A Europa Planetary Spatial Data Infrastructure (PSDI). J. R. Laura[1], C. B. Phillips[2], R. A. Beyer[3], M. T. Bland[1], R. L. Fergason[1], T. Hare[1], P. Schenk[4] [1]USGS Astrogeology Science Center, Flagstaff Arizona; jlaura@usgs.gov,[2]NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [3]SETI Institute and NASA Ames Research Center, [4]Lunar and Planetary Institute/USRA

Introduction: The Mapping and Planetary Spatial data Infrastructure Team (MAPSIT) chartered a Europa Spatial Data Infrastructure (Europa SDI) working group in October 2020. Members were added from the planetary science community with the primary goal of making the currently available Europa spatial data (e.g., from Galileo, Voyager 1, and Voyager 2) as discoverable, accessible, and highly usable as possible. These goals are in line with previously articulated PSDI goals (e.g., [1]).

This abstract provides a snapshot of the current state of the Europa SDI, serves to announce the existence of this group to a larger audience, and seeks to position this work within the larger international Planetary Data Ecosystem [PDE, 2]. An SDI is a separate concept from NASA's Planetary Data System (PDS) that provides distinct and complementary functions in a broader PDE. To illustrate, Section 3.2.2 of [2], indicates that *"Because NASA and its planetary sciences community … have relied so heavily on the PDS for so long…, it has led to a widely held idea that the PDS is the Ecosystem, and that the Ecosystem is the PDS. However, the PDS was not intended to be … [and a] new concept of the Planetary Data Ecosystem is needed"*. The Europa SDI working group is attempting to provide additional functionality, access, and services for Europa data that are built upon the important foundation that PDS provides. The Europa SDI is a component of the PDE that is currently focusing on analysis-ready data/metadata availability and services.

Policies & Standards: The Europa SDI is managed by a chartered working group comprised of the authors of this abstract. This group is focused on the development of policies that support the codification and adoption of standards that maximize the Findable, Accessible, Interoperable, and Reusable (FAIR) [3] use of Europa spatial data. The work of the Europa SDI working group takes the form of policy and standards documents, memoranda describing roles and responsibilities, and active engagement with users and user groups. While most of these efforts are not visible, the user community will benefit from the resulting landscape of discoverable and accessible Europa spatial data that are ready for analysis without processing efforts (e.g., ingestion, radiometric calibration, geometric correction, format conversion post processing for preparation for an analysis environment). The Europa SDI working group has codified spatial standards for data managed by the Europa SDI to ensure data level interoperability (e.g., identical geospatial standards, highly usable formats, identical body parameters, etc.). We are beginning to engage with Europa data producers to bring their data into alignment with these standards and make them available in analysis ready [4,5] formats. The policies governing the management of these data are forthcoming. Finally, now that a concrete example of a Europa focused PSDI exists and can be accessed as described below, this group is beginning to engage with the broad Europa data user community to promote knowledge of our efforts and to ensure our work is in alignment with community needs.

Data Availability: A key component of the Europa SDI (and the component most visible to the external data user) are discoverable, accessible, and usable data [1]. Described another way, the data must be FAIR. The Europa SDI group is collecting and making data available under both data FAIR principles and the spatial standards defined by the Europa SDI governance group. FAIR compliant Europa data are currently freely available to any user in a standards compliant format that is analysis ready [ARD; 4,5].

Here, we will step through each of the FAIR principles and describe what initial steps have been taken to benefit to the Europa data user.

Findable: The Europa SDI data are assigned unique DOIs in line with data delivery and storage leading practices. The data are supplemented with rich metadata including intrinsically captured (e.g., view-geometry or pixel resolution) observation data and qualitative processing and fitness-for-use information. These metadata are used to populate the search Application Programming Interface (API) that makes the data accessible. Findable Europa data ensures that a data user has multiple avenues and search criteria to support discovery.

Accessible: Preliminary data are at https://stac.astrogeology.usgs.gov/browser. Additionally, data are discoverable via a well-documented Application Program Interface at https://stac.astrogeology.usgs.gov/api, with documentation hosted at https://stac.astrogeology.usgs.gov/. Users of Europa data can currently browse through the entire data catalog, and view observation thumbnails, associated metadata, and supplemental data files. Users can also use command line or other programmatic (e.g., Python or JavaScript) tools to query the search API and freely download any data of interest.

Interoperable: Europa SDI data are interoperable at three levels. First, the data conform to the Europa SDI identified spatial standards. Data are provided in a standardized coordinate reference system ensuring interoperability with other Europa SDI data without the need for knowledge of topics such as coordinate reference system transformations. Second, data are made available in a standard spatial data format, the Cloud Optimized GeoTiff (COG) that is widely supported in Geographic Information Systems (GIS) and by lower-level libraries for tool developers. Finally, metadata are available in Federal Geographic Data Committee (FGDC) and Spatio-Temporal Asset Catalog (STAC) formats, both widely used by geospatial data providers; use of these standards ensures metadata interoperability across data discovery and analysis tools.

Reusable: Reusable data are composable. This means that data governed by the Europa SDI can be combined in novel ways. Europa SDI data meet these criteria in three ways. First, the data are released under a permissive Open Data Commons Public Domain Dedication and License (Version 1.0). Second, metadata provide clear plain language, and where appropriate programmatic reproduction instructions, that fully describe the data provenance. Finally, the data comply with Europa SDI data standards which ensure cross data set interoperability.

Through adherence to the FAIR principles, we believe that the data made available under the Europa SDI helps empower users to access large quantities of analysis ready data while being comfortable making informed, data driven decisions and asking questions about the data that are being used [6].

User Engagement: User engagement is proceeding along several different paths. First, the Europa SDI working group are engaging with Outer Planets Assessment Group (OPAG) and the Europa Clipper Mission to educate them on these efforts and begin soliciting input on use. The Europa SDI working group is seeking alignment with community representative organizations to maximize the usability of our efforts, minimize duplication of effort, and grow our user base. Second, the Europa SDI working group is engaging with data producers to bring more data products under the Europa SDI model. This includes the identification of foundational and framework data products [1] of interest to the community and the development of template Memoranda of Understanding so that the roles and responsibilities of the data producer (who creates a product, perhaps under a NASA grant or as part of a mission team), to prepare analysis ready data that is Europa SDI compliant. Third, the Europa SDI working

group is participating in a shared effort to work with tool and interface developers by releasing well documented APIs for programmatic access to the Europa SDI data and metadata. Our objectives are twofold. First, we are seeking to be a source of well-documented and standards compliant data that front-end and tool developers can leverage to build solutions for their users. Second, we seek to help others deploy data services, compliant to the same standards so that a federated network of Europa SDI compliant data providers exists. Finally, the Europa SDI working group is generating the necessary supporting documentation for Europa SDI data users to build confidence discovering, accessing, and using Europa analysis ready data for their work. This effort takes the form of textual documentation describing topics such as applied processing, description of the available data assets, plain text description of the data accuracy and any known issues, qualitative usability and fitness-for-use assessment, and description of related data that may be of interest to the researcher. The documentation also includes hands-on tutorials and cookbook style usage examples.

The end goals of these efforts are to: (1) develop and maintain community driven standards that can adapt and change as the external technologies for the acquisition and use of the data change; (2) publish and maintain longer lived policies that ensure the stability of the data, services, and coordination agreements through active adoption and enforcement by the community, and (3) promote the creation and release of well-documented and referenced analysis-ready data that maximizes democratic use by empowering users to be confident making data driven decisions and asking informed data driven questions.

These efforts will enable current and future Europa scientists to pursue new scientific investigations. We welcome comments and engagement from the broad Europa community and look forward to including future Europa Clipper data in this infrastructure.

References: [1] Laura, J., et al., (2018) Framework for the Development of PSDI: A Europa Case Study, *ESS* 5, 486-502, https://doi.org/ 10.1029/ 2018EA000411. [2] Final Report of the PDE IRB, (2021) https://science.nasa.gov/solar-system/pde-irb/. [3] https://www.go-fair.org/fair-principles/ [4] Committee on Earth Observing Satellites (CEOS) Analysis Ready Data Governance Framework (2021) https://ceos.org/ard/. [5] Dwyer, J.L., et al. (2018) Analysis ready data—Enabling analysis of the Landsat archive: Remote Sensing, v. 10, no. 9, art. no. 1363. doi.org/10.3390/rs10091363. [6] Data-led Academy, 2021 https://dataled.academy/guides/data-democratization/.