

Planetary Spatial Data Infrastructures: Europa and the Moon SDIs J. R. Laura¹, R. Beyer^{4,5}, M. T. Bland¹, R. L. Fergason¹, T. M. Hare¹, L. Keszthelyi¹, N. E. Petro⁶, C. B. Phillips², P. Schenk³, J. D. Stopar³ ¹USGS Astrogeology Science Center 2255 N Gemini Drive, Flagstaff AZ 86001; jlaura@usgs.gov, ²NASA JPL / Caltech, Pasadena, CA. ³Lunar and Planetary Institute (USRA), Houston TX. ⁴SETI Institute Mountain View, CA, ⁵NASA Ames Research Center, Moffett Field, CA, ⁶NASA Goddard Space Flight Center, Greenbelt, MD.

Introduction: Planetary Spatial Data Infrastructures (PSDIs) are community efforts focused on harmonizing geospatial data and standards to support the interoperability of planetary data. PSDIs are broadly supportive of the efforts of the NASA Planetary Data Ecosystem (PDE) [1] to improve discoverability and access to usable spatial data. As previously described [2], these SDIs provide distinct but complementary functions to NASA's Planetary Data System (PDS) within the PDE. At the current early stages, the Europa and Lunar SDIs seek to put a governance structure and standards into place with examples of foundational analysis ready data (ARD) products. The goal is to foster and sustain an environment that supports both data creators and data users. In this environment, data creators across the community will have resources to facilitate data product creation, and mechanisms to ensure products that are readily discoverable, accessible, and usable by users with expertise outside of geospatial data processing. In other words, foundational ARD are usable without each scientist needing to individually process each data set. A key component of this effort is to make available clear and complete descriptions of the processing applied to each data set, because these can determine if a data product is appropriate for a given scientific problem. Another critical element is to leverage new technologies to effectively transport the data from remote locations to the users' analysis environments.

Two planetary SDI governance groups are currently in existence, a Europa SDI (initiated October 2020) and a Lunar SDI (initiated May 2021). Herein, we describe the current state of the governance documents, standards, data availability and efforts of the respective SDIs. Europa and Lunar SDI governance documents, meeting notes, standards documents, and general planetary spatial data infrastructure information are freely available at <https://psdi.astrogeology.usgs.gov/>.

Europa SDI: The Europa SDI working group, as chartered by NASA's Mapping and Planetary Spatial Infrastructure Team (MAPSIT), continues to focus on analysis-ready data availability and services, but has developed a clear path forward as described below.

Governance: The Europa SDI has formally adopted a governance structure with eight primary objectives, as described in the charter. These include: (1) the publication and stewardship of the policy infrastructure

necessary to maintain the SDI and all data providing or sharing agreements covered by the SDI, (2) engage the user community, funding agencies, and NASA advisory groups (AGs) to ensure alignment of the SDI efforts with the users community, (3) publish a set of data standards to ensure interoperability, (4) maintain an inventory of foundational and framework data products with and for the Europa community, (5) provide the infrastructure to link together data creators, data providers, and data users, (6) support (through policy and standards) the creation and maintenance of compliant data discovery and access portals (7) ensure the public release and promotion of Europa SDI managed data products and APIs, and (8) engage with tool developers to ensure tools take full advantage of the available data and services. In support of these objectives, the group has formally adopted the following:

Standards: The standards promoted and formally adopted by the Europa SDI are designed to align with current best practices used by the Europa community and with Open Geospatial Consortium (OGC) standards. Of note, to the Europa SDI has adopted a 0-360 positive East coordinate system centered at 180° using planetocentric latitude. Data for non-polar regions (<55°) will be stored and made available at pixel resolution using a simple cylindrical projection and polar data are stored in an pole centered orthographic projection.

Data Availability: The Europa SDI has, in alignment with SPD41 and SPD41a, encouraged that data be released under the CC0-1.0 (public domain), CC-BY (attribution), or CC-BY-SA (attribution + share-alike) licenses (<https://creativecommons.org/>). Data released in this way are freely usable and can be the foundation for derivative works. Initial data releases and Europa SDI compliant data are described at <https://stac.astrogeology.usgs.gov/docs/data>.

Strategy and Roadmap: The Europa SDI has published (<https://psdi.astrogeology.usgs.gov>) a roadmap of efforts to be completed by the end of 2025. These include (1) the publication of our governance documents, (2) engagement with user groups, funding agencies, AGs, and mission teams (e.g., Europa Clipper and JUICE), (3) publication of adopted data standards, (4) continued maintenance of the inventory of foundational data products, (5) engagement with data

creators and data providers, (6) promote the development of data discovery and access portals for Europa SDI compliant data, (7) maximize the public release of analysis ready Europa data, and (8) engage with tool developers. The roadmap aligns with the priorities in the charter.

Future Work: The Europa SDI working group is currently focusing on two primary tasks. First, the definition of a horizontal datum using the work done by Bland et. al [3] and combining it with new work being done by Schenk [this volume]. This effort will mean that data can be release using consistent horizontal and vertical (the IAU defined sphere) datums. Second, the Europa SDI is beginning the process of engaging with the user community. This includes not only interaction with upcoming missions, but also outreach to community members with data that they would be interested in making broadly available. If you have Europa data that you are interested in making available, please see below and reach out to the Europa SDI working group.

Lunar SDI: A nascent Lunar SDI working group has been established to help support lunar research, landing site analysis and eventual human operations.

Governance: The Lunar SDI has drawn heavily from the successfully adopted Europa SDI governance model. At the time of writing, the governance model is published in an unadopted, draft form.

Standards: The Lunar SDI is actively soliciting feedback on draft standards with the goal of supporting a broad data creator, provider, and user community. Draft standards are published at https://psdi.astrogeology.usgs.gov/moon/standards/data_standards/. Briefly, the Lunar SDI is intending to adopt the body definition standards and ephemeris as defined by the IAU and endorsed by the Lunar Critical Data Product Specific Action Team (LCDP SAT) [4]. This includes maintaining the 2008 JPL DE 421 ephemeris as it is sufficiently close to the update ephemeris (2021) and many products have been published using the 2008 information. Second, the Lunar SDI is considering using a 0-360 longitude domain (matching LRO) with data being stored in an equirectangular projection below 60° N/S and polar stereographic projections centered on the pole above 60° N/S. This is in line with existing data products such as the SELENE/LOLA merged DEM (SLDEM2015). To support cloud distribution the working group is considering adopting the Cloud Optimized GeoTiff as the raster data format and OGC Features API 1.0 / OGC Geopackage for vector data. We are actively soliciting feedback from data creators, providers, and users on these standards before adoption.

Current and Future Work: At the time of writing, the Lunar SDI working group is working to adopt a

governance model, solicit feedback on standards decisions, and codify said standards. Once these tasks are completed, the WG will be working to engage data providers to increase the availability of analysis ready, Lunar SDI standards compliant data (e.g., by encouraging improvements to the metadata associated with widely used existing data products) and engaging with funding agencies to determine how best to fill data gaps identified by the LCDP SAT.

Analysis Ready Data in the Context of PSDIs: A primary focus of the described SDIs is making highly usable data products readily available to the community. The SDI is not a data provider or creator but aims to improve the ability to make data available in a standards compliant way for others to discover, access, and analyze. For example, the USGS Astrogeology Science Center is adopting the SDI endorsed standards and is one source of SDI compliant data. One goal of SDIs is to help identify strategic gaps in data products and standardized technologies and grow the community of contributors and users of the PDE.

Call for Engagement: The Europa and Lunar SDIs are at different places in their development. The Europa SDI is seeking engagement with data creators, the community, and entities interested in acting as data providers. We understand that the overall quantity of Europa data is currently limited, and we would like to maximize the availability of what data has been collected and analyzed. Additionally, we are seeking to support adoption (or modification and adoption) of the data standards that we have identified with the goal of maximizing the value and interoperability with to be collected data (e.g., by Europa Clipper).

As the Lunar SDI has yet to formally adopted a set of standards and are seeking input on the proposed data standards. Additionally, the Lunar SDI is seeking engagement with data providers to serve ARD that we can help promote to the community. The goal here is to help coordinate the disparate lunar data provider community. If you are a provider of data and are interested in providing ARD, please reach out.

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References: [1] NASA PDE-IRB Final Report (2022). [2] Laura, et al. (2021) LPSC LPSC LIII, Abstract #1936. [3] Bland et al. (2021) *Earth Space Sci* 8, e2021EA001935. [4] LCP-SAT Report (2021).