BUILDING A LUNAR SPATIAL DATA INFRASTRUCTURE (SDI). T. M. Hare[1], B. J. Thomson[2], L. R. Gaddis[3], J. Stopar[3], B. A. Archinal[1], J. R. Laura[1] and the MAPSIT steering committee, [1]U. S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ, thare@usgs.gov, [2]Dept. of Earth and Planetary Sciences, Univ. of Tennessee, Knoxville, TN, [3]Lunar and Planetary Institute, Houston, TX.

Introduction: Within the past decade, the planetary community has worked to define spatial data infrastructures (SDIs). An SDI is a robust framework for (1) data and data products, (2) metadata and data access mechanisms, (3) standards, (4) policies, and (5) a user community that helps to define and standardize data and data access necessary to meet common goals [1]. For a planetary spatial data infrastructure (PSDI), Laura and Beyer [2] define the following as required *foundational geospatial data products*: (1) geodetic control networks; (2) topography; and (3) rigorously (i.e., photogrammetrically) controlled and orthorectified images (monochrome or color) tied to a standardized reference frame. They also define higher order, derived products like geologic or compositional maps and feature catalogs as *framework products*. Framework products are no less important and are enhanced by being tightly coupled or tied to the foundational data sets.

PSDI Use Case—The Moon: Given its long history of exploration and the sheer amount of ground-based and spacecraft data gathered for the Moon, a lunar SDI may seem straightforward to envision. However, while gravity information from the Gravity Recovery and Interior Laboratory (GRAIL, [3]) mission and topography from the Lunar Orbiter Laser Altimeter (LOLA, [4]) mission have drastically improved our knowledge of the detailed shape of the lunar geoid (selenoid), many image data sets do not conform to the rigorous definition for a photogrammetrically controlled product. To develop a lunar SDI, this criterion and the other PSDI requirements (i.e., standardized policies, metadata, methods to store and access the data, and support for an international user community) must all be met. Here we briefly introduce the five PSDI themes [5] to aid in the development of a lunar SDI.

PSDI Theme 1—Foundational Data Products: Both existing lunar foundational data and framework data (e.g., geology, mineralogy, feature catalogs) are available as major elements of a lunar SDI. Below, we only list the currently available lunar foundational data sets in order of increasing spatial resolution. To be included, these data should be at a minimum tied to the corrected LOLA spot observations or derived elevation models [4]. For a more complete list of lunar data products and **additional data set references**, please see this publication [2] and presentations [6].

- LOLA defines a lunar geodetic coordinate reference frame and global topography. The spatial resolution of the LOLA-derived digital elevation models are dependent on location, but global extent is good at ~60 m/pix and conservatively the absolute horizontal uncertainty up to ~20 m with a vertical uncertainty of ~1m. Although, gaps between the LOLA tracks of 1 to 2 km are common, and some gaps up to 4 km occur near the equator. Site-specific LOLA-derived products near the poles [7] are sampled to 5 m/pix with a stated improvement for relative horizontal uncertainty and vertical uncertainty of 0.50 m or better. Also, the LOLA/Kaguya Terrain Camera (TC)–derived topography, called SLDEM2015, has a spatial extent from 60°S and 60°N and can be used as a reference geodetic framework at 60 m/pix for non-polar data. All these products are available from the Planetary Data System (PDS).
- LROC NAC controlled mosaics for the poles [8] cover 85.5°N and 90°N and 85.5°S and 90°S at 1 m/pix; these were created by USGS/Astrogeology in 2011 and are available from the Jet Propulsion Laboratory's Moon Trek (https://trek.nasa.gov).
- Lunar Reconnaissance Orbiter Camera narrow angle camera (LROC NAC) supports stereo-derived topography and orthorectified images [2, 6]. However, these products created by Arizona State University (ASU), the University of Arizona, USGS/Astrogeology, and a few other facilities, offer only very sparse spatial coverage at 0.5 to 2 m/pix for orthoimages and 2 to 5 m/pixel for derived topography. These products are available from the PDS and JPL's Moon Trek.

Laura and Beyer [2, p. 10] described other available lunar data products which are *"qualitatively of exceptional accuracy,"* but they cannot be identified as foundational using the strict PSDI definition because their uncertainties are undetermined. This includes data like the LROC wide angle camera (WAC) global mosaic from ASU, the forthcoming (and updated) Clementine UVVIS/NIR mosaic, and the Apollo metric camera mosaic from NASA Ames. Laura and Beyer also describe the mosaics generated from Kaguya terrain camera (TC) to be internally consistent but not tied to LOLA. And finally, the Chandrayaan-1 Terrain Mapping Camera (TMC) may indeed be foundational, but the products are not readily accessible for comparison.

PSDI Theme 2—Data Access and Metadata: A priority goal for any lunar SDI would be to design and maintain a strategic investment in data access that transcends individual missions. This includes goals for deploying a lunar SDI catalog/registry for the discovery of existing analysis-ready data (ARD) and the development of standards and best practices on how to characterize, capture, and represent uncertainty and distortion within the metadata for each product. Such infrastructural services and data catalogs will help to distinguish the needed data storage and access from the many tools that would make use of the data.

The term ARD is meant to define products which are consistently processed to the highest scientific standard and level required for direct use, distributed in a common cartographic projection and format, and accompanied by descriptive metadata while also retaining the traceability of data provenance. Supporting ARD products in this manner should significantly reduce or remove the need for further data processing by the community.

PSDI Theme 3—Standards: A lunar SDI should also define goals related to standards. This might include a common metadata format and data access standards as well as the following:

- Updating of lunar coordinate system and orientation standards, as recommended by the Artemis III SDT [9, Rec. 8.2-1].
- The promotion of common data formats for interoperability between different applications and facilities.
- The establishment of cartographic standards (e.g., symbologies) for engineering elements required for exploration zones, leveraging existing cartographic standards when possible (e.g., from the Federal Geographic Data Consortium).
- Defining standards and best practices for converting, distributing, visualizing, and archiving temporal data sets (e.g., 3D + time).

PSDI Theme 4—Policies: A lunar SDI should define responsibilities and policies established by a lunar SDI governing board or working groups (WGs). An example charter might include:

- A body through which the WG is chartered (e.g., NASA, LEAG, MAPSIT, etc.) to integrate and manage lunar SDI efforts.
- Rules by which to operate (e.g., "by consensus"), commonly agreed upon procedures for making decisions and findings, and an understanding that all decisions and/or recommendations will be communicated to the chartering body.

PSDI Theme 5—User Community: A lunar SDI should prioritize the fostering of a community of practice to support lunar SDI coordination, technical task execution, and sharing of knowledge and capabilities. This includes providing guidance to self-moderated citizen science initiatives and public outreach efforts to aid them in processing data and publishing any ARD in standardized formats with appropriate metadata. A lunar SDI may also define optional services for the community, for example, a method to geospatially link features (e.g., Shackleton crater) to relevant published research to improve feature identification, ease of access, and searchability.

Conclusion: Under a single international lunar SDI umbrella, representative working groups should be built from planetary community members (e.g., mission planners and engineers, scientists, data providers, outreach specialists) to develop goals and identify the data and steps needed to fully support landing site analysis and eventual human operations on the Moon. Lunar SDI WG(s) would then need to perform a full knowledge inventory to help identify strategic gaps in foundational data products, continue to assess the current state of data interoperability in off-the-shelf geospatial tools and available data access methods, as well as to engage and involve the data providers and user communities.

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