CLEMENTINE EDR ARCHIVE SIS

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1. INTRODUCTION

This Software Interface Specification (SIS) describes the organization and contents of the Clementine Archive Collection of Raw Imaging Data. The archive collection consists of a single volume set that contains the primary data products and ancillary data for the UV/Visible (UV/VIS), Near-Infrared (NIR), Long Wavelength Infrared (LWIR), LIDAR High Resolution (HiRes) and star-tracker cameras. The raw data are pristine in the sense that they contain the artifacts, and radiometric and geometric characteristics of unprocessed and uncorrected data. The only processing performed on the data is to organize and format the data according to Planetary Data System (PDS) standards.

The Clementine Archive Collection is a deliverable product to the Planetary Data System and the scientific community that it supports. All data formats are based on the PDS standard, version 3.0, as documented in the PDS Standards Reference [JPL Document D-7669, November 1992, available through the PDS]. Derived and processed images produced by the active flight-operations team supported by the Naval Research laboratory (NRL) or produced by the NASA Science Team are not addressed in this SIS. Clementine derived products are expected to be generated primarily by post-mission data analysis programs supported by NASA. These products will be delivered to the PDS under a separate arrangement.

An overview of the ancillary data products that will accompany the archive of EDR image data products is discussed. However, as of this writing (October 1, 1994) the details associated with the ancillary data volumes are not yet in place. The ancillary data products such as calibration correction files, SPICE kernels, and prelaunch calibration data, are still in preparation by the Lawrence Livermore National Laboratory, NASA funded post-mission investigators, the PDS NAIF Node, and the PDS Imaging Node. The ancillary data products are to be organized on the "dynamic" data volumes of the archive. (Please see section 3 for a discussion of "dynamic" data volumes.)

2. CLEMENTINE IMAGE ARCHIVE COLLECTION

Archive-quality data sets include everything needed to understand and utilize the data. The images archived by themselves are insufficient for the science community to realize the full scientific potential of the data. Thus, it is necessary to provide as part of the archive the necessary ancillary data to perform colorimetric, photometric, and cartographic processing. Software tools need to be included as part of the archive to decompress, display, and calibrate the image data products. Documentation is necessary to describe the data products, imaging instruments, and mission operations. Table 1 summarizes the elements required to fully utilize the image collection. Each element is discussed individually.

The term "archive" describes the total data collection needed to fully utilize the EDR image collection. The archive is stored on CD-ROM media and is divided into static and dynamic data volumes. The static data volumes contain the EDR image data products. The dynamic data volumes contain the ancillary data necessary to utilize the image collection. (Please see section 3. for a more detailed discussion on the contents

and organization of the static and dynamic data volumes that make up the archive.)

Table 1 - Essential Elements of the Image Archive

1. Primary Image Data Set. These are the raw images as acquired by the mission. Images remain in "lossy" compressed format to reduce the data volume of the archive.

2. Requantization matrices for data decompression.

3. Browse Image Data Set. Sub-sampled images in an uncompressed format for rapid browsing of the image collection.

4. Geometric Elements. Data and information characterizing the geometric properties of the imaging systems.

5. Radiometric Elements. Data and information characterizing the radiometric properties of the imaging instruments.

6. Index Elements. Tables summarizing the properties and characteristics of all images in the archive.

7. Documentation Elements. Computer readable files describing the mission, spacecraft, imaging instruments, mission operations, and software.

8. Computer Software Elements. Provides instrument-specific computer-processing capabilities for the images. Software allows general planetary science community to access the images without costly software development.

2.1 **Raw Clementine Images**

The primary data archived is the collection of raw planetary images acquired by the Clementine mission. These data are pristine in the sense that they contain the artifacts and the radiometric and geometric characteristics of unprocessed and uncorrected data. The only processing performed on the data is to organize and format the data according to PDS standards.

The Clementine images are compressed onboard the spacecraft using a space-hardened Matra chip. The compression enables acquisition of many more observations of the Moon. The compression technique performs "lossy" compression and contains a Discrete Cosine Transform (DCT) in the algorithm. The images remain in the compressed format when they are archived to reduce the total volume of the archive collection.

The Clementine images are constructed according to the data object concepts developed by the PDS. By adopting the PDS formats, the Clementine images will be consistent in content and organization with the other planetary image collections that have been archived by the PDS. The "Clementine EDR Image SIS" contains a description of the EDR image data products.

2.2 Requantization Matrices for Data Decompression

The requantization matrix for the DCT compression algorithm is modified throughout the course of a mapping cycle as the viewing conditions and science requirements change. The requantization matrix used for an image is carried as part of the image object within a compressed image file.

2.3 Browse Images

A set of browse images is provided as part of the archive to facilitate rapid viewing of the image collection. Browse images are used to visually search for areas of interest. If a browse image shows a potentially interesting scene, the image can be decompressed for more detailed inspection. Browse images are not in a compressed format, but they are reduced in size by averaging NxN pixel neighborhoods of the original image. The average is stored as a single pixel in the browse image. A browse image is stored in a secondary object in the image file.

2.4 Geometric Elements

The geometric elements are an essential part of the archive; they contain the data and information to characterize the geometric properties of the imaging systems, and to fully describe the viewing geometry of a scene. These data are essential to geodetic, cartographic, and photometric applications.

The geometric elements are organized according to the SPICE kernel concepts adopted by the Navigational Ancillary Information Facility (NAIF) at the Jet Propulsion Laboratory. SPICE is an acronym for **S**pacecraft, **P**lanet, **I**nstrument, **C**-matrix, and **E**vent kernels.

The SPICE kernel data set will be provided on the dynamic data volumes that accompany the EDR data products. SPICE kernels evolve and improve as further analysis is done. The analysis could include correcting not-yet-discovered errors and filling in missing items. It is recommended that persons needing the most complete and accurate observation geometry contact NAIF for the latest Clementine SPICE files.

The PDS data labels attached to the image data products are based on the most up-to-date SPICE information available at the time of product creation.

2.5 Radiometric Elements

The data and information characterizing the radiometric properties of the imaging systems are an essential part of the archive. These ancillary data make it possible to perform colorimetric and photometric processing on the image collection. Table 2 shows the data and information required to characterize and correct for the radiometric properties of the imaging data. The radiometric elements will be provided on the dynamic data volumes that accompany the EDR data products.

Table 2 - Radiometric Elements for the Image Archive

1. Pre-launch camera calibration data. These data are flat-field observations acquired under a variety of ambient temperature conditions, filter wheel settings, light level settings, and the full compliment camera mode settings.

2. Derived calibration files for relative radiometric correction. These files contain gain and dark current corrections for intra-camera performance.

3. Derived coefficients for absolute radiometric calibration.

4. Tables describing camera sensitivity and dark current drift.

5. Tables of camera blemishes and dead detector positions, and fixed-pattern noise.

6. Tables of spectral responsivity for each pass band.

The pre-launch calibration data consist of images acquired by the imaging instruments in a controlled laboratory environment. The image target is a flat-field of known radiance. The observations are made under a variety of temperature conditions, filter wheel settings, and camera mode settings. With these data, the performance of the camera can be determined and radiometric correction files can be derived. Additionally, these observations are used to characterize coherent- and fixed-noise problems such as blemishes and dead detectors. The Lawrence Livermore National Laboratory includes these data on the ancillary data volumes that accompany the EDR data products.

Calibration files for radiometric correction are included as part of the archive. These files include dark current and gain correction files for relative calibration (intra-camera correction), derived coefficients for absolute radiometric correction, and tables that define camera sensitivity and dark current drift. The calibration data files are to be prepared by post-mission data analysis investigators and will be made available as part of the ancillary data volumes that accompany the EDR data products.

The camera modes, camera temperatures, exposure times, filter wheel settings, and other parameters that effect the calibration of an image are stored as part of the E-kernel of the SPICE system. This data is available as part of the ancillary data volumes that accompany the EDR data products. Additionally, the information is provided in the PDS labels of the image files and the index data tables that accompany the data set.

The tables of camera blemishes, dead detectors, fixed pattern noise, and spectral band widths of the optical filters are stored as part of the I-kernel of the SPICE system. This data are available as part of the dynamic data volumes that will accompany the EDR data products.

2.6 Index Elements

The index elements of the archive exist as summary tables describing the camera characteristics and viewing geometry of the images in the archive. Each static data volume contains an index file for the images on the volume.

The index elements can be loaded into a catalog system for use in image search and retrieval applications. The table is organized as a flat file; each row is an image entry, and each column contains an attribute of the image. Part of the index table acts as the E-kernel, containing the camera settings such as filter wheel position, exposure duration, camera modes, and camera temperatures. The index table also contains "user friendly" geometric parameters that describe the viewing geometry of an image scene. These parameters are stated in terms that an image analyst is accustomed to seeing and include parameters such as sub-spacecraft latitude and longitude; latitude and longitude of the center and four corners of the image; solar-incidence, emission, and phase angles; and solar azimuth. Other fields in the index tables include time of observation, spacecraft clock time, orbit number, volume and directory location of the image in the archive, observational intent, names of calibration files to be used for an image, and other ancillary information. The "user friendly" geometric parameters represent the approximate viewing of an image scene and is intended only for image search and retrieval. The primary and refined geometric data are stored in the SPICE kernel files in the archive. Geometric processing software extracts geometry data from the SPICE kernels and not the index table. The geometric elements of the SPICE kernels are not appropriate for search and retrieval methods in their primary form and therefore are not included in the index tables.

2.7 Documentation Elements

Documentation, stored as computer readable files, is an important supplement to the archive. The documentation includes mission, spacecraft, and instrument descriptions; calibration reports; Flight Operations and Science Team reports and memoranda; literature references; and descriptions of the data products and archive contents. The documentation is critical for preservation of the knowledge of a mission after the active mission operations has been included. The documentation focuses on descriptions of aspects of the mission data that are not published in technical journals and are not available through standard published literature. These data are stored on the static and dynamic data volumes that accompany the EDR image archive.

2.8 Software Elements

The software elements provide processing capabilities that address the unique data and instrument specific aspects of the Clementine images. There are four required elements: 1) software for image decompression, 2) a processing capability for radiometric correction, 3) simple image display capability, and 4) a software toolkit to characterize the geometric properties of an image.

Software for data decompression and simple image display exist on each EDR data volume. The radiometric correction software will exist on the dynamic data volumes when they are produced. The software that characterize the geometric roperties of an image is available through the PDS NAIF Node.

In order to serve a wide range of user communities with various levels of programming proficiencies, the archive software is portable across multiple computer platforms. The software exists as executable modules,

for systems commonly used by the NASA planetary community (UNIX/SUN, IBM/PC, and Macintosh), and as source code. The source code can be adapted to meet the needs of other groups with different computer platforms. The source code also preserves the detailed decompression and radiometric correction algorithms.

The decompression and radiometric-correction programs output PDS formatted image files so existing software systems, developed by other organizations, can be used to display and access the images.

The SPICE software Toolkit, distributed by the NAIF facility at JPL, provides the software capability for characterizing the geometric properties of the imaging instruments, and the viewing geometry of a scene. This toolkit is developed in FORTRAN and is portable across several computer platforms.

The CLEMDCMP program, for decompressing a Clementine image, is found in the <software> directory. This program has been developed and tested to run on PC/MS-DOS, SUN/UNIX, and Macintosh environments. The CLIMDISP program is include in the <software> directory tree for image display for IBM/PC platforms. XV has been included to display images in the Sun/UNIX environment. IMAGE is also included to display images in the Macintosh environments. The "M-SHELL" system for PC/WINDOWS, is planned for inclusion on one of the ancillary data sets.

3. ARCHIVE DESIGN

3.1 PDS Standards

Data that comprise the Clementine Image Archive are formatted according to the standards of the Planetary Data System standard, version 3.0 as documented in the PDS Standards Reference manual [JPL Document D-7669].

3.2 Static and Dynamic Data volumes

The Clementine data sets are placed into static and dynamic categories. Static data sets, once produced and validated, are not subject to update or modification. Dynamic data sets have the inherent property that they continue to evolve and improve as the knowledge of the mission parameters improve. These data sets are periodically updated or replaced with new versions, and are likely to be updated by post-mission data analysis programs. Examples of static data sets include the raw compressed images, the ancillary data that describe the camera modes. and errata files that describe problems encountered during production of the CD-ROM volumes. Once the raw images have been received, validated, and properly stored in an archive they will never change. Likewise, the camera modes, once properly recorded, will not change. Examples of dynamic data sets are calibration files for radiometric correction and the C-kernel containing the camera pointing matrix. Calibration files continue to evolve as knowledge of the camera properties improves. The C-kernel is updated in geodetic and cartographic applications.

In the archive, the static and dynamic data sets are physically separated into different volumes. The static data set, containing the raw planetary data make up virtually the entire archive volume set. The

dynamic data sets (calibration files, and SPICE kernels) have modest storage requirements and can be stored on one or two volumes. Once the static volumes are created and validated, they need never be recreated or updated--a desirable quality for the volumes that make up most of the archive. As the dynamic data sets are improved and updated, only the limited number of volumes dedicated to the dynamic data need to be redistributed. Mixing dynamic and static data sets on the same volumes would cause considerable logistic problems in maintaining the archive.

3.3 Handling Errors

It is inevitable that errors will be introduced into the archive even with data validation procedures applied to the volumes. A plan is required to handle errors discovered in data volumes that have already been produced.

As errors are discovered, they are reported to the NRL Clementine data processing facility. An ERRATA report file is maintained to track and document all discovered errors. At the conclusion of the production of the Clementine volume set, a final CD-ROM is prepared that contains corrected files of all problem files.

4. FILE NAMING CONVENTIONS

The file names developed for PDS data volumes are restricted to an 8 character file name and a 3 character extension name with a period separating the file and extension names (this limitation is due to limited file naming scheme of Microsoft DOS). The general form of a file name is "msfxxxxy.rrr" for the Clementine imaging data. Table 3 provides the detailed naming convention for lunar mapping phase of mission. Table 4 describes the file naming convention for non-lunar mapping phases.

Table 3 - File Name Convention, Lunar mapping phase: "msfxxxxy.rrr"

m = Mission Phase
- P = Prelaunch
- L = Lunar mapping
- E = Earth mapping (LEO and phasing loops)

s = Sensor
- A = Star tracker A
- B = Star tracker B
- U = UV/VIS
- H = Hi-Resolution sensor
- N = Near infrared sensor
- L = Long wavelength infrared sensor

f = Filter wheel position (A, B, C, D, E, F)

xxxx = Frame number within revolution

y = Latitude bin for lunar mapping observations. This character signifies a latitude range on the lunar surface where the observation was made. The center latitude of the image defines the character:

A = -90 to -80	M = 30 to 40
B = -80 to -70	N = 40 to 50
C = -70 to -60	O = 50 to 60
D = -60 to -50	P = 60 to 70
E = -50 to -40	Q = 70 to 80
F = -40 to -30	R = 80 to 90

G = -30 to -20
H = -20 to -10
I = -10 to 0
J = 0 to 10
K = 10 to 20
L = 20 to 30

S = "unkown" targets

T = Earth observations prior to systematic mapping

U = Sky observations prior to systematic mapping

V = Lunar observations prior to systematic mapping

W = Sky observations after systematic mapping

Y = Earth observations after systematic mapping

Z = Moon Observations after systematic mapping

Table 4 - File Name Convention, non-Lunar mapping phase: "msfxxxxy.rrr"

m = Mission Phase
P = Prelaunch
L = Lunar mapping
E = Low Earth Orbit (LEO) mapping phase

s = Sensor
A = Star tracker A
B = Star tracker B
U = UV/VIS
H = Hi-Resolution sensor
N = Near infrared sensor
L = Long wavelength infrared sensor

f = Filter wheel position (A, B, C, D, E, F)

xxxx = Frame sequence number within a down-load dump of the spacecraft's solid state data recorder. The The solid state data recorder, holding acquired images, is periodically down-loaded to Earth. Images are numbered sequentially by time of observation.

y = Alpha character. Each 100 sequential images of a camera are assigned an alpha character A-Z. This scheme used to place 100 images per subdirectory.

rrr = Memory down-load sequence number. This number is incremented by one each time a down-load is made of the solid state data recorder within a mission phase.

Examples of file names follow:

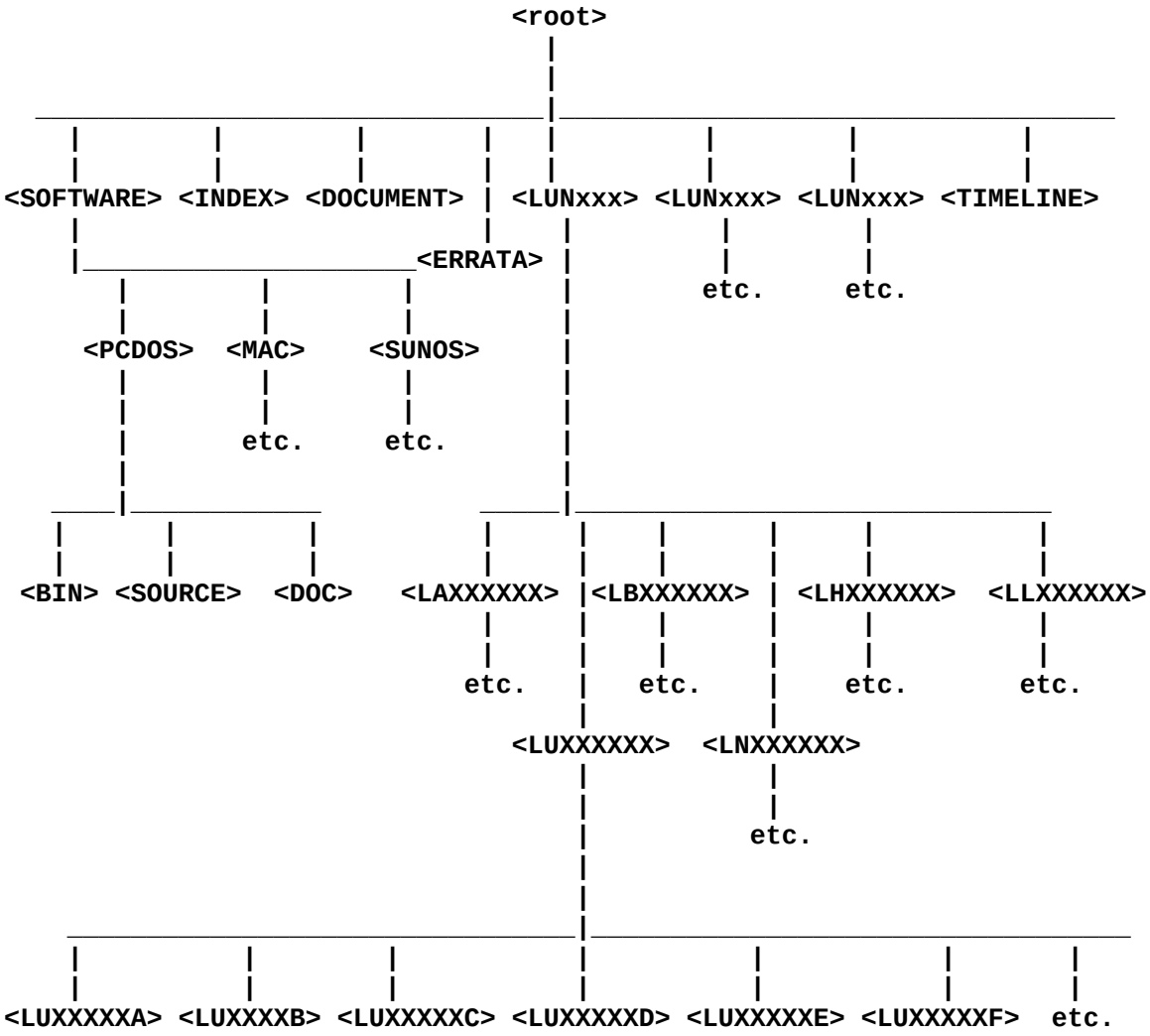
LUA0323B.020 = Image was acquired during the Lunar mapping phase (**L**), by the UV/VIS camera (**U**), with filter wheel position (**A**) (blue filter), the image was the **323**-rd image acquired during orbit **20**. The image falls within the latitude range -80 to -70 (**B**).

ENA0600B.001 = Image was acquire during the Low Earth Orbit phase of mission (**E**) by the Near-Infrared camera (**N**), with filter-wheel position **A**. It is the **600**-th image acquired for the first dump (**001**) of spacecraft's solid state recorder. The image is in the second set of 100 images acquired by the NIR camera (**B**).

5. DIRECTORY STRUCTURE AND CONTENTS FOR STATIC VOLUMES

Figure 1 shows the directory structure overview for the static volumes. Below the root directory are the SOFTWARE, DOCUMENT, INDEX, and orbit directories. Below the SOFTWARE directory are subdirectories for storing software for various hardware platforms. A detailed description of the directory tree is provide in Table 5. An ERRATA directory may exist on the final volume in order to hold any files that were improperly processed in the volume set. Empty directories are not included on the volume. For example, if a star tracker directory (example <LAXXXXXX>) contains no files for an orbit, the directory will not appear on the volume.

TABLE 5 Directory Structure Overview



5.1 Directory Contents

<root> Directory

AAREADME.TXT - General information file. Provides users with information about the Clementine image data products. Directs user to other documents on the volume containing more detailed information.

VOLDESC.CAT - PDS file containing labels that describe the volume data products. Information includes: production date, producer name and institution, volume ID, etc.

ERRATA.TXT - Text file for tracking and recording discovered errors in the Clementine image data products. (This is an optional file.)

<ERRATA> Directory

The <ERRATA> directory tree is reserved for the last volume in the static volume set of the archive. The tree stores data files that correct files of previous files that had errors. The directory tree maintains the same structure as on other volumes.

<DOCUMENT> Directory

The documentation files exist in several forms in order to facilitate access to the documents.
<> Files with extension **'TXT'** or **'ASC'** are ASCII text files that can be read by virtually all text editors.
<> Files with extension **'DOC'** were created with Microsoft-word.
<> Files with extension **'EPS'** are encapsulated PostScript format.

DOCINFO.TXT - Description of the DOCUMENT directory

VOLINFO.* - The files contain detailed descriptions of the Clementine mission, imaging instruments.

EDRSIS.* - Contains the Software Interface Specification for the EDR Image data products. Different formats of EDRSIS exist.

ARCSIS.* - Contains the Software Interface Specification for the Clementine Archive of EDR data products.

<INDEX> Directory

INDXINFO.TXT - Text file describing contents of <INDEX> directory

IMGINDX.TAB - The image index file is organized as a table: there is a row for each image on the volume; the columns contain parameters that describe the observation and camera states of the images. Information includes viewing geometry (such as latitude and longitude of the image center, sun and observation angles, etc.

and camera state information such as filter wheel position, spacecraft clock count, time of observation, image integration time (effective exposure time), and camera modes.

IMGINDX.LBL - Detached PDS label for IMGINDEX.TAB. The image index file is accompanied by a detached PDS label that describes its organization and contents.

IMGINDX.HDR - Header file, used for spread sheet applications for the image index file. This file contains a single line that gives heading names to each row in the index file.

MISSINDX.TAB - Table of missing images. Image file names in this directory were lost during the active fight projects due to a variety problems including: images not properly transmitted to Earth, image files lost between ground receiving station and mission operations center. Images listed in this directory can not be recovered.

MISSINDX.LBL - Detached PDS label that describes the MISSINDX.TAB file.

MISSINDX.HDR - Header file used for spread sheet applications for the missing image index file. This file contains a single line that gives heading names to each row in the missing image index file.

REDOINDX.TAB - This index table may exist on a CD-ROM volume in the <index> directory. If an image could not be recovered from the telemetry archive before a volume was created, then this table contains a list of the image files that will be reprocessed for inclusion on the last volume. This file is identical in format to the IMGINDX.TAB file.

REDOINDX.LBL - Detached label for REDOINDX.TAB

REDOINDX.HDR - Header file used for spread sheet applications for the image index file. This file contains a single line that gives heading names to each row in the index file.

<SOFTWARE> Directory

The software directory and sub-directories contain source code, executable modules, and documentation for the programs available to access and display the Clementine Images. These are simple software tools and not meant to be comprehensive image processing applications. Simple access and display tools are available for the SUN, PC, and MAC environments. Software for each subdirectory is located in subdirectories. Please refer to the "SOFTINFO.TXT" files in the SOFTWARE directory tree for information about each software element included in the Clementine archive.

SOFTINFO.TXT - This file describes the contents of the SOFTWARE directory.

<SOFTWARE.PCDOS> - PC/DOS system
<SOFTWARE.MAC> - Macintosh system
<SOFTWARE.SUNOS> - SUN/UNIX system

<LUNxxx> - Data Directory

These are the top level directories for the EDR image data products. The names of the data directories define the mission phase (**LUN**=Lunar, **LEO**=Low Earth Orbit **EPA**= prelunar mapping phasing loops, **EPB**=postlunar mapping phasing loops). The "**xxx**" characters refer to the revolution number for lunar mapping phase, and solid state recorder down-load dump number for non-lunar mapping phases. The subdirectories under this directory divide the data by camera.

<LUNxxx.LAXXXXXX> - Subdirectory of Star tracker A camera images
<LUNxxx.LBXXXXXX> - Subdirectory of Star tracker B camera images
<LUNxxx.LHXXXXXX> - Subdirectory of Hi-Resolution camera images
<**LUNxxx.LNXXXXXX>** - Near Infrared camera images
<LUNxxx.LLXXXXXX> - Long Wavelength Infrared camera images
<LUNxxx.LUXXXXXX> - UV/Visible camera images

<LUNxxx.LAXXXXXX.LUXXXXXA>
<LUNxxx.LAXXXXXX.LUXXXXXB>
<LUNxxx.LAXXXXXX.LUXXXXXV>
etc.

The directory tree is further subdivided by into additional subdirectories so that there are no more than 256 images per directory. For the lunar mapping phase of the mission, images acquired in a revolution are divided into 10 degree latitude bins. Each subdirectory contains all the data in a 10 degree bin. (A=-90 to -80, B=-80 to -70, C=-70 to -60, etc.)

<TIMELINE>

This directory was added as part of the volume just when production of the volume series began. Because of the late addition of the files contained in this directory, they do not conform to PDS standards. Because these files are supplemental to the overall requirements of the volume design, it was decided that PDS requirements were not required. The timeline data, provided in PDS compliant format, will be made available through the SPICE system on the Clementine ancillary CD-ROM series.

TLINFO.TXT - Description of the time line data available for each lunar orbit.

TLLUNxxx.XLS - Microsoft EXCEL spread sheet file of the time line data for orbit 'xxx'. **TLEPAxxx** files for earth phasing loop A data, **TLEPBxxx files** for earth phasing loop B data, **TLLEOxxx** for low earth orbit data.