data product with a detailed description of the product and a description of how it was generated, including data sources and destinations. The EDR product contains un-calibrated neutron spectra from the Lunar Reconnaissance Orbiter (LRO) LEND. Ancillary data, which will be used in calibration of higher-level data products, is also included. This SIS is intended to provide enough information to enable users to read and understand the data product. The users for whom this SIS is intended are the scientists who will analyze the data, including those associated with the 2008 Lunar Reconnaissance Orbiter and those in the general planetary science community.

1.2 Contents

This Data Product SIS describes how the EDR data product is acquired by the LEND instrument, and how it is processed, formatted, labeled, and uniquely identified. The document discusses standards used in generating the product and software that may be used to access the product. The data product structure and organization is described in sufficient detail to enable a user to read the product. Finally, an example of a product label is provided.

1.3 Applicable Documents and Constraints

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


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


Finally, this SIS is meant to be consistent with the contract negotiated between the 2008 Lunar Reconnaissance Orbiter and the LEND Principal Investigator (PI) in which reduced data records and documentation are explicitly defined as deliverable products.
1.4 Relationships with Other Interfaces

The LEND EDR/RDR Archive Volume SIS describes how the data products specified by this document will be made available through the PDS.

2. DATA PRODUCT CHARACTERISTICS AND ENVIRONMENT

2.1 Instrument Overview

The Lunar Exploration Neutron Detector, LEND, was designed and built by P.I. Igor Mitrofanov at the Russian Space Institute for incorporation into NASA’s Lunar Reconnaissance Orbiter (LRO) as a large orbital neutron telescope for mapping the Moon’s neutron albedo. LEND is the follow-on instrument from the High Energy Neutron Detector (HEND) onboard Mars Odyssey, although LEND incorporates a set of collimated detectors to improve spatial resolution. The methods and procedures of LEND data processing and analysis are based on existing procedures that have been developed for analysis of HEND data. The following paragraphs will briefly describe the LEND instrument.

LEND has eight $^3$He sensors for detecting thermal and epithermal neutrons. Four of the $^3$He sensors are un-collimated and four are collimated. As seen in Figure 2.1, LEND Instrument Overview, external sensors STN1-3 (Sensor Thermal Neutrons) and SETN (Sensor Epithermal Neutrons) are the un-collimated sensors that detect thermal and epithermal neutrons. STN-3 and SETN both have open fields of view. The combination of these two sensors will allow the measurement of local density of thermal and epithermal neutrons around the spacecraft. STN 1 and 2 are located near the midpoint of the instrument and have the thick mass of the collimation module just between them. For sensors on the +X and -X sides, the collimation material absorbs all external particles coming from directions –X and +X, respectively. The velocity vector of LRO will correspond to one of these directions: therefore, sensors STN 1 and 2 will detect neutrons with velocities $(V_n + V_{orb})$ and $(V_n - V_{orb})$, respectively, and will operate as a Doppler filter to separate the flux of external neutrons from the Moon from the local spacecraft background. The full set of four sensors, SETN and STN 1-3, will provide the data to characterize the neutron component of lunar radiation background at the altitude of LRO separately from the neutron component of local background produced by LRO itself.

The collimated sensors of epithermal neutrons, CSETN1-4, are also $^3$He counters, that are installed inside the collimating module, which effectively absorbs external neutrons outside of instrument Field of View. Absorbing neutrons is very difficult; one of the best absorbing materials is $^{10}$B, and its absorption efficiency becomes much higher when neutrons are slower. The LEND collimators have external layers of polyethylene for moderation of impacting neutrons and internal layers of $^{10}$B for their efficiency. These sensors are also enclosed by Cd shields that absorb all neutrons with energies below ~0.4 eV, which mainly correspond to thermal neutrons. The neutron collimator provides the instrument Field of View (FOV): epithermal neutrons of direct flux inside the FOV are recorded by the detector, while the majority of neutrons outside the FOV are absorbed by the collimator. This collimation technique provides mapping of epithermal neutrons from the Moon’s surface with the horizontal resolution of 5 km for LRO at an altitude of 50 km.
The final LEND sensor is the Sensor for High Energy Neutrons (SHEN), which is a stylobene scintillator that produces a flash of light each time a high energy neutron in the energy range 0.3 – 15.0 MeV collides with a hydrogen nucleus and creates a recoil proton. Special shape-sensitive electronics distinguish proton counts from electron counts, and an active anti-coincidence shield eliminates external charged particles. This sensor is installed inside the central hole of the collimation unit, and its Field of View corresponds to 40° (HWHM). The SHEN sensor outputs data in 16 energy channels from 300 keV to more than 15 MeV, and is the source of the SC1-3 spectra.

LEND operates autonomously, collecting data throughout the lunar orbit. LEND generates approximately 0.26 Gbits of measurement data per day. In order to perform early calibration measurements, LEND became active shortly after the first mid course correction (MCC) burn. Operationally, LEND is simple and has only three instrument modes: MEASUREMENTS, STAND-BY, and OFF. While in MEASUREMENTS mode, instrument electronics and detector high voltage are both 'on' and the instrument generates measurement and housekeeping data. In STAND-BY mode, instrument electronics are 'on', detector high voltage is 'off', and only housekeeping data are generated. While in OFF mode, the instrument is 'off', the instrument external heater is 'on', and only external temperature data are generated.

For further information about the LEND instrument and the LEND experiment please see Applicable Document [6].
Figure 2.1. LEND Instrument Overview
2.2 Data Product Overview

The LEND EDR data product contains two types of data.

LEND_SCI_DATA    Neutron Detector science data
LEND_HK_DATA    Neutron Detector housekeeping data

LEND_SCI_DATA is a time series of Neutron Detector science data.
LEND_HK_DATA is a time series on Neutron Detector housekeeping data

2.3 Data Processing

Data format is described in Section 3, Detailed Data Product Specifications on page 11. Data volume is a function of collection rate as parameterized by collection interval. The nominal collection interval is 1 second or 86400 records per day per file. Collection Interval can be changed in the middle of a time series file, which can be determined by noting the difference between record timestamps.

2.3.1 Data Processing Level

The EDR product contains individual raw LEND spectra and associated data corresponding to NASA Processing Level 0, CODMAC Level 2 [see Applicable Document 1].
2.3.2 Data Product Generation

A process termed “ingest” occurs on the LEND Science Operations Center computer which receives data from the LRO Mission Operation Center. The ingest process verifies the consistency of the data. The LEND EDR data product is output by software that maps the stored relational data into the format described by this SIS. Both processes (ingest and output) are rigorously tested. Multiple versions of the data product may be made available if software bugs affecting the output data are uncovered and corrected. In the event of an error whose fix changes released data, it is expected the data will be reprocessed by the revised software and made available.

2.3.3 Data Flow

The LEND-EDR data product will be made available in sequential data releases at three month intervals as specified in applicable document #1 (Appendix 4, Lunar Reconnaissance Orbiter Archive Delivery Schedule).

The release schedule for LEND data product archives is strictly within the nominal six-month period for data processing, data validation, archive generation, delivery to the PDS, validation of the delivery by PDS, and PDS archive release to the public. Once released by the PDS, the LEND data will be available online through a set of PDS search and retrieval tools that will provide access to data from all LRO instruments.

2.3.4 Labeling and Identification

The data set ID provided by the PDS for the LEND EDR data product is:

LRO-L-LEND-2-EDR-V1.0

The version number is incremented should the entire EDR data set be revised.

The file naming convention for LEND EDR data files will be the PRODUCT_TYPE value followed by an eight-digit date specifier in the format YYYYMMDD, e.g. LEND_EDR_SCI_20081223.DAT. The EDR parts will have a detached PDS label in a separate file of the same name, extension .LBL.

2.3.5 Data Product Revisions

Individual EDR products may be revised during the course of the mission. A product's revision status is recorded in its PDS label using the keyword PRODUCT_VERSION_ID. The value of this keyword is "1.0" for the first version of a product. The value is incremented with each product revision. Also, the label keyword PRODUCT_CREATION_TIME is updated with each product revision.

PRODUCT_VERSION_ID and PRODUCT_CREATION_TIME appear in the index table for the RDR archive so that the set of revised products can be easily identified. The index table also includes a RELEASE_ID keyword to indicate the number of the data release in which the product was included. The first release of the mission has a RELEASE_ID value of "0001"; the second release three months later has a value of "0002", and so on. This keyword is not updated for a revised product; it always shows the ID of the release in which the product first appeared.
2.4 Standards Used in Generating Data Products

2.4.1 PDS Standards

The LEND EDR data product complies with Planetary Data System standards for file formats and labels, as specified in the PDS Standards Reference [4].

2.4.2 Time Standards

Time series datum in the LEND EDR data product is sorted according to the value of spacecraft clock. Time series records are tagged by spacecraft time which is the 5 MSB of the spacecraft clock, 4 bytes of seconds and 1 byte of subsecond. The LEND Instrument contains its own internal clock. Values from this clock are also included, units are in 0.016 seconds since the last power on of the instrument.

2.4.3 Coordinate Systems

Not Applicable for this data set.

2.4.4 Data Storage Conventions

Binary files are all fixed-length, stored in most-significant-byte-first (big-endian) format. In text files each record is terminated with a carriage return followed by a line feed.

2.5 Data Validation

LEND EDR products will be validated by the LEND Team for science content and for compliance with PDS archive standards [Applicable Document 4].

3. DETAILED DATA PRODUCT SPECIFICATIONS

The EDR data product shall be grouped into directories with one directory per flight day. Flight day is defined to be midnight-to-midnight UTC. Within each directory shall be the two labels corresponding to the individual parts of the data product. The labels will point to one data file each, and contain pointers to format labels detailing the column layout of the data files.

3.1 Data Product Structure and Organization

In the DATA directory of the EDR archive, data for each flight day will be in a subdirectory named in the format YYYYMMDD, indicating the date at the end of the data acquisition period.

3.2 Data Format

The LEND EDR data product contains two types of data.

LEND_SCI_DATA    Neutron Detector science data
LEND_HK_DATA    Neutron Detector housekeeping data

LEND_SCI_DATA is a time series of Neutron Detector science data.
LEND_HK_DATA is a time series on Neutron Detector housekeeping data

Each product type is stored in a separate file with a detached PDS label. All the product types are stored as binary tables with fixed-length records. Definitions of the columns in the tables are listed in Table 1.
### 3.3 Labels and Headers

Each data file is described by a PDS label in a separate file with the same name, extension “.LBL”. A label file is stored in the same directory as the data file it describes. In most cases, the PDS label includes a pointer to another file that contains the column definitions, in order to avoid repeating the lengthy definitions in every label. These column definition files have the extension “.FMT” and are stored in the LABEL directory of the EDR archive.

The data files themselves do not contain any embedded headers.

Sample `LEND_SCI_DATA` label:

```
PDS_VERSION_ID = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS = 5048
RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = 370

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID = "LEND_EDR_SCI_20090228_DAT"
PRODUCT_VERSION_ID = "1.0"
PRODUCT_TYPE = "LEND_EDR_SCI"
SOFTWARE_NAME = "GEN_LEND_EDR"
SOFTWARE_VERSION_ID = "1.0.0"
INSTRUMENT_HOST_NAME = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_NAME = "LUNAR EXPLORATION NEUTRON DETECTOR"
INSTRUMENT_ID = "LEND"
DATA_SET_ID = "LRO-L-LEND-2-EDR-V1.0"
MISSION_PHASE_NAME = "NOMINAL MISSION"
TARGET_NAME = "MOON"
START_TIME = 2009-02-28T00:00:00
STOP_TIME = 2009-02-28T23:59:59
SPACECRAFT_CLOCK_START_COUNT = "2311228"
SPACECRAFT_CLOCK_STOP_COUNT = "2397627"
^TABLE = "LEND_EDR_SCI_20090228.DAT"
OBJECT = TABLE
COLUMNS = 18
INTERCHANGE_FORMAT = BINARY
ROW_BYTES = 370
ROWS = 5048
DESCRIPTION = "This table contains neutron spectra and associated instrument Parameters as observed by the Lunar Reconnaissance Orbiter (LRO) Lunar Exploration Neutron Detector (LEND). Detailed descriptions for the parameters defined below are contained in the 'LEND_EDR_SIS' document.

The complete column definitions are contained in an external file found in the LABEL directory of the archive volume."```
Sample LEND_HK_DATA label:

```plaintext
PDS_VERSION_ID = "PDS3"

/*** FILE FORMAT **/
FILE_RECORDS = 470
RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = 61

/*** GENERAL DATA DESCRIPTION PARAMETERS **/
PRODUCT_ID = "LEND_EDR_HK_20090228_DAT"
PRODUCT_VERSION_ID = "1.0"
PRODUCT_TYPE = "LEND_EDR_HK"
SOFTWARE_NAME = "GEN_LEND_EDR"
SOFTWARE_VERSION_ID = "1.0.0"
INSTRUMENT_HOST_NAME = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_NAME = "LUNAR EXPLORATION NEUTRON DETECTOR"
INSTRUMENT_ID = "LEND"
DATA_SET_ID = "LRO-L-LEND-2-EDR-V1.0"
MISSION_PHASE_NAME = "NOMINAL MISSION"
TARGET_NAME = "MOON"
START_TIME = 2009-02-28T00:00:00
STOP_TIME = 2009-02-28T23:59:59
SPACECRAFT_CLOCK_START_COUNT = "2311228"
SPACECRAFT_CLOCK_STOP_COUNT = "2397627"

^TABLE = "LEND_EDR_HK_20090228.DAT"
OBJECT = TABLE
COLUMNS = 26
INTERCHANGE_FORMAT = BINARY
ROW_BYTES = 61
ROWS = 470
DESCRIPTION = "This table contains instrument parameters and housekeeping values as observed by the Lunar Reconnaissance Orbiter (LRO) Lunar Exploration Neutron Detector (LEND).

Detailed descriptions for the parameters defined below are contained in the 'LEND_EDR_SIS' document.

The complete column definitions are contained in an external file found in the LABEL directory of the archive volume.

^STRUCTURE = "LEND_EDR_HK.FMT"
END_OBJECT = TABLE
END
```

This table contains instrument parameters and housekeeping values as observed by the Lunar Reconnaissance Orbiter (LRO) Lunar Exploration Neutron Detector (LEND).

Detailed descriptions for the parameters defined below are contained in the 'LEND_EDR_SIS' document.

The complete column definitions are contained in an external file found in the LABEL directory of the archive volume.

^STRUCTURE = "LEND_EDR_HK.FMT"
END_OBJECT = TABLE
END
4. APPLICABLE SOFTWARE

4.1 Applicable PDS Software Tools

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

PDS products may also be viewed with the program LRO_LEND_PDS_VIEWER, developed by the University of Arizona Lunar Planetary Lab. The LRO_LEND_PDS_VIEWER Data Viewer is a software tool for browsing and displaying LRO LEND PDS data files in tabular or graphical format, and label/format files in text format. The tool validates and reads LRO LEND PDS EDR and RDR files. PDS files may be acquired through the PDS Geosciences Node. There is no charge for LRO_LEND_PDS_VIEWER. A setup file is available for download at http://pds-geosciences.wustl.edu/missions/lro/lend.htm under Online Tools. Running the setup file will install the software and create a start menu and desktop icon for launching the tool. Installation requires roughly 5.4 MB of disk space. This software can be run from a Windows based system that has Java 1.6 or greater installed. You may download the Java Runtime environment for Windows free at http://java.com/en/download/inc/windows_upgrade_xpi.jsp

A user guide for the LEND viewer software may be displayed from its help menu.

Table 1. LEND EDR Data Columns

This table lists the columns in all LEND EDR data files in alphabetical order. The format of each type of data file, including column positions, sizes, data types, units, and full descriptions, can be found in the format files (*.FMT) in the LABEL directory.
<table>
<thead>
<tr>
<th>Column Name</th>
<th>Data Type</th>
<th>Length</th>
<th>Description</th>
<th>File</th>
<th>Column#</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMAND1</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>Last received command</td>
<td>HK</td>
<td>2</td>
</tr>
<tr>
<td>COMMAND1_TIME</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>Last received command time</td>
<td>HK</td>
<td>3</td>
</tr>
<tr>
<td>COMMAND2</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Last received command</td>
<td>HK</td>
<td>4</td>
</tr>
<tr>
<td>COMMAND2_TIME</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Last received command time</td>
<td>HK</td>
<td>5</td>
</tr>
<tr>
<td>COMMAND3</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Last received command</td>
<td>HK</td>
<td>6</td>
</tr>
<tr>
<td>COMMAND3_TIME</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Last received command time</td>
<td>HK</td>
<td>7</td>
</tr>
<tr>
<td>COMMAND4</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>4&lt;sup&gt;th&lt;/sup&gt; Last received command</td>
<td>HK</td>
<td>8</td>
</tr>
<tr>
<td>COMMAND4_TIME</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>4&lt;sup&gt;th&lt;/sup&gt; Last received command time</td>
<td>HK</td>
<td>9</td>
</tr>
<tr>
<td>DATA_COLLECTION_TIME</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>2</td>
<td>Value of “collection time” register, length of time in 0.016 seconds</td>
<td>SCI</td>
<td>3</td>
</tr>
<tr>
<td>DATA_FRAME_NUMBER</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>2</td>
<td>Incremental frames counter</td>
<td>SCI</td>
<td>2</td>
</tr>
<tr>
<td>DISCRIMINATOR_LEVELS</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>2</td>
<td>Current discriminators level values. 10 MSb used. Bit 0 – for detector 1,</td>
<td>HK</td>
<td>12</td>
</tr>
<tr>
<td>HEATING_THRESHOLD_TEMPERATURE</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>Current heaters thresholds levels</td>
<td>HK</td>
<td>13</td>
</tr>
<tr>
<td>HEATER_STATES_CMD_ACCEPT</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>1</td>
<td>Bit 0 – heater 1 state</td>
<td>HK</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bit 1 – heater 2 state</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bit 2 – heater 3 state</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bit 3 – heater 4 state</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HV_LEVELS</td>
<td>MSB_UNSIGNED_INTEGER</td>
<td>4</td>
<td>20 LSb used for HV values. Bits 0,1 – for detectors 1, bits 16, 17, 18, 19</td>
<td>HK</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– for scintillation detector</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bit 20 – ACI for SC IN NEUTRONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column Name</td>
<td>Data Type</td>
<td>Length</td>
<td>Description</td>
<td>File</td>
<td>Column#</td>
</tr>
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<td>4</td>
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<td>HK; SCI</td>
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<td>LRO_TIME_SEC</td>
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<td>PARAMETERS_CHANGED</td>
<td>MSB_UNSIGNED_INTEGER</td>
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<td>SC1_SPECTRUM</td>
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<td>SC3_SPECTRUM</td>
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