UPDATES TO THE CHANDRAYAAN-1 MOON MINERALOGY MAPPER ARCHIVE. M. St. Clair[1], C. Million[2], and A. Ianno.[3,] Million Concepts (mstclair@millionconcepts.com)

Introduction: The Moon Mineralogy Mapper (M3) [1, 2] was a hyperspectral camera hosted on the Indian Space Research Organization's (ISRO) Chandrayaan-1 (CH-1) lunar orbiter [3]. It was funded by NASA and formally managed as a collaboration between Brown University and JPL (although the M3 team included personnel from many other institutions and organizations). Between November 2008 and CH-1's untimely demise in August 2009, M3 imaged ~95% of the lunar surface to ~30 nm spectral and ~140 m spatial resolution in the 460-3000 nm range, and smaller portions of the lunar surface to ~10 nm spectral and ~70 m spatial resolution in the 400-3000 nm range. [4] Its observational data corpus provides one of the most complete hyperspectral surveys of the lunar surface to date, matched only by the slightly less complete maps provided by Kaguya / SELENE's spectrally finer but spatially coarser Spectral Profiler. [5]

In collaboration with USGS Astrogeology personnel at the PDS's Imaging Node (IMG), We have produced a Planetary Data System Version 4 (PDS4) bundle that modernizes this crucial data archive in order to improve accessibility, discoverability, and maintainability:

Title: *Chandrayaan-1 Orbiter Moon Mineralogy Mapper Collected Data Sets*

Logical Identifier (LID): urn:nasa:pds:ch1_m3

It is presently in review with the PDS, with expected release in Q2 or Q3 2021.

Existing Archive Contents: The M3 archive is currently held by IMG. It primarily contains files produced by the M3 instrument team, along with supporting materials from ISRO and other JPL groups. It was initially delivered to IMG in June 2010 and received several additions and revisions up to August 2012. These holdings are divided among 3 data sets:

1. CH1-ORB-L-M3-2-L0-RAW: L0 data; instrument telemetry depacketized and labeled at JPL but uncalibrated and left in raw detector counts [6]
2. CH1-ORB-L-M3-4-L1B-RADIANCE: L1B data; the L0 data selenolocated and reduced to units of radiance at JPL (three versions of this set exist; we drew on the final, most-revised one) [7]
3. CH1-ORB-L-M3-4-L2-REFLECTANCE: L2 data; the L1B data photometrically corrected and reduced to reflectance values at Applied Coherent Technology Corporation [8]

These sets are stored across four data volumes: USA_NASA_PDS_CH1M3_0001 - 0004 [9]. In addition to observational data, these volumes contain documentation, calibration, and geometry products.

New Features of PDS4 Bundle: L1B and L2 observational data were previously stored as ENVI arrays with detached headers. L0 data were archived in an unusual, deprecated ENVI format specified by ISRO that includes detailed timing information in a line prefix table -- an "interleaved" table that packs binary clock ticks on the "edge" of the image array. We have converted all observational data (and other binary arrays) to simple FITS arrays, and decoded unusual objects like the L0 timing tables into detached CSV tables.

We have organized all data objects into PDS4 products with consistent, compliant labels, supported by a minimal mission dictionary (shared with the CH-1 mini-RF instrument data archive) [10]. This includes objects like calibration files that were not formally organized as PDS3 products in the source archive. The bundle also contains a variety of other small changes for PDS4 compliance -- number format changes, PDF standardization, and so on -- and corrects some inconsistencies in the PDS3 metadata structure. Finally, it contains high-quality summary documentation intended to provide users with a rapid overview of the bundle's contents, provenance, and capabilities.

Methodology and Tooling: In the course of this conversion effort, we developed a flexible Python software stack for generating PDS4 products. Its purpose is similar to that of the PDS Transform Tool [11] and the Metadata Injector for PDS Labels [12], but is designed to fill a separate niche. Specifically, it is designed to support use cases in which some or all of the following are true:

1. Data as well as metadata require modification, especially if it is efficient or desirable to transform data and metadata simultaneously
2. Some metadata required for PDS4 labels are not available in individual PDS3 labels; PDS3 labels are not available for some products; or, for whatever other reason, PDS4 metadata attributes cannot be populated by performing operations on PVL
3. Metadata attributes require manipulation that is difficult or impossible to perform in the Velocity template language (particularly if it is not being used as part of a Java workflow)

This stack is based around *pdr*, the Planetary Data Reader [13], a pre-alpha project eventually intended for inclusion in the open source PlanetaryPy project [14]. It provides a class, pdr.Data, that represents a data product, including metadata and one or more digital objects, as a single logical entity. The class constructor transparently reads PDS3 and PDS4 labels (using *pvl* [15] and *pds4_tools* [16]). It loads their referenced digital objects, like images and tables, into standard Python formats like *numpy* arrays and *pandas* DataFrames, providing an interface that allows developers to rapidly and efficiently manipulate planetary data and metadata at the product level using terse, idiomatic Python. pdr is not intended primarily as a product conversion library, but it provides a logical and conceptual infrastructure for the *pdr.converter* module, which is.

pdr.converter implements subclasses of *pdr*.Data designed to support transformations between 'versions' of a data product. Further submodules (in this case, *m3_conversion*) subclass members of pdr.converter to cover specific data sets and product categories. They allow developers to flexibly specify logic that defines and enacts relationships between 'versions' of data and metadata, including transformations defined by operations in external libraries and tools (like *fitsio*, *astropy-.io, gdal*, or even non-Python tools ranging from the PDS Validate Tool to legacy mission software).

pdr.converter also implements a very simple XML template system for creating PDS4 labels. We intentionally do not incorporate a full-scale template engine/language like Genshi or Velocity. Any complicated formatting or modification of individual metadata attributes is intended to occur in Python. pdr.converter templates simply contain flags that tell a pdr.-converter object's label-writing method where to place specific metadata (or which sections of a label to not render at all).

Opportunities: First and foremost, this bundle will make M3 data more accessible to new users, both by easing incorporation of data into new workflows and supporting discoverability via PDS's forthcoming product search and other tools for exploring PDS4 data. Ready access to low-level timing information currently stored in a hard-to-interpret file format may also help efforts to recalibrate and register data.

The M3 data corpus has many known ‘scientific’ issues entirely distinct from the category of ‘format issues addressed by our conversion effort. These include both photometric calibration problems (some of which have unapplied correction 'recipes' in the archive) and geometric problems (due partly to problems with CH-1's star trackers). An ongoing multi-institution project [17] is in process to correct some of these issues, but continues to experience uncertainties of unknown origin that have prevented a full release [18]. We hope our modernized bundle serves as useful infrastructure for this and other projects, providing opportunities for researchers to use, fuse, and further improve this unique and essential corpus of observational data.

References:

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