SEEING CLEARLY THE GROUND BENEATH OUR FEET: A PLANETARY SPATIAL DATA INFRASTRUCTURE.

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Introduction: Planetary spatial data returned by spacecraft, such as images used to make mosaics, controlled basemaps, and digital elevation models (DEMs), are of critical importance to NASA and other space agencies [1]. The 2014 NASA Data Plan [2] states that effective data management can increase the pace of scientific discovery and promote better use of resources. However, many of these data remain inaccessible to the general science user because they are difficult to find, process, and interpret. The Mapping and Planetary Spatial Infrastructure Team (MAPSIT) is a NASA community assessment group (AG) that recently produced a Roadmap that includes findings for how to develop a Planetary Spatial Data Infrastructure (PSDI) for all bodies of NASA interest in the Solar System (https://www.lpi.usra.edu/mapsit/roadmap). Here we discuss the main findings recommended by the Roadmap, as well as ideas for how MAPSIT and the community can help move toward making data discoverable, accessible, and useable.

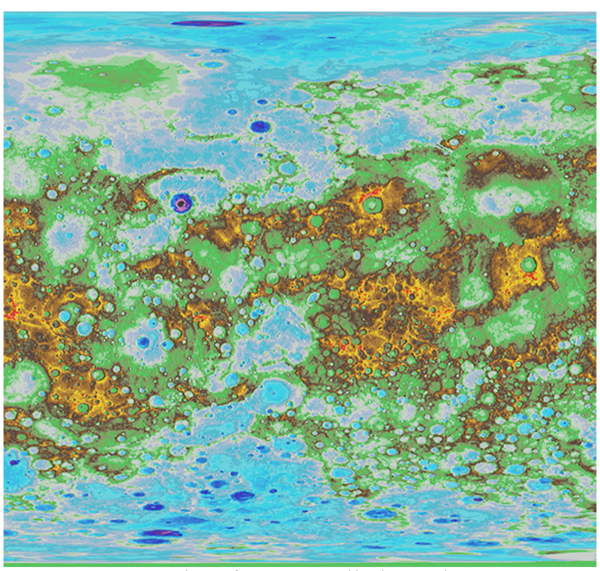

Fig. 1. Example of a controlled product: Mercury MESSENGER Mercury Dual Imaging System (MDIS) narrow-angle camera (NAC) and wide angle camera (WAC) derived global DEM [3]. Half the globe is shown, from 0° to 180° E longitude.

Planetary Spatial Data Infrastructure: MAPSIT, through its Roadmap, seeks to offer guidance on how to make planetary spatial data accessible and useable, and to encourage leading practices in acquiring new data, creating higher-level products and development of tools.

PSDIs involve the end-to-end life cycle of planetary spacecraft data, with the data first being correctly obtained and processed so that accurate registration, and subsequent accurate geolocation, can be guaranteed. While missions are now required to return radiometric and geometric calibration and engineering data and documentation, derived data products such as registered basemaps that can be made from these [e.g., 1, 6] do not explicitly happen on every mission, nor are they required by NASA. Many long-duration or high-data-volume missions never produced registered basemaps, and this is left for future data users.

PSDIs are essentially frameworks to support Solar System spatio-temporal data discovery, access, and use. As described in [1] and references therein, SDIs include users, policies, access networks, standards, and spatial data. Foundational data products support PSDIs and include global topographic mosaics and other spatial products that are based on the best-available data and that are accurately scaled and registered to a defined common coordinate frame [e.g., 4] associated with a given planetary surface (**Fig. 1**). These products serve as a base to which additional products can be geodetically controlled, e.g. via photogrammetric, radargrammetric, or altimetric solutions [1, 6].

A comprehensive plan needs to be put in place to build a framework under which data are correctly obtained and processed and placed in locations where they can be discovered and used by multiple stakeholders, many of whom may not have expertise in data processing. Such a model is similar to what the terrestrial community has in place through the NSF Arctic Data Center (https://arcticdata.io/), the Canadian Polar Data Catalogue (https://www.polardata.ca/) or the Landsat Enhanced Thematic Mapper site [1, 6]. Nonexpert users can easily go to these portals and access data they know have been properly registered and processed for accurate use. It is clear that a similar construct is needed to fully realize the potential of planetary data and to fulfill NASA's future science and exploration goals [2, 4].

Roadmap: MAPSIT developed findings in 2019 (https://www.lpi.usra.edu/mapsit/roadmap) aimed at enabling seamless discovery, access, and use of spatial data for all users, developing interfaces that exploit current technologies, and evolving capabilities in pursuit of these goals. The main Roadmap findings are:

Finding I: NASA missions should be encouraged to obtain high-quality data that can be registered to or used to improve existing spatial foundational data products, or create new ones for unseen territory, and thus maximize the value of the NASA science return.

Finding II: NASA-funded projects, including missions and Research and Analysis (R&A) projects, that obtain or create spatial data should be encouraged to deliver data in formats that are easily usable and that conform to standards agreed upon by the community.

Finding III: Existing and new planetary spatial data should be easily discoverable and accessible, and data access tools must evolve with the technology.

Finding IV: MAPSIT should coordinate with community representatives and groups, such as NASA Assessment Groups (AGs), to ensure that foundational data products are produced and that Planetary Spatial Data Infrastructures (PSDIs) are developed and maintained for each planetary body in the Solar System to best enable NASA exploration and mission goals.

Finding V: NASA and the planetary community should support the development of tools, technologies and expertise to ensure planetary spatial data are properly acquired, processed and available for effective use to the fullest extent, now and into the future.

Execution of Roadmap and Creation of PSDI: The findings of the MAPSIT Roadmap are inherently broad because of the cultural and logistical challenges involved in how planetary data are obtained, stored and distributed. The current NASA mission Data Plan [2] requires that the Principal Investigator or lead institution be responsible for all proper data acquisition and subsequent release to approved data repositories. This includes raw data with accompanying processing information, as well as higher-level products produced for the mission. Data are required to be "ready to use" [e.g., 7]. Whatever higher-level products are made is the decision of the mission, and often the creation of basemaps that are not fully controlled to the body is considered sufficient for the mission needs. The creation of controlled products, which would have significantly more value for users out into the future, may go beyond the capabilities, lifetime, or resources of the mission/instrument teams (c.f., a Titan controlled basemap has not been made).

Furthermore, at the end of mission lifetimes, data servers and viewing tools built through the hard work of the mission teams are often terminated because of decreased funding or because key personnel move onto other projects. While all the raw and higher-level data are in principle available on public repositories, the tools and software required to process and view the data may be difficult to understand and recreate.

Data Ecosystem: NASA is currently discussing its "data ecosystem" – how data moves from spacecraft to user and how data technology can continue to improve. The timing and circumstances are therefore appropriate for establishing a Planetary Spatial Data Infrastructure. Such an activity will require consideration of many questions, including: Can NASA successfully require all missions to produce accurately obtained, calibrated, and controllable spatial data? Should missions be required to provide all their specifically-created, higher-order products, including basemaps, mosaics and digital elevation models, to the public? Should missions be required to provide controlled products (keeping in mind very few of these have been created for solar system bodies)? In the absence of these mission-created higher-level products, should NASA provide funding to make such foundational products? To whom? Should publicly available data servers be required to use accurately registered (controlled) data? Should NASA support a clearinghouse, and who should design and maintain this? What tools and technologies should NASA invest in so that data move toward improved usability? We propose to stand up a focus group to address these many and varied concerns and to move toward a PSDI structure all can agree on.

Conclusions: The ultimate goal of the creation of a Planetary Spatial Data Infrastructure is to enable seamless discovery, access, and use of spatially-enabled data for all users, similar to what the terrestrial community has in place, and to support NASA in its science and exploration goals.

References: [1] Laura J. M. et al. (2018) *Earth & Space Sci., 5*(9). [2] https://www.nasa.gov/sites/default/files/files/NASA_Data_Plan.pdf [3] Becker K.J. et al. (2016) 47th LPSC. [4] Beyer R. A. et al. (2018) *Planet. Sci. Informatics & Data Analytics Conf.,* Abstract #6067. [5] Archinal B. A. et al. (2018) *Celestial Mech. and Dynam. Astro., 130*(22). [6] Laura J. et al. (2017) *Int. J. Geo-Inf. 6, 181; doi:10.3390/ijgi6060181.* [7] New Frontiers AO, NF4+AO.pdf, https://nspires.nasaprs.com/