Mapping and Planetary Spatial Data Infrastructure Roadmap 2019-2023

Mapping and Planetary Spatial Infrastructure Team

Executive Summary

Spatial data contribute to the success of endeavors at NASA if they are correctly acquired and accessible to all interested groups. We encourage the creation of initiatives to ensure that planetary spatial data are correctly obtained and processed and are discoverable and usable for a wide range of research and exploration purposes. We describe steps needed to work toward these goals. We also evaluate the needed expertise, tools and capabilities for development and delivery of planetary spatial data products. We suggest these efforts should be initiated by the planetary science community and coordinated by NASA and should focus on how to most effectively enable NASA science and exploration goals.

Preamble

This document was prepared by the Steering Committee of the Mapping and Planetary Spatial Infrastructure Team (MAPSIT; Radebaugh et al. 2017; 2019), which was established by NASA and the planetary science community in the fall of 2014, following recommendations from the Planetary Science Subcommittee (PSS) of the Science Committee of the NASA Advisory Council (NAC). The MAPSIT community is comprised of all planetary scientists with interest in planetary spatial data. This roadmap represents a summary of the spatial data-related topics considered to be of highest current priority in the coming five-year period (2019 to 2023). The overarching theme is ***to ensure that planetary spatial data meet the broadest needs of the planetary science community.***

Intent

The intent of this roadmap is to offer guidance on how to make planetary spatial data accessible and useable and to encourage best practices in acquiring new data and development of products and tools. We first describe planetary spatial data and the current level of accessibility to users. We then define planetary spatial data infrastructures (PSDIs), which are frameworks to support Solar System spatio-temporal data discovery, access and use, and describe how they can help realize the potential of the data and fulfill NASA's future science and exploration goals. We then present findings that seek to enable seamless discovery, access and use of spatial data for all users, to develop interfaces that exploit current technologies, and to evolve capabilities in pursuit of these goals.

Background and Definitions

Planetary Spatial Data: Planetary spatial data are any data with a spatial component from orbital, remotely sensed data to rover-collected, navigation images, to collected samples with a spatial component (Laura, et al. 2017; 2018a,b). Planetary spatial data are currently collected in raw form, processed by instrument teams, put onto intermediate, team-based servers and websites and ultimately made available via the Planetary Data System (PDS) archive. The PDS manages close to 2 petabytes of data (PDS Roadmap, 2017) and large amounts of new data are archived each year by active space missions. Most frequently, data stored within the PDS are not spatially enabled for immediate use by non-expert research scientists. Instead, adequate metadata are provided along with the image data that enable the user to use SPICE information, sensor models, processing pipelines, and occasionally photogrammetric control software to create spatially enabled products. Significant expertise is required to perform these operations and interpret the spatial correctness of the products.

Current Discoverability, Accessibility and Usability of Spatial Data: MAPSIT recognizes that there are numerous efforts within the NASA planetary science community that focus on some aspect of making data discoverable, accessible and usable to some subset of the community. Most missions have their own web servers to store raw and processed data and make it available to their mission team members, though these servers often disappear when mission funding ends. The PDS has a specific NASA charter to archive and deliver mission data (e.g., Gaddis et al. 2018), but their services focus on medium- to long-term preservation (an engineering focus) rather than on delivery of the most usable, often highly derived, products (a user focus; Laura et al., 2018a). The typical planetary data user, who often is not an expert in spatial data manipulation, or in the naming conventions or data types from a given mission, may not able to access or use archived planetary data without a significant investment of time. Furthermore, there is no requirement placed on NASA missions to accurately register their spatial data onto the target planetary body's surface, an often laborious and complex process that leads to the necessary quantified, accurate knowledge of the location and scale of objects within spatial data, and that allows for the proper use and comparison of the data. These accurate data products often do not exist for many planetary bodies, or were created with now outdated standards, coordinate frames, and techniques.

Planetary Spatial Data Infrastructures: A Planetary Spatial Data Infrastructure (PSDI) is a plan for describing the bounds within which spatial data planning should occur and for organizing the resultant data in a standardized way so that data are discoverable, accessible and usable in support of an endeavor (Laura et al. 2017; Hargitai et al. 2019). While one overarching PSDI may be pursued for Solar System data management, there should also be a multitude of more focused SDIs centered around a body or exploration or scientific task or theme. An ideal PSDI should serve a broad community whose members do not need to be experts in spatial concepts and who may not understand the details of storing, finding, and using spatially enabled data (Laura et al. 2017). Most users of planetary spatial data want the data to "just work", and a PSDI should enable this.

Foundational Data provide the basic positional structure upon which all other data are registered (Duxbury et al. 2002; LRO and LGCWG 2008; Archinal et al. 2009, 2018). These include mosaics and other spatial products that are based on data that are accurately scaled and registered to a given planetary surface. These products, along with their quantitative assessment of spatial efficacy, serve as a base to which additional products can be photogrammetrically controlled. Upon this structure sit higher-order, more specialized **Framework Data**. These can be diverse and include hyperspectral compositional data, names and map units (Laura et al. 2017).

Assembling all accurately registered, foundational data into a structure with an interface that supports straightforward access to products for any user is an important part of a Planetary Spatial Data Infrastructure (PSDI). This philosophy naturally encourages the desire to complete many different SDIs for various solar system bodies and efforts (Archinal et al. 2017; Laura et al., 2017; Laura et al., 2018a,b; Hargitai et al. 2019). PSDI-related efforts may include gathering all data needed for selection or characterization of a safe landing site or establishing and using a geodetic coordinate reference frame to support spatially accurate measurement, navigation and traditional mapping techniques. The nascent PSDI community is focused on describing the steps needed to correctly obtain and process planetary spatial data to support development of new foundational products and creation of additional usable products necessary for future science and exploration. Currently envisioned, planetary body-focused PSDIs address the needs of upcoming NASA missions (Archinal et al., 2017; Laura et al., 2018b) by laying out what products exist, which are still needed, and what formats and product types are most usable for the mission and research community. Ideally, PSDIs can help reveal to NASA where strategic knowledge gaps exist and where it is most scientifically interesting and technically feasible to land, image, or fly past planetary bodies for science or exploration. PSDIs enable the best and most effective use of spatial data and are needed for all planetary bodies, at different scales, to support a wide variety of purposes.

Planning for the Future: A strong focus on people and standards is critical for the success of PSDIs, while technology is inherently impermanent. Thus, there is a need for expertise, tools and capabilities in staying current with the changing technologies. Then we can correctly obtain and process spatial data and make them usable and accessible, and we can create and maintain PSDIs. Where shortfalls exist in these areas, data are lost or not used to the fullest potential.

Findings

Spatial data usability and the development of PSDIs at all levels help NASA succeed at Solar System exploration. The MAPSIT Steering Committee, in collaboration with members of the planetary science community, presents 5 findings below that should be addressed in the 2019 to 2023 timeframe to move forward expeditiously to support NASA's near-future exploration goals.

Finding I: NASA missions should be encouraged to obtain high-quality data that can be incorporated into existing foundational data products, or create new foundational data products for unseen territory, and thus maximize the value of the NASA science return. NASA and the MAPSIT community should work with missions to:

- Encourage obtaining data of the highest possible quality, with awareness of current ephemerides and use of spacecraft tracking, so that it can be placed spatially on the planet and within the region as accurately as possible.
- Ensure that data calibration plans are in place prior to launch and in flight, and that calibration data and documentation are delivered to the public in a timely fashion during the mission.
- Collect data that are synergistic, such as images that can be mosaiced, such that they can support the development or refinement of foundational data products.
- Ensure that data are geodetically controlled as soon as possible during or after the mission.
- Ensure that derived products used by the team (e.g., high-level thematic maps, special mosaics, GIS layers, etc.) are delivered publicly as soon as possible during or after the mission.

Finding II: NASA-funded projects, including missions and 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. NASA and the MAPSIT community should work to:

- Develop and maintain a community forum for selecting and maintaining data format standards.
- Establish product formats that meet community needs for interoperability.
- Encourage mission teams and research projects to incorporate their data into existing Planetary Spatial Data Infrastructures that are publicly available and can be used by others:
    - Ensure that community standards for data formats and usability are met
    - Ensure that sophisticated search services and visualization capabilities (such as those used by mission teams) are made available to the public.
    - Ensure that these capabilities are captured and maintained for use that continues beyond the duration of the mission or project.
    - Missions and data providers should be required to develop data user guides and other documentation and support materials for training the user community in the use of data they deliver.

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

- Educate the community on the difference between back-end data providing services and the front-end tools that make the data discoverable.
- Create a clearinghouse or data portal for planetary spatial data that is easily accessible and useable (Beyer et al. 2018).
    - Ensure data are accessible via common methods (e.g. via online Web Map Services), rather than using single tools or proprietary formats.
    - Make sure these services use a standard Application Programming Interface (API) or that can work well with a variety of interfaces.
    - Ensure this data portal technology evolves continually.
- Coordinate with mission teams and other data delivery system supporters (e.g., JMARS, (Planet) Trek developers, etc.) to ensure that community data format standards are used.
    - Duplication of effort in data delivery tools should be avoided where possible.
    - Data transparency and access, such as the processing steps followed for the data products, must be made sufficient in these tools.
- Ensure that current, high-use tools, such as web servers created by missions, entities or NASA, are maintained until a replacement is created.
- Support improvements in the quality and abundance of metadata (information about the data) for spatial data products to ensure they can be readily identified and cross-referenced in search tools in order to improve data discoverability.
- Continue to support restoration of existing (sometimes historic) data products and metadata for high-priority targets and development of usable products from these.

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. NASA and the MAPSIT community should work to:

- Determine the gaps that exist in creation of control networks and PSDIs for given bodies or disciplines according to the needs of upcoming missions and exploration timelines.
- If there is insufficient data to make necessary foundational products, identify what data are missing and how this can be addressed by future missions.
- Encourage the creation of higher-order products, such as orthoimages, mosaics, geologic maps and elevation data (topography, shape models, DTMs), to support current or upcoming exploration of planetary bodies.

- Encourage creation of PSDIs that can support other aspects of Solar System exploration, such as human field exploration, sample acquisition, analysis and return, and planetary astronomy.

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. NASA and the MAPSIT community should work to:

- Develop a community group or special action team to review and report to MAPSIT and NASA on needed tools, technologies and expertise in spatial data analysis.
    - Look to other data user groups, especially those of Earth-based SDIs, and spatial data technologists for needed expertise and solutions that have worked.
- Continue to fund specialists in creating, maintaining and updating data access tools that evolve with the technology.
- Encourage research into new ideas about spatial data manipulation and processing and data access technologies through funding of special projects on these topics.
- Ensure key areas of expertise and institutional knowledge are maintained within the fields contributory to PSDI through training and encouraging prioritizing hiring and retention of spatial data experts.
    - Hold training sessions for existing spatial data experts, such as those sponsored by missions at national science meetings, the Planetary Data Workshops (see https://astrogeology.usgs.gov/groups/Planetary-Data-Workshop), and the Planetary Science Informatics and Data Analytics (PSIDA) workshop (see https://psida.rsl.wustl.edu/).
    - Targeted funds to support new hires with spatial data expertise should be made available, and recruitment fairs, scholarships and other strategies for bringing in students, postdocs and scientists should be pursued.

Conclusions

The ultimate goal of this Planetary Spatial Data Infrastructure Roadmap is to enable seamless discovery, access and use of spatially enabled data for all users, to help develop interfaces that exploit current technologies and evolving capabilities in pursuit of this goal, and to support NASA in its science and exploration goals. These tasks collectively support a broad community effort to develop tools, data products, and services that support a range of community members to use current technologies for data storage, processing, and visualization, and to deliver products that "just work" for users.

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Supporting Materials (or "Appendix")

Community-driven lists of prioritized foundational and derived data products: On the basis of these Roadmap findings, the MAPSIT Steering Committee proposes to produce, with input from NASA's Assessment Groups (AGs), a prioritized list of foundational spatial data products, including those that are currently available and those that need to be developed or improved (e.g. brought up to date with updated standards, coordinate frames, and techniques). Each product should have associated requirements for resolution, coverage, accuracy and precision. At the end of the Appendix is a recommendation from MAPSIT to SBAG, delivered in April 2019.

Examples of planetary data delivery services:
NASA Planetary Data System (PDS; https://pds.nasa.gov/), NASA-USGS Planetary Spatial Data Infrastructure (PSDI) Research Program (Keszthelyi et al, 2018) the NASA Regional Planetary Image Facilities (RPIFs; https://www.lpi.usra.edu/library/RPIF/index.shtml), and several NASA mission-related data services (JMARS and related services provided by Arizona State University, https://jmars.asu.edu/, Planet Trek versions developed by NASA JPL and ARC, https://science.nasa.gov/science-activation-team/solar-system-trek, etc.).