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# Lunar Reconnaissance Orbiter Project

# Telemetry and Command Database Style Guide

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**National Aeronautics and Space Administration**

**Goddard Space Flight Center**
**Greenbelt, Maryland**

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Questions or comments concerning this document should be addressed to:

LRO Configuration Management Office
Mail Stop 431
Goddard Space Flight Center
Greenbelt, Maryland 20771

**Signature Page**

***Prepared by:***

*Original Signed By* _____
Maxine Saylor Date
LRO Test Conductor
Honeywell, Code 444

***Reviewed by:***

*Original Signed By* _____
Richard S. Saylor, Jr. Date
LRO Ground Systems & Operations Lead
Honeywell, Code 444

*Original Signed By* _____
Arlin Bartels Date
LRO Payload Systems Manager
NASA/GSFC, Code 431

***Approved by:***

*Original Signed By* _____
David F. Everett Date
LRO Mission Systems Engineer
NASA/GSFC, Code 599

**LUNAR RECONNAISSANCE ORBITER PROJECT**

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# 1.0 INTRODUCTION

The Lunar Reconnaissance Orbiter (LRO) is the first robotic mission of the Robotic Lunar Exploration Program (RLEP). The primary objective of the LRO mission is to conduct investigations that support future human exploration of the Moon. The launch readiness date for LRO is October 2008.

## 1.1 PURPOSE AND SCOPE

The LRO Project has multiple teams contributing database inputs in order to generate a fully integrated database for use by the Integrated Test and Operations System (ITOS) ground system. Therefore, it is necessary to define a common format and naming convention to avoid conflicting inputs and to ensure usability. This document contains guidelines for naming command mnemonics, telemetry mnemonics, discrete names, analog conversion definitions, limit definitions, and database filenames as well as the overall format of the files and individual record types.

All teams contributing database inputs to the LRO ITOS ground system shall follow these guidelines.

## 1.2 DOCUMENTATION

The following list contains the applicable and reference material used to generate this document. Refer to these sources to support, further define, and clarify the information in this document.

### 1.2.1 Applicable Documents

| | |
|---|---|
| http://itos.gsfc.nasa.gov/ | Integrated Test and Operations System (ITOS) website |

### 1.2.2 Reference Documents

| | |
|---|---|
| 431-REF-000554 | Sample ITOS Telemetry Database Definition File |
| 431-REF-000555 | Sample ITOS Pseudo-telemetry Database Definition File |
| 431-REF-000556 | Sample ITOS Command Database Definition File |
| N/A | ITOS User's Guide |

## 2.0 MISSION OVERVIEW

LRO is the first mission of the RLEP. The goal for the RLEP is to prepare for future human exploration of the Moon. LRO specific objectives are:

- Characterize the lunar radiation environment, biological impacts, and potential mitigation
- Determine a high resolution global, geodetic grid of the Moon in three dimensions
- Assess in detail the resources and environments of the Moon's polar cap regions
- Perform high spatial resolution measurement of the Moon's surface

The LRO instrument complement includes six instruments. Together, all six instruments allow LRO to meet the mission objectives.

LRO will also fly a technology demonstration instrument called the Mini-Radio Frequency (RF). The purpose of the Mini-RF is to demonstrate new radar technology for future use in planetary resource mapping. The Mini-RF payload will operate on a non-interference basis throughout the mission.

As of the creation of this document, the major spacecraft (SC) and subsystem functions are:

- **Command and Data Handling (C&DH)**
  - Provides SC processor for attitude control algorithms, command/telemetry processing.
  - Communication cards provide the interfaces to the S-band/Ka-Band RF systems.
  - Hardware command decoding for computer-free recovery
  - Provides high speed and low speed data bus to the instruments and SC components
  - Provides large volume recorder for measurement data and orbiter housekeeping (HK)

- **Guidance Navigation and Control (GN&C)**
  - Three axis control with reaction wheels
  - Star Trackers (STs), Inertial Measurement Unit (IMU), Coarse Sun Sensors (CSS) used for attitude control
  - Momentum management is performed periodically with thrusters
  - Control pointing of the Solar Array (SA) and High Gain Antenna (HGA) gimbals

- **Communication**
  - Ka-band transmitter for high rate measurement downlink using the HGA
  - S-Band transponders connected to the omni antennas and HGA for receipt of ground commands and telemetry downlink
  - Orbit determination via turnaround ranging

- **Power**
  - SA located on gimbals for power generation
  - One Lithium Ion battery for launch and 48 minute lunar occultations
  - Power switching and distribution
  - Battery charging control
- **Mechanical and Mechanism**
  - Deployable SAs and HGA
- **Flight Software (FSW)**
  - Complex algorithms computed on central processor including Attitude Control System (ACS), stored commanding, telemetry and measurement data processing, and fault detection and correction.
  - SC time distribution/maintenance

The six instruments are:

- **Lunar Orbiter Laser Altimeter (LOLA):** LOLA will determine the global topography of the lunar surface at high resolution, measuring landing site slopes and search for polar ice in shadow regions.
- **Lunar Reconnaissance Orbiter Camera (LROC):** LROC will acquire targeted images of the lunar surface capable of resolving small-scale features that could be landing site hazards. LROC will also produce wide-angle images at multiple wavelengths of the lunar poles to document the changing illumination conditions and potential resources.
- **Lunar Exploration Neutron Detector (LEND):** LEND will map the flux of neutrons from the lunar surface to search for evidence of water ice and provide measurements of space radiation environment which can be useful for future human exploration.
- **Diviner Lunar Radiometer Experiment (DLRE):** Diviner will map the temperature of the entire lunar surface at 300-meter horizontal scales to identify cold-traps and potential ice deposits.
- **Lyman-Alpha Mapping Project (LAMP):** LAMP will observe the entire lunar surface in the far ultraviolet (UV). LAMP will search for surface ice and frost in the Polar Regions and provide images of permanently shadowed regions illuminated only by starlight.
- **Cosmic Ray Telescope for Effects of Radiation (CRaTER):** CRaTER will investigate the effect of galactic cosmic rays on tissue-equivalent plastics as a constraint on models of biological response to background space radiation.

# 3.0 INTEGRATED TEST AND OPERATIONS SYSTEM DATABASE STYLE GUIDELINES

The following sections outline style guidelines related to the content and format of ITOS database files and records. Each LRO team responsible for generating database inputs is expected to adhere to these guidelines.

## 3.1 MNEMONIC NAMING CONVENTION

Mnemonics may contain only alphabetic and numeric characters. For LRO, due to the length limitation, the use of underscores in mnemonic names is not allowed. In general, each mnemonic name (telemetry, command, and pseudo-mnemonic) must be unique and limited to a maximum length of 20 characters, although a length of no more than 15 characters is preferred. Effort should be made to keep the mnemonic length as short as possible when defining mnemonics.

LRO telemetry and command (T&C) mnemonics for SC subsystems and instruments, ground support equipment (GSE) T&C mnemonics and pseudo-telemetry mnemonics will have the following naming convention:

Format: <subsys><component><description><value_state>

Where:

- subsys: required 2-character field as assigned in Table 3-1. Indicates the major subsystem/instrument associated with the telemetry point/command.
- component: required 2 to 5-character field as assigned in Table 3-2. (If your component was not defined in Table 3-2, please come up with your own unique designation.) Indicates the FSW task, module, board, circuit, component or GSE rack/component where the value was generated or where the command is intended to go. In the case of duplicate components, please end the component field with the component number or letter designation (i.e. Star Tracker #1 = ST1, Reaction Wheel #4 = RW4)
- description: required field of variable length. Describes the function of the telemetry point. Please follow designations for standard descriptions in Table 3-3.
- value_state: optional field of variable length. Indicates the functional element value or state. This field may be left blank if the telemetry point is adequately identified in the description field. Please follow designations for values/states in Table 3-3.

The remaining portion of the mnemonic name may be assigned at the discretion of the developer. However, it is strongly recommended that the mnemonic name utilize a sequence of characters that make it easily identifiable to the end user, the Mission Operations Team. For example, if a

particular type of temperature sensor is widely used throughout the SC, a mnemonic based on its location rather than the type of sensor is preferred.

All pseudo-mnemonic names must end in an "X" so that they are easily distinguishable from telemetry from the SC or GSE.

### 3.1.1 Naming Assignments and Abbreviations

To avoid duplicating names for different subsystem database inputs, it is essential that a common naming convention be employed. Table 3-1 defines the two-character prefix to be used when naming all commands, telemetry mnemonics, pseudo-mnemonics, subsystem identifiers, discrete names, analog conversions, and limits. A pseudo-mnemonic is used to provide further manipulation of telemetry mnemonics, such as logical expressions, concatenation, scientific expressions, etc. The combination of two or more telemetry mnemonics to perform an engineering calculation is a typical usage.

**Table 3-1. Prefix Assignments**

| Prefix | Subsystem Assignment |
|---|---|
| Spacecraft Subsystems: | |
| AC | Attitude Control Subsystem hardware components ~~and any ACS/GNC-related FSW Tasks~~ |
| ~~PD~~ | ~~Propulsion/Deployment Electronics~~ |
| PW | Power Subsystem generation and distribution |
| RF | Radio Frequency Communications/transponders/transmitter/switches |
| TH | Thermal Control Subsystem |
| SW | C&DH FSW |
| CD | C&DH Hardware |
| GS | Ground Support Equipment (GSE) |
| Instruments: | |
| CR | CRaTER |
| DL~~V~~ | Diviner |
| LA | LAMP |
| LN | LEND |
| LO | LOLA |
| LR | LROC |
| MR | Mini-RF |

Table 3-2 defines the designation for subsystem components to be used when naming all commands, telemetry mnemonics, pseudo-mnemonics, subsystem identifiers, discrete names, analog conversions, and limits. A "#" at the end of the abbreviation indicates the number or letter designation for the component should be identified as part of the abbreviation. If your component is not listed please create your own unique abbreviation and use it consistently.

## Table 3-2. Component Assignments

| Attitude Control Subsystem | |
|---|---|
| **Abbreviation** | **Description** |
| CSSx | Coarse Sun Sensor #x |
| GYx | Gyro #x |
| PDx | Propulsion/Deployment Electronics #x |
| RWx | Reaction Wheel #x |
| STx | Star Tracker #x |
| **C&DH Hardware** | |
| **Abbreviation** | **Description** |
| DSB | Data Storage Board |
| KCOM | Ka-Band Communications Card |
| LVPC | Low-Voltage Power Card |
| MAC | Multi-Analog Card |
| SBC | Single Board Computer |
| SCOM | S-Band Communications Card |
| **Communications** | |
| **Abbreviation** | **Description** |
| HGA | High Gain Antenna |
| KCOM | Ka-Band Communications |
| KEPC | Ka-Band Electronics Power Card |
| KTWT | Ka-band Traveling-Wave Tube |
| RCVR | Receiver |
| SCOM | S-Band Communications |
| SW | Switch (RF Switch) |
| TWTA | Traveling-Wave Tube Amplifier |
| XMTR | Transmitter |
| XPR | Transponder |
| **Diviner** | |
| **Abbreviation** | **Description** |
| DREB | Diviner Remote Electronics Box |
| INST | Diviner Instrument Processor |
| **Propulsion/Deployment** | |
| **Abbreviation** | **Description** |
| ATx | 20 Newton ACS Thruster #x |
| HGARx | High Gain Antenna Restraint #x |
| HPLV | High Pressure Latch Valve |
| HPLVS | High Pressure Latch Valve Status (Micro-Switch) |
| MLVx | Manifold Latch Valve #x |
| MLVSx | Mainfold Latch Valve Status #x (Micro-Switch) |
| NTx | 80 Newton Insertion Thruster #x |
| PVx | Pyro Valve #x |
| SARx | Solar Array Restraint #x |
| SBWx | Separation Break Wire #x |
| TLVx | Tank Latch Valve #x |
| TLVSx | Tank Latch Valve Status #x (Micro-Switch) |
| **Power** | |
| **Abbreviation** | **Description** |
| BAT | Battery |
| OM | Output Module |
| PMC | Power Monitor Card |
| SA | Solar Array |
| SAM | Solar Array Module |

| Flight Software | |
|---|---|
| **Abbreviation** | **Description** |
| ADC | Attitude Determination and Control |
| CF | CCSDS File Delivery Protocol |
| | |
| CI | Command Ingest |
| CK | Checksum |
| DI | Data Ingestion |
| DS | Data Storage |
| ES | Executive Services |
| EVS | Event Services |
| FDH | Fault Detection Handling |
| FM | File Manager |
| FT | CFDP File Transfer |
| HGA | High Gain Antenna Application |
| HK | House Keeping Data Storage |
| HS | Health & Safety Manager |
| IM | Instrument Manager |
| MD | Memory Dwell |
| MM | Memory Manager |
| MS | EDAC Memory Scrubber |
| OM | Onboard Models |
| SA | Solar Array Application |
| SB | Software Bus |
| SC | Stored Commanding |
| SH | Software Scheduler |
| SPW | Spacewire Manager |
| ST | Self Test |
| TM | Time Services |
| TO | Telemetry Output |
| TS | Telemetry Services |
| XS | Executive Services |
| **Lunar Reconnaissance Orbiter Camera** | |
| **Abbreviation** | **Description** |
| NACL | Narrow-angle Camera Left |
| NACR | Narrow-angle Camera Right |
| SCS | Sequence Control System |
| WAC | Wide-angle Camera |
| | |
| | |
| **Mechanisms** | |
| **Abbreviation** | **Description** |
| HGGCx | High Gain Gimbal Controller #x |
| SAGCx | Solar Array Gimbal Controller #x |
| | |
| **Ground Support Equipment** | |
| **Abbreviation** | **Description** |
| BATSIM | Battery Simulator |
| DPC | Direct Power Conditioner |
| GDS | Goddard Dynamic Simulator |
| LDSIM | Load Simulator |
| SAS | Solar Array Simulator |

Table 3-3 suggests abbreviations for standard mnemonic descriptions. Please follow these abbreviations when possible. If needed, please create your own unique description and use it consistently.

**Table 3-2. Mnemonic Description Abbreviations**

| Abbr | Description | Abbr | Description |
|---|---|---|---|
| A | NSI #1 of 2 (pyro valve and restraint reference) | ENG | Engineering |
| AC | Close coil #1 of 2 (latch valve reference) | ERR | Error |
| ADDR | Address | EXE | Execution |
| AGC | Automatic Gain Control | FEP | Front End Processor |
| AMP | Amplitude | FIRE | Fire (pyro) |
| ANG | Angle | FLG | Flag |
| ANT | Antenna | FLT | Filter |
| AP | Open coil #1 of 2 (latch valve reference) | FMT | Format |
| APID | CCSDS Application ID | FN | Fine |
| ARM | Arm (pyro) | FPGA | Field Programmable Gate Array |
| AUX | Auxiliary | FRM | Frame |
| B | NSI #2 of 2 (pyro valve and restraint reference) | FS | Frequency Standard |
| BAT | Battery | FW | Filter Wheel |
| BC | Close coil #2 of 2 (latch valve reference) | FWD | Forward |
| BDY | Body | GCE | Gimbal Control Electronics |
| BOT | Bottom | GN | Gain |
| BP | Base plate or Open coil #2 of 2 (latch valve reference) | HI | High |
| BS | Bias | HK | Housekeeping |
| BUF | Buffer | HTR | Heater |
| BUS | Bus | HW | Hardware |

| | | | |
|---|---|---|---|
| CAL | Calibrate/Calibration | I | Current |
| CCD | Charge Coupled Device | ID | Identification |
| CFG | Configuration | INIT | Initialization |
| CHN | Channel | INST | Instrument |
| CKSM | Checksum | INT | Internal |
| CLD | Cold | LCK | Lock |
| CLS | Closed | LD | Load |
| CLK | Clock | LIM | Limit |
| CLR | Clear | LN | Line |
| CMD | Command | LO | Low |
| CNT | Count | LSB | Least Significant Bits |
| CNV | Convert/Converter | LVL | Level |
| COHO | Coherent | MAG | Magnetic |
| CTRL | Control | MAX | Maximum |
| D | Down Stream Valve Seat (thruster reference) | MD | Mode |
| DET | Detector | MEM | Memory |
| DIR | Direction | MF | Mainframe / Main Frame |
| DIS | Disable | MIN | Minimum |
| DLY | Delay | MIRR | Mirror |
| DMP | Dump | MOD | Modulation |
| DNLK | Downlink | MON | Monitor |
| DRV | Drive | MSB | Most Significant Bits |
| DWL | Dwell | MSG | Message |
| EEPR | EEPROM | MUX | Multiplexer |
| EL | Elevation | N | Negative |
| ENA | Enable | NOCO | Non-Coherent |

| | | | |
|---|---|---|---|
| ENC | Encode / Encoder | NOOP | No Operation |
| OC | Over current | SA | Solar Array |
| OFF | Off | SCI | Science |
| ON | On | SEL | Select |
| OP | Operation | SH | Safehold |
| OPHTR | Operational Heater | SHNT | Shunt |
| OPN | Open | SHT | Shutter |
| OR | Override | SHTR | Survival Heater |
| OS | Offset | SIG | Signal |
| OSC | Oscillator | SN | Sensor |
| OT | Over Temperature | SPD | Speed |
| OV | Over voltage | SPN | Spin |
| OVR | Over | SPR | Spare |
| P | Positive | STAT | Status / State |
| PB | Playback | STW | Stow |
| PKT | Packet | SW | Software |
| PNT | Point / Pointing | SYNC | Synchronize |
| POS | Position | SYS | System |
| PRG | Program | TBL | Table |
| PROM | Programmable Read-Only Memory | TDRS | TDRSS |
| PRS | Pressure | TELE | Telescope |
| PRV | Previous | TLM | Telemetry |
| PS | Power Supply | TMP | Temperature |
| PWR | Power | TNK | Tank |
| PYRO | Pyrotechnic | TOP | Top |
| RAM | Random Access Memory | TRQ | Torque |
| RCVD | Received | U | Upstream Valve Seat (thruster reference) |
| RCVR | Receiver | ULK | Unlock |
| REC | Record | UPD | Update |
| REF | Reference | UPLK | Uplink |
| REJ | Reject | UTC | Universal Time Coordinated |
| REV | Reverse | V | Volts |
| RF | Radio Frequency | VAL | Value |
| RLY | Relay | VC | Virtual Channel |
| RPM | Revolutions per Minute | VEC | Vector |
| RPT | Report | VEL | Velocity |
| RST | Reset | VLV | Valve |
| RT | Real Time | WRM | Warm |
| | | WD | Word |

Table 3-4 provides the standard unit abbreviations for LRO. These abbreviations are to be used only when defining units in the Telemetry (TLM) record's Unit field (field 8). Do not use them

in defining mnemonic names. Please adhere to these abbreviations. If you require an abbreviation not listed please make sure it is unique and easily identifiable by the Mission Operations Team.

**Table 3-3. Unit Abbreviations**

| Abbreviation | Unit Measurement | Abbreviation | Unit Measurement |
|---|---|---|---|
| % | Percent | kg/m2 | Kilograms per square meter |
| A | Amp | kHz | Kilo Hertz |
| arcs | Arc Seconds | Km | Kilo Meters |
| AU | Astronomical Units | km/s | Kilo Meters per second |
| bps | bits per second | M | Meters |
| Bps | Bytes per second | mA | Milli Amp |
| C | Degrees Centigrade | Mbps | Mega bits per second |
| cm | Centimeters | MBps | Mega Bytes per second |
| cm/ct | Centimeters per count | Ms | Milli Seconds |
| cnt | Counts | Nm | Newton Meter |
| cyc | Cycle | Nm2 | Newton Meters Squared |
| days | Days | ohms | Ohms |
| dB | decibels | pix | Pixels |
| deg | Degrees | R | Degrees Rankin |
| eV | Electron Volts | rad | Radians |
| frms | Frames | rpm | Revolutions Per Minute |
| Gbps | Giga bits per second | rps | Revolutions per second |
| GBps | Giga Bytes per second | s | Seconds |
| hr | Hours | uA | Micro Amp |
| Hz | Hertz | uS | Micro Second |
| K | Degrees Kelvin | V | Volts |
| kbps | Kilo bits per second | V/ct | Volts per count |
| kBps | Kilo Bytes per second | W | Watts |

## 3.2 DATABASE EXCHANGE RECORD FILES

For LRO several types of DBX files exist. They include spacecraft telemetry DBX files, ground system support equipment (GSE) telemetry DBX files, pseudo-telemetry DBX files and command DBX files. These files and their naming conventions are discussed in the paragraphs that follow.

All DBX filenames will use only lowercase characters.

There will be one spacecraft telemetry DBX file for each spacecraft Application ID (APID) which will contain all the spacecraft telemetry mnemonics and only the spacecraft telemetry mnemonics associated with that APID.

Spacecraft telemetry DBX file names will start with the assigned two-character prefix from **Error! Reference source not found.** for the subsystem from which the telemetry within the file originates, followed by an underscore, followed by the assigned prefix from Table 3-2 of the subcomponent from which the telemetry within the file originates if applicable, followed by an underscore, followed by an abbreviation of the type of telemetry contained within the file if applicable, followed by _tlm_, followed by the APID of the telemetry within the file in 4 digit decimal format, followed by the dbx file extension.

The following are examples of spacecraft telemetry DBX filenames:

- Flight software limit checker task diagnostic telemetry with APID 18
  Filename: sw_lc_diag_tlm_0018.dbx
- Diviner housekeeping telemetry with APID 125
  Filename: ~~dv~~dl_hk_tlm_0125.dbx

Some ground support equipment used at I&T will provide its own status telemetry to ITOS. This telemetry may or may not be associated with an APID. There will be one GSE DBX file per GSE component or APID.

GSE telemetry DBX file names will start with the assigned two-character prefix GS, followed by an underscore, followed by the assigned prefix from Table 3-2 of the subcomponent from which the telemetry within the file originates if applicable, followed by an underscore, followed by an abbreviation of the type of telemetry contained within the file if applicable, followed by _tlm_, followed by the APID of the telemetry within the file in 4 digit decimal format if applicable, followed by the dbx file extension.

The following are examples of GSE telemetry DBX filenames:

- Ground support equipment solar array simulator telemetry
  Filename: gs_sas_tlm.dbx
- Ground support equipment Goddard Dynamic Simulator Attitude Determination and Control housekeeping telemetry with APID 13
  Filename: gs_gds_adc_hk_tlm_0013.dbx

Pseudo-telemetry may be defined for any subsystem or component. Since this telemetry is derived by ITOS it is not assigned an APID. Pseudo-telemetry DBX files should contain only pseudo-telemetry associated with one subsystem or component of a subsystem.

Pseudo-telemetry DBX file names will start with the assigned two-character prefix from **Error! Reference source not found.** for the subsystem from which the telemetry within the file originates, followed by an underscore, followed by the assigned prefix from Table 3-2 of the subcomponent from which the telemetry within the file originates if applicable, followed by an underscore, followed by an abbreviation of the type of telemetry contained within the file if applicable, followed by_pseudo_tlm_, followed by the dbx file extension.

The following are examples of pseudo-telemetry DBX filenames:

- Flight software limit checker task diagnostic pseudo-telemetry
  Filename: sw_lc_diag_pseudo_tlm.dbx
- Power system calculated load power pseudo-telemetry
  Filename: pw_ld_pwr_pseudo_tlm.dbx

There will be one command DBX file for each command Application ID (APID) which will contain all the command mnemonics and only the command mnemonics associated with that APID.

Command DBX file names will start with the assigned two-character prefix from **Error! Reference source not found.** for the subsystem to which the command belongs, followed by an underscore, followed by the assigned prefix from Table 3-2 of the subcomponent to which the telemetry command belongs if applicable, followed by an underscore, followed by _cmd_, followed by the APID of the commands within the file in 4 digit decimal format, followed by the dbx file extension.

The following are examples of command DBX filenames:

- Flight software checksum task commands with APID 4
  Filename: sw_ck_cmd_0004.dbx
- RF Communications commands with APID 12
  Filename: rf_cmd_0012.dbx

### 3.2.1 DBX File Format

This document is not intended to be a tutorial on ITOS database exchange records. Its purpose is to point out the requirements for the use/style of the exchange records for the LRO mission.

For detailed instructions on how to use the ITOS database exchange records to define telemetry and commands, please read and follow the ITOS Database Building documentation in the ITOS User's Guide found on the following URL: http://itos.gsfc.nasa.gov/

To ensure readability, the DBX files will adhere to specific formatting guidelines. DBX file comments, mnemonic descriptions and mnemonic unit definitions should make use of both upper and lower case text. However, all other content of DBX files will be uppercase only, including mnemonic names. Following this case convention will aid in readability of the DBX files. Please note, however, that ITOS is not case sensitive to mnemonic names. The following sections describe the contents and the format of the telemetry (TLM), pseudo-telemetry and command (CMD) DBX files.

ITOS provides reasonable defaults for many of the fields of the DBX records. When possible, rely on their defaults rather than inputting data into the field. However, be sure to include information in the LRO required fields even if the ITOS default will work.

Templates of a command (431-REF-000556), pseudo-telemetry (431-REF-000555) and telemetry (431-REF-000554) DBX file are provided for project use in the Library on Next Generation Integrated Network (NGIN) website located at https://lunarngin.gsfc.nasa.gov/.

#### 3.2.1.1 File Header

All DBX files must contain the LRO DBX file standard header. The format for this header can be found in the DBX file examples in Appendix B. The information in the header, Date, Author, Change Description, should be updated in detail every time a change is made to the DBX file. Also in the header, code should be included which will be used during the Integration and Testing (I&T) and Operations phase to keep track of revisions using ~~the Current Version System~~Subversion Version Control ~~(CVS~~SVN) software. This code looks like $Revision$ followed by $Id~~: nn_tlm_apid.dbx,v,log~~$ ~~where the nn_tlm_apid.dbx is the actual name of the DBX file~~. Please note: It is not required to log changes in the header of the file. Change information will be captured during the checkin process where the user will be requested to identify the changes made to the file/files.~~If the CVS software is being used to track changes, filling out the change information in the header is not required since CVS will maintain the change information.~~

#### 3.2.1.2 Integrated Test and Operations System Field Delimiters

Within any DBX file, fixed column widths will be used for each field to ensure optimum readability. A field (column) delimiter definition record (DEL record type) will be defined in the first record in each DBX file, just after the File Header. For LRO, the vertical bar ("|") is the standard field delimiter. Refer to Appendix B for an example.

#### 3.2.1.3 Comments

Comments and blank lines will be used liberally to distinguish between sets of telemetry packets, commands with multiple FLD/SUB records, and configuration control information, etc. Comments begin with a '#' character and continue to the end of the line. To place a '#' in a description field, use '\#' or quote the entire description text.

#### 3.2.1.4 Telemetry DBX File

##### 3.2.1.4.1 Subsystem Identifiers

Telemetry mnemonics may be assigned to one or more subsystems. The subsystem name is used to limit database searches or reports and for general information. Subsystem identifiers (SSI record type) have a maximum length of 15 characters, and must start with the assigned two-character prefix from Table 3-1. These records will be included as part of the telemetry DBX file and will appear as the first record after the Field Delimiter Record. All SSI records in a DBX file should be grouped together in the same section. Refer to Appendix B for an example. A definition in all fields is required for LRO.

##### 3.2.1.4.2 Map Records

The basic definition sequence of a telemetry stream starts with the definition of a MAP record for a specific segment of the stream. The MAP record defines general information about a given Application ID (APID) stream referred to as the packet attributes. For LRO, a MAP record should be defined for each packet that is defined. The MAP record should immediately follow the SSI record and be followed immediately by the PKT records for that APID. Refer to Appendix B for an example. A definition in record fields 1-4, 7 and 8 is required for LRO. Please note that field 7 must contain the packet header time mnemonic for the packet that the map is defining. This will insure that limit/cfgmon/event flags will show the correct time in the ITOS events window.

##### 3.2.1.4.3 Packet Records

The PKT record defines how to extract a single telemetry value from a single occurrence in one APID. The PKT record should immediately follow the MAP record that corresponds to its APID and be followed immediately by the TLM records for that APID. All PKT records for the APID should be grouped together. Refer to Appendix B for an example. A definition in record fields 1-3, 5, 7-10, and 13 is required for LRO.

##### 3.2.1.4.4 Telemetry Records

The TLM record further defines telemetry mnemonics. The TLM record should immediately follow the PKT record that corresponds to its APID and be followed immediately by the MAP

record for the next APID to be defined. All TLM records for the APID should be grouped together. Refer to Appendix B for an example. A definition in record fields 1-3, 5-7, 8 if possible (put quotations marks around the unit abbreviation to avoid errors with specials characters such as backslashes, etc.), and 15 is required for LRO.

#### 3.2.1.4.5 Limit Records

The LIM record defines a limit range for an integer or floating-point telemetry mnemonic. A limit set consists of two concentric ranges called the “yellow limits” and “red limits”. A limit definition record may contain more than one limit set. The system chooses which limit set to apply to a mnemonic using the “limit switch”, explained in the ITOS documentation. LIM records for all mnemonics should be grouped together at the bottom of the DBX file. Refer to Appendix B for an example. A definition in record fields 1-3 and 12 is required for LRO.

All definition names for limits must also begin with the assigned two-character prefix in Table 3-1 and may contain only alphanumeric characters. Like mnemonics, the limit names are limited to 15 characters, but unlike mnemonics, underscores are allowed when naming these elements.

#### 3.2.1.4.6 Discrete Conversion Records

Discrete conversions, defined in DSC records, transform a range of numeric values into a set of text strings. The telemetry value is compared to each range in the set. If the value falls within the specified range, the state text associated with that range is displayed. The high value of one range can be the same as the low value of the next range; otherwise, overlapping ranges are discouraged. DSC records for all mnemonics should be grouped together at the bottom of the DBX file. Refer to Appendix B for an example. A definition in record fields 1-6 and 9 is required for LRO.

Please do not use anything other than the default (black) for the background color (Field 8.) Please use green as the default foreground color for nominal conversions. (Field 7)

ITOS pages at I&T will display telemetry in green and page text in white, by default. And all pages will have a black background color, by default. This information is provided here to aid you in your color schemes for discrete conversions, should you choose to use them.

All definition names for discrete conversions must also begin with the assigned two-character prefix in Table 3 1 and may contain only alphanumeric characters. Like mnemonics, the conversion names are limited to 15 characters, but unlike mnemonics, underscores are allowed when naming these elements.

#### 3.2.1.4.7 Analog Conversion Records

Analog conversions, defined in ALG records, transform an integer number of "counts" (the output of an analog to digital converter, for example) into a floating-point value in "engineering units", such as volts, amps, degrees, etc. The ALG record defines the coefficients for an 8th order polynomial. The integer or floating-point telemetry value is applied to the polynomial and the result is a floating-point value. ALG records for all mnemonics should be grouped together at the bottom of the DBX file. Refer to Appendix B for an example. A definition in record fields 1-3 and 12 is required for LRO.

All definition names for analog conversions must also begin with the assigned two-character prefix in Table 3 1 and may contain only alphanumeric characters. Like mnemonics, the conversion names are limited to 15 characters, but unlike mnemonics, underscores are allowed when naming these elements.

#### 3.2.1.4.8 Expression Conversion Records

Expression conversions, defined in XPR records, define a System Test and Operations Language (STOL)-language expression of one variable which is used to generate a look-up table for converted values, upon building the database. This allows a means other than ALG records for converting to EU. These should only be used where polynomials (ALG records) cannot be used reasonably, since the look-up tables utilize a lot of memory. XPR records for all mnemonics should be grouped together at the bottom of the DBX file. Refer to Appendix B for an example. A definition in record fields 1-3 and 12 is required for LRO.

All definition names for expression conversions must also begin with the assigned two-character prefix in Table 3 1 and may contain only alphanumeric characters. Like mnemonics, the conversion names are limited to 15 characters, but unlike mnemonics, underscores are allowed when naming these elements.

#### 3.2.1.4.9 Selector Records

ITOS also supports the use of selector records, SEL. These records allow packet data to direct how part of a packet is to be unpacked. This feature allows a packet to have a variable, but defined, format. The use of these records on the LRO mission is expected to be rare, if at all. Therefore, these records will not be further discussed in this document and no examples of this record are provided in Appendix B. Please refer to the ITOS documentation for more information on the SEL record.

#### 3.2.1.4.10 Telemetry Packet Header Mnemonics

An exception to the general telemetry mnemonic naming convention is for telemetry packet header field mnemonics, which will be standardized with the format of the single character 'H', followed by a three hexadecimal-digit telemetry packet Application ID (APID) and a field name, respectively. Table 3 5 contains the fields for a representative packet, APID xxx. Packet header

mnemonics shall be included as PKT and TLM records in all telemetry DBX files at the start of each APID for that subsystem.

**Table 3-4. Telemetry Packet Header Records**

| Mnemonic | Start Byte | Start Bit | Length in Bits | Data Type | Description |
|---|---|---|---|---|---|
| HxxxPKTVNO | 0 | 0 | 3 | U1 | APID xxx Packet ID Version Number |
| HxxxPCKT | 0 | 3 | 1 | U1 | APID xxx Packet ID Type |
| HxxxSHDF | 0 | 4 | 1 | U12 | APID xxx Packet ID Secondary Header Flag |
| HxxxAPID | 0 | 5 | 11 | U12 | APID xxx Packet ID Application ID |
| HxxxSEGF | 2 | 0 | 2 | U1 | APID xxx Packet Sequence Control Segmentation Flag |
| HxxxCNT | 2 | 2 | 14 | U12 | APID xxx Packet Sequence Control Source Sequence Count |
| HxxxPLEN | 4 | 0 | 16 | U12 | APID xxx Packet Length |
| HxxxTIME | 6 | 0 | 48 | TIME42 | APID xxx System Time when packet was formed |

### 3.2.1.5 Pseudo-Telemetry DBX File

#### 3.2.1.5.1 Subsystem Identifiers

Pseudo-telemetry may be assigned to one or more subsystems. The subsystem name is used to limit database searches or reports and for general information. Subsystem identifiers (SSI record type) have a maximum length of 15 characters, and must start with the assigned two-character prefix from Table 3 1. These records will be included as part of the pseudo-telemetry DBX file. Refer to Appendix C for an example.

#### 3.2.1.5.2 Telemetry Records

The pseudo-telemetry DBX file assigns each pseudo-telemetry data point to a recognizable name, or mnemonic, and is defined by a telemetry record (TLM record type). The TLM records will be organized by subsystem.

In addition to a mnemonic name, each telemetry record includes fields to identify other attributes of the pseudo-telemetry point. Refer to the ITOS Database Building documentation for the definition of and more information on the TLM record. Appendix C provides an example of a Pseudo-telemetry DBX file that shows how these fields may be defined. A definition in record fields 1-3, 5-7, 8 if possible, and 15 is required for LRO.

Please note that LIM, DSC and ALG, XPR records must also be included in the pseudo-telemetry DBX file if such has been defined in the TLM record of the pseudo-telemetry DBX file. Please follow the same guidelines for these records as explained in Sections 3.2.1.4.5 – 8.

Also, note that packet header information is not to be included in the pseudo-telemetry DBX, since pseudo-telemetry is not contained within a Consultative Committee for Space Data Systems (CCSDS) packet.

#### 3.2.1.6 Command DBX File

The command DBX file is comprised of all command-related records (CMD, FLD, and SUB record types). The following sections discuss the LRO requirements for each command record type.

##### 3.2.1.6.1 Subsystem Identifiers

Command mnemonics may be assigned to one or more subsystems. The subsystem name is used to limit database searches or reports and for general information. Subsystem identifiers (SSI record type) have a maximum length of 15 characters, and must start with the assigned two-character prefix from Table 3 1. These records will be included as part of the command DBX file and will appear as the first record after the Field Delimiter Record. All SSI records in a DBX file should be grouped together in the same section. Refer to Appendix B for an example. A definition in all fields is required for LRO.

##### 3.2.1.6.2 Command Records

Command records are to be organized in ascending order by APID and Function Code/ Command Type, respectively. Refer to the ITOS Database Building documentation for the definition of and more information on the CMD record. Appendix D provides an example of a command DBX file that shows how these fields may be defined. A definition in record fields 1-4, 6 and 15 is required for LRO.

##### 3.2.1.6.3 Command Field Records

For commands that require commandable inputs, the command field record (FLD record type), also called a submnemonic, is utilized. These records will immediately follow the associated CMD record. Refer to the ITOS Database Building documentation for the definition of and more information on the FLD record. Refer to Appendix D for an example. A definition in record fields 1-5, 7-9, and 13-14 is required for LRO.

Note that the “Field Name” (field 3) does not require the pre-defined subsystem prefix, whereas the “Discrete Set Name” (field 13) does.

##### 3.2.1.6.4 Command Discrete Conversion Records

For commands that include command field records, a discrete conversion record (SUB record type) may be defined to convert a numerical command input to an alphanumeric discrete name. For example, a value of zero (0) may correspond to an “ON” state and a value of one (1) may correspond to an “OFF” state. This allows the user to use “ON” and “OFF” rather than memorizing which function corresponds to 0 or 1. This significantly increases the usability of the command. Similarly, if a command field needs to be commandable, but is commonly set to

the same value, the special name "default" may be used to represent the default value when no other value is specified. This allows the user to use the command field when needed, but otherwise omit it if the default value is acceptable. If a “default” conversion and value are not identified for a given field, the field will always require an input value to be commanded.

In the DBX files, these records will immediately follow the associated FLD record(s). Refer to the ITOS Database Building documentation for the definition of and more information on the SUB record. Refer to Appendix D for an example. A definition in all SUB record fields 1-5 and 7 is required for LRO.

All definition names for discrete conversions must also begin with the assigned two-character prefix in Table 3 1 and may contain only alphanumeric characters. Like mnemonics, the conversion names are limited to 15 characters, but unlike mnemonics, underscores are allowed when naming these elements.

### 3.2.2 DBX File ~~Current Version System (CVS)~~Subversion (SVN) Pseudo-Telemetry Mnemonic Inclusion

In order to help ITOS users easily determine the version of the DBX file used to generate the running version of the ITOS telemetry and command database, LRO is mandating the inclusion of a pseudo-telemetry mnemonic in each DBX file (even the command DBX files.) This pseudo-telemetry mnemonic will be assigned an initial value equal to the version of the DBX file according to the ~~CVS~~SVN. This will allow users to display on a page the ~~CVS~~ SVN versions of all the DBX files used to create the database version in use by ITOS.

The TLM record used to create this pseudo-telemetry mnemonic should appear in every DBX file as the next record after the DEL record. The pseudo-telemetry mnemonic name should be named HapidxxxSVN~~CVS~~, where apid=the apid of the commands or telemetry in the DBX file or apid= SSX, where SS is the subsystem prefix of the pseudo-telemetry contained in the DBX file, and xxx=either CMD or TLM depending on if there are TLM records or CMD records in the DBX file. The TLM record must also contain the following text in the Initial Value field: “$Rev~~ision:~~$”. A description of the mnemonic must also be included in the TLM record definition.

The DBX file examples in Appendices B, C, and D contain examples of what the TLM record used to define this pseudo-telemetry mnemonic must contain.

### 3.2.3 Summary

The following provides a summary of the guidelines when creating and maintaining DBX files to ensure readability and usability:

a. Within each record type, fixed column widths will be used for each field to improve readability.

b. Comments and blank lines will be used liberally to distinguish between sets of telemetry packets, commands with multiple "FLD"/"SUB" records, and configuration control information, etc.

c. In subsystem telemetry DBX files, the "PKT & TLM" records will be specified in the same byte order as the data is organized in the telemetry packet.

d. The "PKT", "TLM", "DSC", "ALG", and "LIM" records for a given telemetry mnemonic will have unique names and be contained in the same file. This is the preferred method. However, if specific "DSC", "ALG", or "LIM" records are to be used by several subsystems, they may be defined in the DBX files of only one of the subsystems. CAUTION: This requires careful coordination with other DBX file developers to ensure that the needed records are defined and not mistakenly deleted.

e. In command definitions, the "FLD" records for a given command will immediately follow the "CMD" records for that command.

f. In command definitions, the "SUB" records for a given command will immediately follow the "FLD" records for that command.

g. In all DBX files, the inclusion of a pseudo-telemetry mnemonic which is assigned the value of the file's ~~CVS~~ SVN version number is mandatory and should appear just after the DEL record.

## Appendix A. Abbreviations and Acronyms

| Abbreviation/ Acronym | DEFINITION |
|---|---|
| | |
| ACS | Attitude Control System |
| ALG | Algorithm Database Record |
| APID | Application Identification |
| C&DH | Command and Data Handling |
| CCB | Configuration Control Board |
| CCR | Configuration Change Request |
| CCSDS | Consultative Committee for Space Data Systems |
| CM | Configuration Management |
| CMD | Command |
| CMO | Configuration Management Office |
| CRaTER | Cosmic Ray Telescope for Effects of Radiation |
| CSS | Coarse Sun Sensor |
| ~~CVS~~ | ~~Current Version System~~ |
| DB | Database |
| DBX | Database Exchange |
| DLRE | Diviner Lunar Radiometer Experiment |
| DSC | Discrete Database Record |
| EU | Engineering Unit |
| FSW | Flight Software |
| GN&C | Guidance, Navigation, and Control |
| GN&O | Guidance, Navigation, and Operation |
| GSE | Ground Support Equipment |
| GSFC | Goddard Space Flight Center |
| HDBK | Handbook |
| HGA | High Gain Antenna |
| HK | Housekeeping |
| I&T | Integration and Test |
| ID | Identification |
| IMU | Inertial Measurement Unit |
| ITOS | Integrated Test and Operations System |
| LAMP | Lyman-Alpha Mapping Project |
| LEND | Lunar Exploration Neutron Detector |
| LOLA | Lunar Orbiter Laser Altimeter |
| LRO | Lunar Reconnaissance Orbiter |
| LROC | Lunar Reconnaissance Orbiter Camera |
| MAP | Map Database Record |
| NASA | National Aeronautics and Space Administration |

| Abbreviation/ Acronym | DEFINITION |
|---|---|
| | |
| NGIN | Next Generation Integrated Network |
| OPS | Operations |
| PKT | Packet |
| REF | Reference |
| RF | Radio Frequency |
| RLEP | Robotic Lunar Exploration Program |
| RW | Reaction Wheel |
| SA | Solar Array |
| SC | Spacecraft |
| SEL | Selector Database Record |
| SSI | Subsystem Identifiers |
| ST | Star Tracker |
| STOL | System Test and Operations Language |
| SVN | Subversion Version Control System |
| T&C | Telemetry and Command |
| TLM | Telemetry |
| UV | Ultraviolet |
| XPR | Expression Conversion Database Record |