LROC Planetary Spatial Data Infrastructure Overview. N. M. Estes, K. N. Paris, J. S. Barnett, K. S. Bowley, J. Leland, R. Hoppe, L. Davis, B. Beal, M. S. Robinson, and the LROC Team, School of Earth and Space Exploration, Arizona State University, nme@ser.asu.edu

Introduction: A well-designed Planetary Spatial Data Infrastructure (PSDI) plan guides all phases of a project from data collection to long-term data archiving. PSDI should leverage standards wherever possible to maintain compatibility with common software packages and make the data as easily accessible as possible. This accessibility includes searching, downloading, and interacting with the data. In recent years, the Mapping and Planetary Spatial Infrastructure Team [1] has been organizing a community effort to establish standards and best practices for a PSDI, and the Lunar Reconnaissance Orbiter Camera (LROC) team is excited to participate in this ongoing community effort. The LROC PSDI was developed over the past 9 years and continues to evolve, making LROC data more accessible by more users in a wider variety of software packages.

The LROC dataset contains experiment data records (EDR), calibrated data records (CDR), reduced data records (RDR), and ancillary files (browse images, histograms, etc) for a total of >13 million files with a total size of 938 TB. LROC data users include scientists, student researchers, teachers, and the public. No single interface or tool can satisfy the needs of such a diverse group, so a variety of tools and documentation included in the LROC PSDI make the data easy to find and navigate.

Processing: Dataset consistency, validation, and compatibility are a direct result of how a dataset is processed and archived. The LROC dataset is processed through a series of automated pipelines [2] that are managed by a software suite written in-house called Rector [3, 4]. All products are recorded and tracked in a PostgreSQL database along with checksums, creation times, and other tracking information. LROC data are released as Planetary Data System (PDS) 3 products. Each product also has a pyramidal TIFF browse product (GeoTIFF in the case of map projected products) that supports many other components of the PSDI.

In addition to automated EDR and CDR processing, the LROC science team generates many types of RDR products including a global Wide Angle Camera (WAC) DTM [5], Narrow Angle Camera (NAC) DTMs [6], photometrically normalized WAC mosaics [7, 8], controlled NAC mosaics [9], shapefiles, and other products.

Archive: A typical PDS release from LROC contains approximately 60,000 EDRs and CDRs, a variable number of RDRs, and a large number of ancillary products (approximately 400,000 files total). An automated tool gathers all EDR and CDR data for a PDS volume, stages both the file system and database changes necessary to publish the volume, and generates all the PDS index files and other metadata that accompany each volume. Once published, the data are available through the NASA PDS system, and the PDS tree is directly navigable on the LROC PDS data node [10]. The LROC PDS archive is then augmented with a variety of tools to create the overall PSDI.

Desktop GIS: Lunaserv is a web map service (WMS) software package developed at the LROC SOC [11, 12]. WMS is a standard used by a wide variety of geographic information system (GIS) tools to access large geographic datasets without first downloading or processing them. The Lunaserv server hosted at the LROC SOC hosts over 150 layers of LROC maps, observation footprints, regional products, and other lunar data. By leveraging the WMS standard, these data can then be used in websites, and in desktop GIS tools such as ArcGIS, QGIS, JMARS, GRASS, and many more. As part of the LROC PSDI, Lunaserv provides access to end users as well as providing map services to the other components in the LROC PSDI.

In-Browser GIS: Another important tool in the LROC PSDI is Quickmap [13]. Quickmap makes available the same data served by Lunaserv, but within the context of an online GIS tool. Quickmap provides many navigation and analysis tools that help a user quickly find and visualize the data they need. While Quickmap does not have as large or complex a set of analysis tools as a desktop GIS package, the ability to explore the Moon using nothing more than a web browser puts many capabilities at the user's fingertips without the need for any complex or expensive software packages.

Search Interfaces: While most RDR products are map projected, LROC EDRs and CDRs are not, so

they cannot be placed directly on a map without additional processing steps. Both Lunaserv and Quickmap can find these products, but more specialized search interfaces also exist [14, 15] that provide the ability to narrow down data based on time, lighting conditions, and other metadata. The browse images created for each LROC PDS product are pyramidal TIFF. This format tiles the image as well as storing multiple resolutions of the image. This specialized file format allows every product in the LROC dataset to be browsed at full resolution online without downloading the product first or installing any software other than a web browser.

Curated Interfaces: In addition to the mapping and PDS interfaces that make the entire LROC dataset available, there are also two interfaces that provide access to a limited curated set of images.

*Featured Sites [16]:*There are many commonly requested sites on the Moon: Apollo, new impact, spacecraft impact, and robotic exploration sites. A large number of images for each site are available via the Featured Sites interface that include the ability to browse traverse maps, view different lighting conditions, and other features. This functionality is also available on LROC kiosks in the LROC visitor center at Arizona State University in Tempe, AZ, the National Air and Space Museum in Washington D.C., and the Ries Crater Museum in Nördlingen, Germany.

Featured Images [17]: The LROC dataset is used to make new discoveries and provide new views of many interesting features. On a regular basis, members of the LROC science team write posts about one of these features. Nearly a thousand of these posts have been made to date, and they are all available via the Featured Images section of the LROC website. When looking for information on a lunar feature, this section can be a great place to start. Referenced products all list PDS product IDs to facilitate going back to the original data. High resolution images used in each post are made available with full resolution image browsing, and in many cases, map links are available enabling seamless further exploration.

Outreach: With multiple options available to access the LROC dataset, educating LROC data users on how to select and use these interfaces for various projects is an important consideration. For example, the LROC team has a presence at the Lunar and Planetary Science Conference and the Planetary Data Workshop (PDW). A brochure that lists all the tools and uses together with typical use cases is also available in addition to human expertise to answer detailed questions. Work is ongoing adding helpful documentation in the tools themselves or with each product. Featured Image posts are published when a new tool or major revision is made. The archive section of the LROC website also contains a list, description, and links to many of these tools [18].

Conclusion: Making such a large dataset easy to search and use by a diverse user base is a difficult task. The LROC PSDI includes several components that work together to make this dataset as accessible as possible within in the allocated resources. Several tools are available to access LROC data that facilitate the most common use cases both in the browser and in more specialized software packages. The downside to having multiple interfaces is helping the user find which interface is the best tool for their particular need. The LROC team is employing a variety of methods to inform people on the availability and function of these interfaces.

Future Work: Web and GIS standards are a moving target. As new standards, tools, and techniques become available, we will evaluate and incorporate them into the LROC PSDI as appropriate. Work is also underway to revamp the search interfaces for EDR, CDR, and RDR data to provide a more streamlined and intuitive experience for LROC data users.

References: [1] Radebaugh J., PDW (2017), MAPSIT Overview and Goals [2] Paris, K. N., et al., PSIDA (2018), #6059 pipeline abstract [3] Estes, N. M., et al., PDW (2012), p.55 [4] Estes, N. M., et al., PSIDA (2018), #6035 [5] Scholten, F., et. al. (2012), , JGR., 117, E00H17, doi:10.1029/2011JE003926. [6] Henriksen, M. R., et al., Icarus (2017), 283, 122-137. [7] Boyd, A. K., et al., LPSC (2012), #2795 [8] Sato, H., et al., (2014), JGR, 119, doi:10.1002/ 2013JE004580 [9] Klem, S. M., et al., LPSC (2014), #2885). [10] http://lroc.sese.asu.edu/data/ [11] Estes, N. M., et al., PDW (2015), #7035 [12] http://webmap .lroc.asu.edu/ [13] http://quickmap.lroc.asu.edu/ [14] http://wms.lroc.asu.edu/lroc/search [15] http://wms .lroc.asu.edu/lroc/rdr_product_select [16] http://lroc .sese.asu.edu/featured_sites [17] http://lroc.sese.asu .edu/images [18] http://lroc.sese.asu.edu/archive