Fiscal Year 2023 Planetary Science Division Response to the Final Report of the Planetary Data Ecosystem Independent Review Board

"The data gathered by the planetary sciences community is humanity's treasure. Along with NASA, and all elements of the Planetary Data Ecosystem, it is our responsibility to preserve and ensure its present and future usability." PDE IRB (2021)

Status as of September 30, 2023

NASA Planetary Science Division
Fiscal Year 2023 Planetary Science Division Response to the Final Report of the Planetary Data Ecosystem Independent Review Board

<u>Concurrence</u>

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1. Introduction

"*The NASA Planetary Science Division (PSD) is engaged in one of the oldest scientific pursuits: the observation and discovery of objects in our solar system.*" (c.f. PDE IRB, 2021, p. A-67)

NASA's Planetary Science Division (PSD) advances the scientific knowledge and understanding of the solar system through exploration. The PSD recognizes that both the collection of data and the tools and technology to enable the use and analysis of those data are critical to scientific discovery. Data and technology combined provide the foundation to better understand the history of solar systems and the distribution of life within the universe. In acknowledgement of the essential partnership of science and technology, the PSD defined the Planetary Data Ecosystem (PDE) as the "ad hoc connected framework of activities and products that are built upon and support the data collected by planetary space missions and research programs, which primarily are NASA funded," (c.f. PDE IRB, 2021). Examples of information included in the PDE are data returned from space missions and ground-based facilities and generated by research and analysis projects. In addition to observational and research data, the PDE is broadly defined to include physical samples that may be of utility to a wider community, such as samples created in laboratory experiments or those collected at Earth analog field sites, and also contributions from citizen-scientists. The PDE includes standards, such as those for planetary science data and metadata; software and tools such as data processing pipelines, missions support, analysis tools, search and browse tools, display tools, and models and simulation tools. The PDE also includes the publications that can describe both the scientific results of analysis and the new knowledge gained from those pursuits. In addition, publications can describe the methods used to analyze data, generate higher-order data products, the software, models, and tools developed, and education and communication products.

The PDE encompasses a very broad collection of data, software, tools, and publications, and the PSD recognized that as the development and support of this ecosystem grew organically, it also grew to be more complex. The PSD sought to proactively assess the current state of the ecosystem and identify opportunities to improve the efficiency and effectiveness of the system. To address this need, the Planetary Data Ecosystem Independent Review Board (PDE IRB) was chartered by NASA in the fall of 2020 to conduct a wholistic review of the PDE with the goals of defining the full environment, identifying missing or overly redundant elements, and providing findings and prioritized recommendations. The PDE IRB delivered its final report in April 2021, which included 67 Findings and 65 prioritized Recommendations. These recommendations fall into three broad categories:
- Continued strategic development of the overall Ecosystem (Section 2)
- Barriers to data preservation (Section 3)
- Barriers to access, usability, and development (Section 4)

The PDE IRB final report, PDE charter, and PDE IRB meeting recordings can be found at: https://science.nasa.gov/planetary-science/data/pde-irb/. Comments and feedback on this response document are welcome. Please email any comments, additional information, or corrections, to hq-pde@mail.nasa.gov.

1.1 Planetary Science Division Response Status Summary

In this document, the PSD provides a status update on Division actions and efforts towards developing a more connected and effective PDE in response to the Findings and

Recommendations in the PDE IRB report. This update describes efforts that have been completed from April 2021 to September 2023. Each finding is given a status corresponding to the PSD's assessment of completion. A definition of each status and a legend of the color scheme used is provided in Table 1.

Table 1. Definition of status categories and legend.

Color Legend	Status Category	Category Definition
	Completed	Concrete steps have been taken to address the recommendation and the goals of the recommendation have been met. No additional actions are necessary.
	Maintenance	Concrete steps have been taken to address the recommendation and the goals of the recommendation have been met. Ongoing efforts are needed to maintain the standards set by the recommendation.
	In Progress	Efforts towards addressing this recommendation are in progress, or portions of the recommendation have been met.
	Not yet started	Actions towards addressing this recommendation have not yet begun.

The PSD has made significant progress on addressing the recommendations described in the PDE IRB final report. This significant progress has been completed in collaboration with the Planetary Data System (PDS), the Science Mission Directorate (SMD) Office of the Chief Science Data Officer (OCSDO), and others within SMD. Based on the PSD's assessment of the actions taken in response to each recommendation and whether those actions address the full recommendation, the status of the PSD response to each recommendation in the PDE IRB final report is described in the remainder of this document. In summary (see also Figure 1):

- *11 recommendations (17%) have a completed status*, where the goals of the recommendation have been met with no additional actions necessary to satisfy the recommendation.
- *14 recommendations (21%) have a maintenance status*, where the goals of the recommendation have been completed, yet it is recognized that ongoing efforts are needed to maintain the standards set by the recommendation. This category also includes an update on one Finding.
- *30 recommendations (45%) have an in progress status*, where efforts are currently in progress or only portions of the recommendations have been met.
- *11 recommendations (17%) have a status of not yet started*, where actions toward addressing the recommendation have not yet begun.
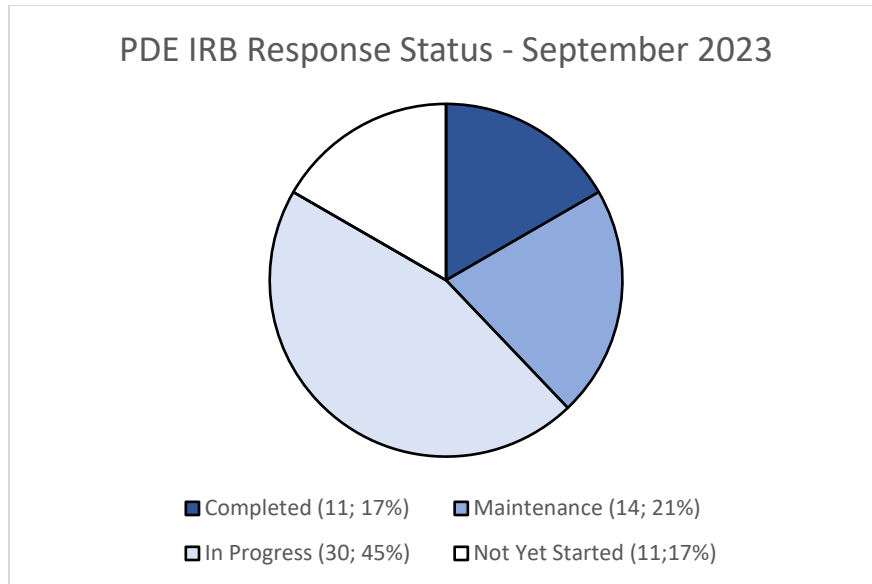
Figure 1. Chart illustrating the status of the Planetary Science Division (PSD) response of each recommendation in the PDE IRB final report as a percentage and based on efforts from April 2021 to September 2023. This chart illustrates the number and percentage completed for all PDE IRB recommendations and provides a summary of the PSD's overall response.

2.2 Acronym Usage

Throughout this document, a substantial number of acronyms are used. So that this document can be utilized by the widest audience possible and responses to these recommendations can be read in any order, the acronym is defined upon its first use for each recommendation. In addition, a full list of acronyms used in this document are provided in Appendix A.

2. Continued Strategic Development of the Overall Ecosystem

Continued Strategic Development -
September 2023

- ■ Completed (3; 11%)
- ■ Maintenance (7; 25%)
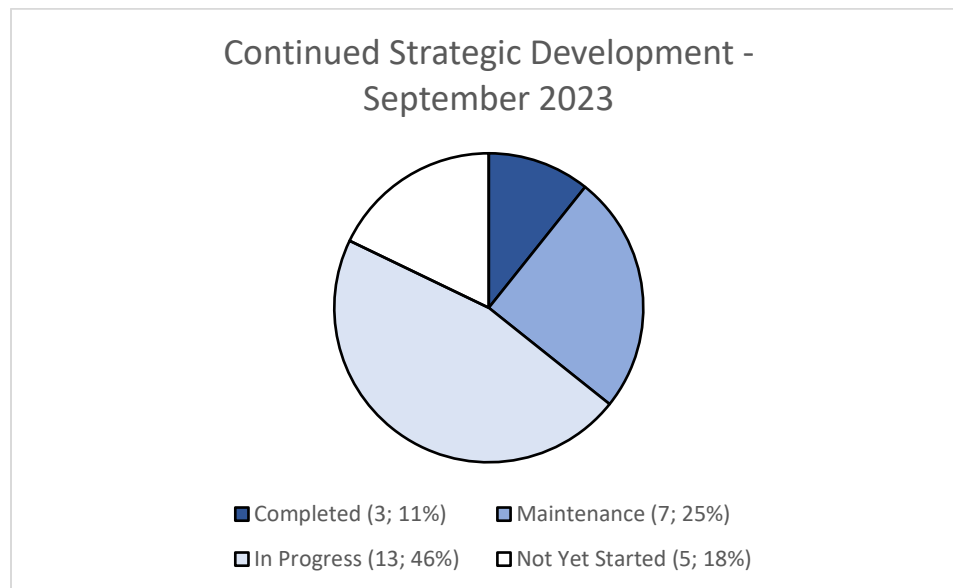- ■ In Progress (13; 46%)
- □ Not Yet Started (5; 18%)

Figure 2. Chart illustrating the status of the Planetary Science Division response of each recommendation in the category "Continued Strategic Development of the Overall Ecosystem" as a percentage and based on efforts from April 2021 to September 2023. There are 28 recommendations within this category, and this chart illustrates the number and percentage status for this sub-section of the PDE IRB recommendations.

Status: Maintenance

Recommendation 01 - NASA should proceed with developing the concept of the Planetary Data Ecosystem so that the usability and archival needs of the entire planetary sciences community—all people, professional or amateur, who produce, provide, and/or use data—are better met.
FY23 Response: The Planetary Science Division (PSD) acknowledges this concurrence from the Planetary Data Ecosystem Independent Review Board (PDE IRB) regarding the concept of a Planetary Data Ecosystem (PDE) and the PSD will continue to develop this idea and support infrastructure related to the usability of planetary data for the entire community and the public.

Status: In Progress

Recommendation 02 - NASA should lead work to refine the full scope of the Planetary Data Ecosystem and build community consensus around the Ecosystem. NASA should continue to refine the short definition as well as the detailed list that answers the question: "What is the PDE?" that clearly differentiates it from the PDS.
FY23 Response: Efforts are underway to refine the concept of the Planetary Data Ecosystem (PDE) and clearly define what the PDE encompasses, and the Planetary Science Division (PSD) is committed to this long-term effort. For example, the PSD PDE team is developing an inventory of PDE elements, using the Planetary Data Ecosystem Independent Review Board (PDE IRB) documentation in the final report as the foundation. This inventory will help to define the current scope of the PDE and can be used to identify unmet community needs and seed discussion. To build community consensus around the PDE, the PSD will seek feedback from

the planetary community through available mechanisms such as workshops, Requests for Comment or Information, and Town Hall meetings. We continue to use the definition of the PDE as the ad hoc connected framework of activities and products that are built upon and support the data collected by planetary space missions and research programs, which primarily are NASA funded.

Status: Not Yet Started

Recommendation 03 - NASA should ensure that the responsibilities, accountabilities, governance, and service levels for those elements of the Ecosystem that are funded by the NASA Planetary Science Division are clearly defined.

FY23 Response: The Science Mission Directorate Science Information Policy, SPD-41a, was released in December 2022, which describes NASA requirements and guidelines for the public release of data, software, and science results. In March 2023, a PSD supplement to SDP-41a was developed that provided Planetary Science Division (PSD)-specific guidance. These documents define responsibilities for public release of information and serve as a foundation to address this recommendation. In addition, the PSD Planetary Data Ecosystem (PDE) team is developing an inventory of PDE elements, using the PDE Independent Review Board (PDE IRB) documentation as the foundation, to define the current, funded scope of the PDE, identify unmet community needs, and define the PDE (see also response to Recommendation 2). Once elements of the PDE are defined, next steps include ensuring that responsibilities, accountabilities, governance, and service levels for those elements are clearly defined.

Status: Maintenance

Finding 08 - There is no mechanism for transparent, widespread communication of plans, timelines, or developments of new or changed capabilities, either from NASA to other Planetary Data Ecosystem communities and elements, or among the elements of the Ecosystem.

FY23 Response: There is now a Planetary Data website that provides NASA Planetary Science Division (PSD) with a mechanism to communicate plans, timelines, or developments of new or changed capabilities widely. Elements within the PDE should communicate their plans and developments through typical community mechanisms including conference abstracts and presentations, journal publications, and presenting at relevant Planetary Assessment or Analysis Groups (AGs) and community Working Groups or workshops. In addition, NASA PSD selected a Planetary Data Ecosystem (PDE) Chief Scientist, Moses Milazzo, in December 2021. The PDE Chief Scientist provides an independent link between the larger PDE community, the Planetary Data System (PDS), and NASA Headquarters, and communicates PDE and Open Science-related topics to the community, including developments of new or changed capabilities. The PDE Chief Scientist is also an additional means for communication with the community and to gather community feedback. We consider this recommendation to be addressed while also acknowledging that fostering additional mechanisms for communication and collaboration within the PDE is an ongoing community effort.

Status: Completed

Recommendation 04 - (Non-consensus) NASA should ensure that a sustained, community-led coordinating organization for the PDE exists that mirrors the other planetary Assessment or Analysis Groups (AGs), reports to the Planetary Science Advisory Committee, and meets regularly.

FY23 Response: The existing planetary Assessment or Analysis Group (AG), [Mapping and Planetary Spatial Infrastructure Team](#) (MAPSIT), is chartered to help "ensure that planetary data are usable for any purpose, now and in the future." This AG will help to advocate for cross-domain needs across the Planetary Data Ecosystem (PDE) and the planetary community. In addition, body- and domain-specific AGs may also advocate for the data, software, and infrastructural needs of specific communities they represent and independent of MAPSIT. Further, NASA Planetary Science Division (PSD) selected a PDE Chief Scientist, Moses Milazzo, in December 2021. The PDE Chief Scientist provides an independent link between the larger PDE community, the Planetary Data System (PDS), and NASA Headquarters. Finally, in May 2023, the PSD hired a Planetary Data Officer, and one responsibility of this position is to develop, maintain, and evolve the PDE, using the Planetary Data Ecosystem Independent Review Board (PDE IRB) final report as a guiding document.

Status: In Progress

Recommendation 05 - NASA should expand intra- and inter-agency efforts to ensure that best practices, lessons learned, and appropriate technologies are shared and implemented across Planetary Data Ecosystem elements.

FY23 Response: The Planetary Science Division (PSD) Planetary Data Ecosystem team has identified several actions to be taken at NASA Headquarters that promote intra- and inter-agency collaboration in this area. These actions include working with the Science Mission Directorate (SMD) Office of the Chief Science Data Officer Working Groups supporting NASA's Open Source Science Initiative to participate in cross-divisional sharing of knowledge and solutions regarding available data sets, software, and tools, and to identify core services and leverage assets across SMD. We are also engaging with the [Mapping and Planetary Spatial Infrastructure Team](#) (MAPSIT), additional planetary Assessment or Analysis Groups (AGs), and relevant Divisions within SMD and within other NASA Directorates to raise and discuss community recommended practices and lessons learned surrounding Open Science practices. Finally, the PSD has active intra-agency collaborations with the US Geological Survey (USGS) and the National Geospatial-Intelligence Agency and will continue to foster these relationships. Future work will be to identify additional cross-disciplinary organizations of data producers, managers, and users and evaluate the impact of active participation. Best practices related to data generation, archival, and sharing and the technologies that support these efforts will continually advance and evolve and continue efforts will be necessary.

Status: Completed

Recommendation 06 - NASA should encourage collaboration around cybersecurity policies, practices, and infrastructure to preserve the integrity and availability of data and systems across the PDE.

FY23 Response: NASA strongly supports following required and recommended cybersecurity policies and practices to ensure the integrity and availability of all data, services, and systems. Projects that are hosted on NASA-provided infrastructure will use either Science Mission Directorate (SMD) core data and computing services or NASA Center facilities. SMD and Center provided infrastructure undergo frequent review to ensure compliance with all NASA cybersecurity requirements. NASA-funded and eligible projects are encouraged to use these services, but use is not required. Any NASA-funded projects using their institutional technical infrastructure should comply with the cybersecurity requirements of that institution. For any Planetary Science Division (PSD)-funded archives/repositories or for projects receiving long-term funding, PSD will require a cybersecurity plan that will be reviewed according to NASA documented processes. The PSD will coordinate with SMD and the Office of the Chief Science

Data Officer cybersecurity teams to share recommended practices as more of our community gain operational expertise in cloud environments and participating in existing communities of practice is encouraged.

Status: Maintenance

Recommendation 07 - NASA should maintain active leadership in the International Planetary Data Alliance (IPDA).

FY23 Response: The Planetary Science Division (PSD) will continue to collaborate with our international partners and maintain active leadership in the International Planetary Data Alliance (IPDA). For example, the US representatives on the IPDA are from the Planetary Data System and supports the sharing of standards and consistent practices, which helps to increase interoperability across international planetary science datasets. In addition, in June 2023 the Planetary Data Officer attended the 2-day IPDA meeting in person, met with international colleagues, and developed and fostered these relationships. This participation and collaboration will continue to be prioritized and the PSD Planetary Data Ecosystem (PDE) team will seek additional opportunities for collaboration.

Status: In Progress

Recommendation 08 - NASA should encourage the development of and participation in other cross-disciplinary organizations of data producers, data managers, and data users by PDE participants.

FY23 Response: The Planetary Science Division Planetary Data Ecosystem team members actively participate in the NASA Science Mission Directorate (SMD) Open Source Science Initiatives and in multiple cross-divisional working groups within SMD. In addition, we support community driven cross-disciplinary organizations, such as OpenPlanetary, as a means for collaboration and sharing of best practices among the community. Workshops such as the Planetary Data Workshop and the Planetary Science Informatics and Data Analytics (PSDIA) also encourage discussion and collaboration among data producers, data managers, and data users. Future work will include identifying additional cross-disciplinary organizations of data producers, managers, and users and evaluating the impact of active participation.

Regarding support for general community participation in cross disciplinary organizations of data producers, data managers, and data users, the PSD encourages the development of such groups and the participation by community members. These groups are essential to sharing best practices and lessons learned across communities of practice and can be a mechanism by which community needs are identified and communicated to the PSD. According to 2 CFR 200.405, participation in such groups could be an allowable cost for grants and cooperative agreements if the proposer can tie the participation directly to the proposed project effort. General participation is not an allowable cost, as the participation opportunity must be directly related to the proposed work effort. Following the proposal review and selection process, documents are submitted to the NASA Grant Officer for review to determine if proposed costs are allowable, allocable, and reasonable for the proposed work. Additionally, for grants and cooperative agreements, the Grant Officer will review the risk posed by applicants as required in 2 CFR 200.205. To complete these required reviews, NASA may request proposers to submit additional documentation.

For additional information on policy that govern Federal awards, see:
- The Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards (2 CFR 200) at: https://www.ecfr.gov/cgi-bin/textidx?tpl=/ecfrbrowse/Title02/2cfr200_main_02.tpl
- The NASA supplement to 2 CFR 200, 2 CFR 1800, at: https://www.ecfr.gov/cgi-bin/textidx?SID=a742969f637a69b85ae9174705ae9d4a&mc=true&tpl=/ecfrbrowse/Title02/2chapterXVIII.tpl 29
- NASA Grants and Cooperative Agreement Manual at: NASA Grants Policy and Compliance Branch

Status: In Progress

Recommendation 09 - NASA should seek CoreTrustSeal certification, and thereby WDS [World Data System] membership, for the PDS data (discipline) nodes. NASA should encourage CoreTrustSeal certification for other PDE elements that serve as data repositories.

FY23 Response: The Planetary Science Division (PSD) and Planetary Data Ecosystem (PDE) recognize the importance of an independent assessment and review of the Planetary Data System (PDS) (and any PSD-funded repositories) against FAIR (Findability, Accessibility, Interoperability, and Reusability) and community recommended practices and we are committed to ensuring that planetary data collected and generated by PSD-funded efforts are available and accessible to the broadest community possible. 2022 guidance from the White House National Science and Technology Council on *Desirable Characteristics of Data Repositories for Federally Funded Research* states "While several organizations provide for repository certification standards, Federal agencies have elected not to adopt existing certification criteria, due in part to the cost and complexity of certification processes and of differences in needs and expectations of different agencies and their research communities. Nevertheless, agencies aimed to ensure the desirable characteristics supplied in this guidance document would be consistent with many of the criteria used to certify data repositories. At the same time, agencies expect that many repositories that do not seek certifications will already exhibit these characteristics and will be able to improve their ability to make data FAIR."

With this guidance, the PDE would consider supporting PSD-funded repositories obtaining CoreTrustSeal (or similar) certification, while evaluating available staffing and budgetary resources, to help facilitate alignment with community recommended practices. There are ongoing discussions with Science Mission Directorate and all Divisions on how NASA repositories and archives are assessed for FAIR and the value of being a member of the World Data System (WDS) international organization, for which CoreTrustSeal certification is a requirement. In addition, the Planetary Data System (PDS) is having ongoing discussions to determine the costs and benefits of seeking CoreTrustSeal certification and WDS membership.

Status: In Progress

Recommendation 10 - NASA should prioritize the reuse of data and metadata standards, data format conversion tools, and Application Programming Interfaces (APIs) across other organizations rather than inventing new ones.

FY23 Response: The Science Mission Directorate (SMD), Planetary Science Division (PSD), and Planetary Data System (PDS) have made significant progress on the sharing and reuse of existing standards and infrastructure, and several actions are ongoing. The PDS has developed the PDS4 metadata standard, and this standard has been adopted by the International Planetary Data Alliance (IPDA) to facilitate interoperability and search capabilities across

international agencies, including the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), and others. Through a contract managed by the USGS, the PSD has collaborated with the open-source project Geospatial Data Abstraction Library (GDAL) to ensure that common planetary data formats and cartographic projections are incorporated into this highly used open source input/output (I/O) software library. This effort enables all software and tools, including many commercial platforms, that use GDAL as the I/O module to automatically provide support and capability for planetary geospatial data. Future work includes supporting the development of community metadata standards for all planetary data communities and ensuring needed data conversion (or other) tools are developed and available in an open-source manner. As an example, an Extraterrestrial Materials Analysis Group (ExMAG) - Lunar Exploration Analysis Group (LEAG) Specific Action Team will discuss and inform community standards and guidelines for astromaterial data analyses, and potentially laboratory sample analysis in general. Representatives of the PSD Planetary Data Ecosystem (PDE) team and the PDS actively participate in the SMD Data Standards working group and in the Open Geospatial Consortium (OGC). Through these efforts, awareness of existing tools and standards are gained that we can then recommend (or require, as appropriate) to our community.

Status: In Progress

Recommendation 11 - The Planetary Data Ecosystem should regularly (on a one- to two-year time scale) assess the Findability, Accessibility, Interoperability, and Reusability (FAIR) of data across each PDE element for machine-actionable access to data. This assessment should be used to establish the priorities for Ecosystem management and advisory groups.

FY23 Response: The Planetary Science Division Planetary Data Ecosystem team is developing an inventory of PDE elements, using the Planetary Data Ecosystem Independent Review Board (PDE IRB) documentation as the foundation, to define the current, funded scope of the PDE, identify unmet community needs, and define the PDE (see also response to Recommendation 2). This inventory will include an initial and informal evaluation of the Findability, Accessibility, Interoperability, and Reusability (FAIR) of data across each PDE element. This evaluation will help to inform priorities for PDE management. Based on the results of this initial effort, we will evaluate whether to repeat, and potentially include independent assessment, in future years and on a regular time scale while considering available staffing and budgetary resources.

Status: Maintenance

Recommendation 12 - As NASA considers future evolution of the PDS, it should consider the positive aspects of what the PDS has accomplished within the context of the Planetary Data Ecosystem—as well as the context of history—and work to preserve the continuing positive outcomes from the PDS, including: maintaining or increasing funding levels as appropriate; working with Mission teams to continue to improve communications about and efficiency of data archival; continuing collaboration with domestic and international partners; and continuing to improve bundle creation and validation software.

FY23 Response: The Planetary Science Division (PSD) agrees that the Planetary Data System (PDS) has had a significant positive impact on data preservation, archival, and in providing open source planetary data to the public for decades. The PSD and the PDS will continue to collaborate to improve working with Mission teams, develop and maintain software and tools to facilitate data archival, and improve communications with the planetary community surrounding data archival. The PSD will also continue and grow our collaborations with domestic and

international partners and recognizes that continual diligence is necessary to ensure the PSD and PDS upholds the intention of this recommendation.

Status: Maintenance

Recommendation 13 - NASA should ensure that PDS has adequate expertise and funding to maintain current standards and to support ongoing improvements, including funding of peer-review of data submissions.

FY23 Response: The Planetary Science Division (PSD) is committed to the continued support for data archival efforts and ensuring that PSD-supported repositories, including the Planetary Data System (PDS), are staffed adequately and with needed expertise. PDS Nodes will continue to be properly funded based on expectations of the PDS's scope and tasks. PSD-funded calls will also continue to include a discussion of the PDS peer-review process, including the time and effort required by data preparers. In addition, PSD will continue to encourage researchers to be reviewers of PDS datasets as is the case for papers.

Status: In Progress

Recommendation 14 - Consideration should be given to how to make clear the differing responsibilities and expectations of the data preservation mission from the distribution of usable data. Consistent with Recommendation 2 for the broader Ecosystem, the prioritized goals and scope of PDS need to be carefully and explicitly defined by NASA, with input from the Ecosystem and broader community, and clearly articulated to all members of the community. Mandates above and beyond the agreed-upon scope must be negotiated and accompanied by commensurate funding. NASA should fund PDS nodes at levels appropriate to the full scope of work defined by the selected proposals as well as any accumulated duties.

FY23 Response: The Planetary Science Division (PSD) agrees that the mission of preserving data and distributing usable data are often distinct and require different methods and guidelines. Additional community discussion is needed to clarify the responsibilities and expectations of these two critical activities. This will be an ongoing and iterative process to help ensure the implementation of a wise and community-driven solution. In addition, the PSD is committed to funding the Planetary Data System (PDS) nodes at levels appropriate to the scope of work defined by the selected proposals and to discuss and negotiate any additional necessary efforts identified in response to new NASA mandates, while also balancing the needs of the planetary community.

Status: Completed

Recommendation 15 - All data dictionaries and information models for the PDS and for other archival elements need peer-review and contextual review (i.e., do these data dictionaries link well with other and existing data dictionaries while avoiding unnecessary redundancy?).

FY23 Response: The Planetary Data System (PDS) has developed a common taxonomy and glossary of terms and maintains discipline specific data dictionaries. The PDS Management Council has formed a Data and Change Control Board Working Group that designs and develops both the PDS4 information model and its schemas for labeling planetary data, as well as for the development of standardized data dictionaries. The working group reports findings and recommendations to the PDS Management Council regarding proposed changes to the PDS4 information model and data dictionaries. Discipline specific data dictionaries are developed by PDS staff members with background in relevant scientific disciplines and data science. Note that PDS discipline data dictionaries are publicly available on GitHub and to the

Planetary Data Ecosystem (PDE) community for comment. In addition, the PDS uses local data dictionaries (LDD) to address needs not included in the basic model, and in 2023 the PDS established a discipline LDD (dLDD) change control board where each dLDD team is responsible for reviewing and approving changes to local data dictionaries. These two inter-related working groups address this recommendation that data dictionaries and information models undergo peer-review and contextual review and to ensure they work well with other existing data dictionaries.

To assure community involvement, several members of the PDS Management Council are also members of the [International Planetary Data Alliance](#) (IPDA), an organization that includes international space and planetary science agencies that is specifically dedicated to the development of the PDS4 information model. The IPDA meets twice a year to discuss developments and recommendations for both PDS4 and related planetary data management practices. The PDS directly engages the broader PDE on related concerns at major conferences and meetings, where PDS staff members work outreach booths and present conference talks.

Status: In Progress

Recommendation 16 - Create a shared, common taxonomy, controlled vocabulary, high level data dictionary, and/or glossary of terms across the Planetary Data Ecosystem. This will substantially advance the machine-actionability of Ecosystem data, and specifically improve interoperability and reusability as described in the FAIR data principles.

FY23 Response: Within the Planetary Data System (PDS), there are existing standards for geospatial data that include planetary taxonomy that are currently in use among large segments of the geospatial community. Related to Recommendation 15, the PDS has developed a [common taxonomy and glossary of terms](#) and maintains discipline specific data dictionaries (see also Recommendation 15 response). The PDS Management Council has formed a Data and Change Control Board working group that designs and develops both the PDS4 information model and its schemas for labeling planetary data, as well as for the development of standardized data dictionaries. In addition, the PDS uses local data dictionaries (LDD) to address needs not included in the basic model, and in 2023 the PDS established a discipline LDD (dLDD) change control board where each dLDD team is responsible for reviewing and approving changes to local data dictionaries. The PDS discipline data dictionaries are also publicly available on [GitHub](#) and to the Planetary Data Ecosystem (PDE) community for comment. These two inter-related working groups addressed this recommendation for a shared, common taxonomy, controlled vocabulary, high level data dictionary, and/or glossary of terms. In addition, Astromat has defined taxonomies for laboratory sample data based on past experience archiving laboratory data for terrestrial samples. The vocabulary for laboratory analytical methods is publicly maintained in machine-readable format. A cross-discipline Specific Action Team between the Extraterrestrial Materials Analysis Group (ExMAG) and the Lunar Exploration Analysis Group (LEAG) is engaged to identify future sample and data analysis archival needs for this community, which includes a review of the current taxonomy and controlled vocabulary being used by Astromat. Additional efforts are needed to identify existing taxonomy standards for data that is not geospatial or laboratory sample data and that may be promoted within those communities. Promotion of these standards, developing and evolving these standards, and educating the PDE community is an ongoing effort.

Status: In Progress

Recommendation 17 - NASA should consider a more open and centralized Management Council for PDS governance that includes greater emphasis on systemwide governance in regard to structure, standards, and related processes. A major goal should be to increase the efficacy of decision-making and multi-way communication with Ecosystem stakeholders.

FY23 Response: The Planetary Science Division (PSD) considers this recommendation to be met and that current activities are effective, transparent, and responsive to the planetary science community's needs. The Planetary Data System (PDS) operates as a centralized organization through the PSD Management Council. In collaboration with the PSD Program Scientist from NASA Headquarters, the PDS Management Council has representation from all PDS Discipline Nodes and makes technical and operational decisions regarding overall PDS management, operation, standards development, adoption of new technologies, and related processes. In addition, multi-way communication with Ecosystem stakeholders is achieve through several mechanisms. All Nodes make a concerted effort to reach out to and be accountable to the community through Node Advisory Board activities, meeting and workshop presentations and feedback sessions, formal and ad hoc support of data providers and users, the PDS community survey, and sponsorship of the Planetary Science Informatics and Data Analytics conference. Further, NASA PSD selected a Planetary Data Ecosystem (PDE) Chief Scientist, Moses Milazzo, in December 2021. The PDE Chief Scientist is an ex officio on the PDS MC and is an additional means for communication with the broader community and to gather community feedback.

Status: Not Yet Started

Recommendation 18 - The makeup and distribution of nodes should be examined more closely to ensure that the PDS contains the appropriate and relevant node elements and subject matter expertise, that unnecessary duplication of effort and data do not occur, and that appropriate flexibility regarding scope and content is built into policy.

FY23 Response: As the needs of the planetary data community evolve and as NASA data archiving policies change (e.g., introduction of SPD-41a), the Planetary Science Division (PSD) must also evaluate the available data archiving tools and repositories to ensure community needs are met and in a manner that minimizes duplication of effort and data. This evaluation includes the examination of the Planetary Data System (PDS). At minimum, the PSD will evaluate the composition and distribution of PDS nodes every 10 years and in alignment with the regular solicitation to re-compete PDS node leadership. Mid-term reviews (i.e., every 5 years) also provide an opportunity to examine and make minor modifications to the PDS archive, while maintaining a reasonable scope of work and considering budgetary constraints. We will also seek input from the planetary community using mechanisms such as workshops, Requests for Comment or Information, and Town Hall meetings, and use that feedback to develop the PDS solicitation requirements and criteria.

Status: Not Yet Started

Recommendation 19 - Mission teams should not be re-formatting NASA-produced data for archiving; this should be internal to NASA. It would make more sense for NASA radio-science experts to decide on a single, existing archival standard format for spacecraft tracking and ancillary data and to directly archive these data without relying on mission intervention.

FY23 Response: There is a potential opportunity to streamline archival efforts of data and ancillary information. The Planetary Science Division (PSD) will investigate the efforts of mission

teams to reformat spacecraft tracking and ancillary data for archiving. Based on such an investigation, PSD will explore solutions for simplifying this archival process.

Status: Not Yet Started

Recommendation 20 - NASA should review its contract agreements to ensure that mission instrument data archiving and future access and usability is an obligation that is appropriately considered and funded. As part of the agreement entered into with NASA, mission and instrument teams should be expected (and funded) to develop level one requirements that include raw, calibrated, higher-level, and foundational data product planning, execution, processing, delivery, and archival.

FY23 Response: NASA currently has requirements ensuring data is archived in a manner that allows for the preservation of raw and level 1 data products, calibration artifacts, and necessary data processing and calibration software into antiquity, and the contracts enforce the achievement of all NASA-imposed requirements. During Key Decision Point (KDP) reviews throughout the mission planning and development process, data and software management plans are developed and individuals in Planetary Science Division review and approve a mission data plan. In addition, and prior to mission closeout (Phase F), there is also a KDP-F. For closeout the main objective is to ensure there is adequate funding to ensure that mission data, final processing and other artifacts are migrated to the archive. During KDP-F there is an opportunity to discuss the mission budget if additional data archiving needs are recognized during mission operations and sustainment (Phase E). Recently, a requirement for mission Open Science Data Management Plan (OSDMP) review by the Planetary Data Officer was adopted, which could help identify needed foundational data products. However, mission teams are not required to conduct foundational data product planning, execution, processing, delivery, and archival at this time, although some mission teams produce and archive such products. In addition, we welcome and encourage the community to propose to relevant solicitations to generate and archive these higher-order data products and address this need.

Status: Maintenance

Recommendation 21 - NASA should treat mission data archival as a systems engineering concern by including early funding for mission data acquisition, processing, and archiving of data and foundational data products (including cartographic products, data acquisition contextual information, coordinate system standards, etc.) so that they are planned well in advance of data acquisition.

FY23 Response: The discussions between the Planetary Science Division (PSD), mission teams, and the Planetary Data System (PDS) to develop an appropriate data archival plan occurs throughout the mission development lifecycle and there are requirements to ensure policy-compliant data archiving. These contracts then enforce the achievement of all NASA-imposed requirements. The PSD and mission teams put forth significant effort to anticipate needed data products, and an Open Science Data Management Plan (OSDMP) is developed considering mission and community needs relative to available mission funding and maintaining a balanced portfolio. In addition, the PDS works with mission teams early in the process to support the development of a data archiving strategy, peer reviews all data products, provides training, and ensures mission data products are available to the community. Recently, a requirement for mission OSDMP review by the Planetary Data Officer was adopted, which could help identify needed foundational data products. Thus, there are many reviews and checks to help ensure that mission data archiving is planned well and in advance of data acquisition. The PSD acknowledges that the current processes must continue to be exercised.

Status: Not Yet Started

Recommendation 22 - NASA should consider a series of investigations or workshops to better understand the full costing of archival for various personas: mission archival managers, telemetry managers; instrument archival managers, R&A data producers; etc. The results of these workshops should be made publicly available and should be included with Data Management Plan templates.

FY23 Response: The Planetary Science Division recognizes the importance of the community having access to accurate archival costs data to inform proposal budgets and data management planning efforts. This recommendation will be addressed in future years.

Status: In Progress

Recommendation 23 - NASA should provide regular, accessible, and effective training programs for researchers, data producers, mission specialists, and others who need to archive with the PDS. This should not just be provided by the PDS: entities with experience delivering to the PDS should also be involved. There should also be training for peer-review of data archives. We also recommend that this training and documentation address data preparation from the perspective of reusability and interoperability, such as the Earth Science Data Systems Working Group (ESDSWG) Data Product Development Guide (DPDG) for Data Producers.

FY23 Response: The Topical Workshops, Symposia, and Conferences (TWSC) solicitation invites proposals for events, including asynchronous and virtual workshops and training programs, that would help address this need. Proposal submissions are encouraged to develop needed community training for archival with the Planetary Data System (PDS) and other Planetary Data Ecosystem-related topics. The Planetary Science Division (PSD) has funded meritorious TWSC proposals to develop training in response to community needs and will continue this support as resources allow. For example, in June 2022, PSD selected a proposal (PI: Dr. David Williams, ASU) to offer a series of Planetary Data Training Workshops that occurred in May and June 2023. Workshops topics include planetary data management, planetary Geographic Information Systems (GIS) training (ArcGIS, open source GIS, and JMARS), Integrated Software for Imagers and Spectrometers (ISIS3) for image processing, SOCET SET-Ames Stereo Pipeline for digital elevation model (DEM) production, and making planetary data available outside of the PDS. Also, through the Transform to Open Science Training (F.14 TOPST) ROSES solicitation, a proposal was selected (PI: Dr. Sierra Brown, Million Concepts) to create a self-paced learning course in open science data, tools, and techniques targeted to learners ranging from interested laypeople to experienced scientists. This course will focus on skills, data, and workflows that are relevant to research in planetary science and astronomy and include: (1) accessing and analyzing publicly available NASA data (including cloud-based datasets), (2) using both general and discipline-specific open-source software libraries for data access, manipulation, analysis, and visualization, (3) creating, managing, and sharing open science workflows. In addition, the Science Mission Directorate Office of the Chief Science Data Office developed TOPS Open Science-101 curriculum, which provides information for topics such as open science, open data, and open software. Finally, the PDS provides training, documentation, and direct one-on-one consultation for data archival. These PDS services are available and provide a benefit to both mission data teams and individual investigators. As these efforts continue, we will evaluate success, lessons learned, and whether this (or similar) efforts should continue and on what cadence.

Status: In Progress

Recommendation 24 - (Non-consensus) Several members of the review panel strongly recommend that the PDS move forward with a lightweight user registration system. Other members have concerns and strongly recommend a cautious approach so that any registration system implemented does not create additional barriers to access to, acquisition of, or usability of planetary data.

FY23 Response: Currently, no user registration is required for Planetary Data System (PDS) download from services that reside on the premises of the Discipline Node. As PDS data holdings and services migrate to a cloud environment, a light-weight registration will likely be required for using cloud-based computational and analytical services or downloading data. The PDS Management Council is continuing to discuss approaches that minimize barriers for the user and provide high-quality services while also ensuring that cloud-related costs and resources can be effectively managed.

Status: In Progress

Recommendation 25 - NASA should continue to execute against the PDS cloud computing strategy, including selective refactoring of current systems to enable cloud migration, such as the adoption of containerization and further work to establish well-defined and well-documented application programming interfaces.

FY23 Response: Efforts to execute against the Planetary Data System (PDS) cloud computing strategy are ongoing. The NASA Planetary Data System is working on a multi-year effort to establish a Planetary Data Cloud (PDC) Platform. This effort includes developing pilot projects to migrate targeted data sets and services to the cloud and to help inform the data management strategy for the PDS use of cloud technologies and services that could be provided to users. For example, the availability of planetary data sets and services in a cloud environment will enable users to perform computation alongside the data, without the need to download, streamlining analysis and discovery. The PDS recognizes the significant potential that cloud-based services bring to our services and to our users, and discussions are ongoing to determine how to best leverage the potential of the cloud while also considering the costs and complexity of this technology.

Status: Maintenance

Recommendation 26 - The PDS should continue discussions and collaborations with other NASA elements, including EOSDIS and OCIO, to leverage the work done in these organizations and ensure that Planetary Science Division needs are appropriately considered in establishing NASA standards and practices.

FY23 Response: This recommendation has been addressed, and largely due to the hiring of the Planetary Science Division (PSD) Planetary Data Officer in May 2023. One role of this position is to serve on cross-divisional groups focused on advancing data sharing and use policies. Through these efforts and collaborations, the PSD is continually learning about efforts that can be leveraged and considered as we develop and evolve the Planetary Data Ecosystem (PDE). In addition, the Planetary Data System (PDS) and the Planetary Data Officer will develop a plan to help facilitate PDS collaborations with other NASA archives and PDE elements. Finally, the Planetary Data Officer and others on the PDE team advocate for the needs of the planetary community as NASA and Science Mission Directorate standards and practices are developed and evolved.

Status: In Progress

Recommendation 27 - NASA should consider the impact of cloud computing adoption on organizational efficiency and the development of a broader planetary ecosystem, above and beyond the technical capabilities that public cloud computing brings to addressing data provider and data user needs.

FY23 Response: In response to Executive Orders, NASA's current policy on cloud use is a "Cloud Smart" approach where cloud-based options are available and encouraged for use when it makes sense for the application and in consideration of other NASA High End Computing (HEC) or organizational on-premises computer resources. NASA has an Authority to Operate (ATO) with all major cloud-providers (i.e., Amazon Web Services (AWS), Azure, and Google Cloud) and Science Mission Directorate (SMD) is developing cloud support services as part of the SMD Office of the Chief Science Data Officer core data and computing services infrastructure. Significant steps have been made to address cloud access and availability. We consider this recommendation to require ongoing effort to consider the impact of cloud computing adoption on organizational efficiency and the development of a broader planetary ecosystem, as technology infrastructure and cost models evolve.
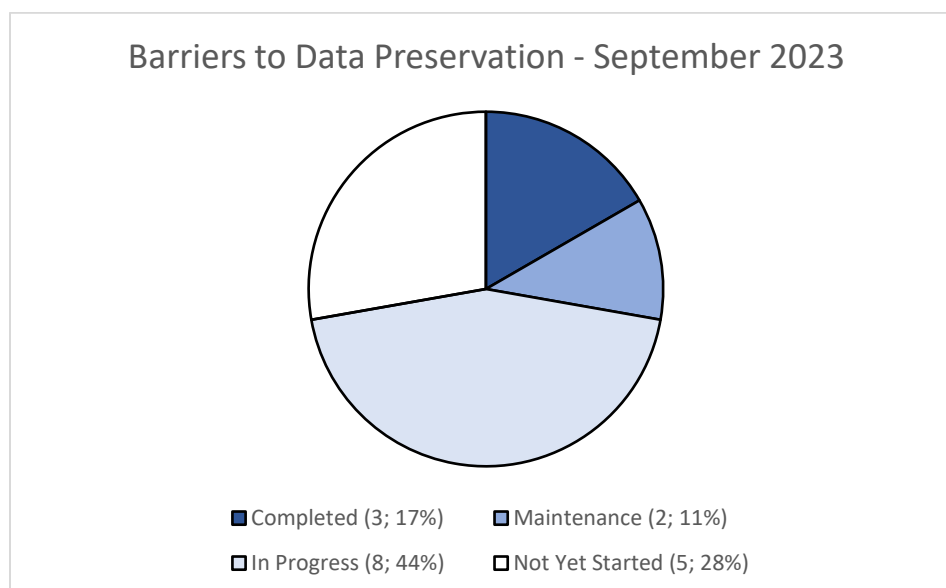
3. Barriers to Data Preservation

Figure 3. Chart illustrating the status of the Planetary Science Division response of each recommendation in the category "Barriers to Data Preservation" as a percentage and based on efforts from April 2021 to September 2023. There are 18 recommendations within this category, and this chart illustrates the number and percentage status for this sub-section of the PDE IRB recommendations.

Status: In Progress

Recommendation 28 - NASA should establish a carefully crafted strategy to identify and prioritize the data preservation needs of the planetary science community that are not currently being addressed.

FY23 Response: The Planetary Science Division (PSD) Planetary Data Ecosystem (PDE) team is developing an inventory of PDE elements, using the Planetary Data Ecosystem Independent Review Board (PDE IRB) documentation as the foundation, to define the current, funded scope of the PDE, and identify unmet community needs. This PDE inventory will be used to assess how the usability and archival needs of the planetary sciences community are currently being supported and identify gaps in that support. The PSD will then develop a community-based plan to address these identified gaps, and will seek feedback from the planetary community through available mechanisms such as workshops, Requests for Comment or Information, and Town Hall meetings. This inventory and community feedback will help inform data preservation priorities for PDE management. Additional infrastructure for the public release of model results is needed and cross-divisional discussions will be used to identify potential solutions.

Status: In Progress

Recommendation 29 - NASA should consider ways of archiving outside of the PDS that are amenable to creating FAIR and standards-based archives of these growing data sets.

FY23 Response: The Planetary Science Division (PSD) Planetary Data Ecosystem (PDE) team is developing an inventory of PDE elements, using the Planetary Data Ecosystem Independent Review Board (PDE IRB) documentation as the foundation, to define the current, funded scope

of the PDE, and identify unmet community needs. In addition, we are defining criteria for a PSD-funded repositories based on 2022 guidance from the White House National Science and Technology Council on *Desirable Characteristics of Data Repositories for Federally Funded Research* and guidelines for Science Mission Directorate (SMD)-acceptable data repositories in Appendix D of SPD-41a. Through these efforts, we will identify methods of archiving data and software that are available to the planetary community, including repositories funded by the PSD and other SMD Divisions, and evaluate responsiveness of these repositories to Findability, Accessibility, Interoperability, and Reusability (FAIR) principles and Federal and SMD guidance. This inventory will also highlight PDE element types where no known NASA-supported repository exists and will help to inform priorities for PDE management.

Status: Maintenance

Recommendation 30 - The Science Mission Directorate should elevate support for information and data science issues to parity with other areas in order to systematically address NASA's unmet data preservation needs.

FY23 Response: Since the Planetary Data Ecosystem (PDE) Independent Review Board (IRB) final report was published, the Science Mission Directorate (SMD) has hired a Chief Science Data Officer and developed the Office of the Chief Science Data Officer (OCSDO). This office is collaboratively developing a cross-divisional comprehensive data science strategy for SMD. This strategy aims to leverage the latest advancements in data science to enhance NASA's capabilities in scientific research, data management, and collaborative innovation. The OCSDO also includes an effort aimed at providing an infrastructure and support for information and data science issues across SMD. These services include cloud hosting services with separate security profiles appropriate for data preservation /archival and science analysis/collaboration; advanced search capabilities across all divisions and to support cross-discipline science; and policy development to provide archival guidelines for the NASA science community. Also in May 2023, the PSD hired a Planetary Data Officer, and one role of this position is to develop, maintain, and evolve the PDE, using the PDE IRB final report as a guiding document. In addition, open science cross-divisional funding solicitations have been added to Research Opportunities in Space and Earth Science (ROSES) solicitations (section F) to provide additional funding opportunities for information and data science activities. Together, these systematic efforts are helping to elevate and address NASA's previously unmet data preservation needs. We consider this recommendation to be addressed, recognizing that maintenance, communication, and evaluation of the effectiveness of these efforts are continually needed.

Status: Completed

Recommendation 31 - NASA should establish an archive for planetary radar data either within the PDS Small Bodies Node or separately. This archive should facilitate preservation and usability of data at all processing levels by preservation of data processing procedures (or software). Because of the unique situation of Arecibo Observatory, time is of the essence to preserve the data and prevent irretrievable loss.

FY23 Response: The Planetary Science Division (PSD) currently supports radar data analysis, publication, and archiving of Arecibo data at the Planetary Data System (PDS) Small Bodies Node (SBN). Meetings between the PDS SBN and the Arecibo, Jet Propulsion Laboratory (JPL), and Goldstone radar groups to coordinate formats and processes among their substantial radar data archiving efforts are ongoing and continue to be of priority. SBN is actively working with these radar observers to prepare and submit their data to the PDS and expand SBN holding of ground-based radar data observations. Additionally, PSD has supported the creation

of a Radio Science sub-Node of the PDS established in collaboration with the Planetary Radar and Radio Sciences Group (PRRSG) at JPL and which provides a Planetary Radar Advisory Role to the PDS. No further actions are planned to be taken in response to this recommendation, as the remaining component of archival of software is part of a larger Ecosystem discussion.

Status: Not Yet Started

Recommendation 32 - NASA should support the establishment of public archives of analysis-ready data from observational facilities for which such archives do not already exist.
FY23 Response: The Planetary Science Division recognizes the importance of public archives of analysis-ready data from observational facilities. This recommendation will be addressed in future years.

Status: Completed

Recommendation 33 - NASA should establish a requirement for the preservation of mission-supported laboratory analyses of returned sample material that makes the information accessible to the planetary science community. Time is of the essence to establish these requirements, as NASA will receive the largest sample return since Apollo in approximately two years.
FY23 Response: Astromat is the official NASA archive for astromaterial sample data collected both from mission-supported and Research and Analysis (R&A) funded efforts (including laboratory analyses of returned samples and meteorites) and Astromat has been selected for funding through 2028. The Astromat repository will include extensive consideration for SPD-41a requirements, Findability, Accessibility, Interoperability, and Reusability (FAIR) data practices, incorporating the PDS4 metadata standard for potential future interoperability, and implementation plans for compliance. Astromat also participates in OneGeochemistry, an international initiative to develop and promote standards and best practices for lab analytical data in geochemistry. OneGeochemistry is part of a project called WorldFAIR that is executed by CODATA and the Research Data Alliance and funded by the EU to "advance implementation of the FAIR principles and, in particular, to improve interoperability and reusability of digital research objects, including data." Conversations with Astromat and the Planetary Science Division are collaborative and ongoing. The Astromaterials Data Management and Archiving Working Group has been established within the Extraterrestrial Materials Analysis Group (ExMAG) Facilities and Informatics Subcommittee to advise on the tools and best practices for supporting community compliance with SPD-41a within the context of the data generated from the analysis of astromaterials. In addition, a cross-discipline Specific Action Team between the ExMAG and the Lunar Exploration Analysis Group (LEAG) is being planned to identify future sample and data analysis archival needs for this community.

Status: Completed

Recommendation 34 - NASA should require data preservation with appropriate metadata in an approved archive or repository for data produced by laboratory analysis of returned samples supported by ROSES Data Analysis Programs (DAP).
FY23 Response: Related to Recommendation 33, Astromat is the official NASA archive for astromaterial sample data collected both from mission and Research and Analysis (R&A) funded efforts (including laboratory analyses of returned samples and meteorites) and Astromat has been selected for funding through 2028. The Astromat repository will include consideration

of SPD-41a requirements, Findability, Accessibility, Interoperability, and Reusability (FAIR) data practices, incorporating the PDS4 metadata standard for potential future interoperability, and implementation plans for compliance. Conversations with Astromat and the Planetary Science Division are collaborative and ongoing. The Astromaterials Data Management and Archiving Working Group has been established within the Extraterrestrial Materials Analysis Group (ExMAG) Facilities and Informatics Subcommittee to advise on the tools and best practices for supporting community compliance with SPD-41a within the context of the data generated from the analysis of astromaterials. In addition, a cross-discipline Specific Action Team between the Extraterrestrial Materials Analysis Group (ExMAG) and the Lunar Exploration Analysis Group (LEAG) is being planned to identify future sample and data analysis archival needs for this community.

Status: In Progress

Recommendation 35 - NASA should adopt or develop a standard set of metadata and links to ensure that contextual data are adequately tied to returned and gathered samples. With Mars 2020 gathering and caching samples for later return to Earth, time is of the essence.
FY23 Response: Astromat will be the archival location for astromaterial sample data (including Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS Rex), Artemis, and Mars Sample Return missions) and this tool is archiving these data using the PDS4 metadata standard. The use of the PSD4 metadata standard by both Astromat and the Planetary Data System (PDS) will help to ensure that contextual data collected by the mission team (e.g., environmental conditions, images and other data collected by orbital and lander instruments) archived in the PDS are tied to returned and gathered samples. In addition, implementation of persistent identifiers for samples (International Generic Sample Number; IGSN) is a critical step to link contextual data to samples and analytical data and is recommended by the Planetary Science Division in its supplemental guidance to SPD-41a. Additional efforts are still needed to support the archival of contextual data related to mission operations and planning information (see Recommendation 38).

Status: In Progress

Recommendation 36 - NASA should assess the current state of planetary analog repositories and develop the requirements for the establishment of a permanent planetary analog repository or archive.
FY23 Response: The Planetary Science Division (PSD) Planetary Data Ecosystem (PDE) team is developing an inventory of PDE elements, using the Planetary Data Ecosystem Independent Review Board (PDE IRB) documentation as the foundation, to define the current, funded scope of the PDE, and identify unmet community needs. Currently funded planetary analog repositories include individual the USGS Terrestrial Analog Data Portal (TADP) and Astrobiology Habitable Environment Database (AHED). In addition, the PSD PDE team is defining criteria for a PSD-funded repositories based on 2022 guidance from the White House National Science and Technology Council on *Desirable Characteristics of Data Repositories for Federally Funded Research* and guidelines for Science Mission Directorate-acceptable data repositories in Appendix D of SPD-41a. Through these efforts, PSD will identify methods of archiving analog field data that are available to the planetary community and establish appropriate archival guidelines.

Status: Not Yet Started

Recommendation 37 - NASA should establish a primary archive or repository for mission telemetry streams that is accessible to the planetary science community to the extent permitted by regulatory limitations.

FY23 Response: The Planetary Science Division recognizes the importance of the community having access to mission telemetry streams to the extent permitted by regulatory limitations. This recommendation will be addressed in future years.

Status: Not Yet Started

Recommendation 38 - NASA should establish a requirement for the preservation of mission operations and planning information that makes the information accessible to the planetary science community to the extent permitted by regulatory limitations.

FY23 Response: The Planetary Science Division recognizes the importance of the community having access to mission operations and planning information to the extent permitted by regulatory limitations. This recommendation will be addressed in future years.

Status: Not Yet Started

Recommendation 39 - NASA should evaluate and develop a plan for historical information preservation with the aim of making these data available to the public to the extent possible.

FY23 Response: The Planetary Science Division recognizes the importance of the community having access to historical information and to ensure that the preservation of these data is a priority. This recommendation will be addressed in future years.

Status: In Progress

Recommendation 40 - NASA should establish requirements that specify the archive(s) or repositories of record for higher-level data products, with the ultimate goals of systematic collection and reuse of these high-level data products.

FY23 Response: The Planetary Science Division (PSD) Planetary Data Ecosystem (PDE) team is defining criteria for a PSD-funded repositories, including those for high-level data products, based on 2022 guidance from the White House National Science and Technology Council on *Desirable Characteristics of Data Repositories for Federally Funded Research* and guidelines for Science Mission Directorate (SMD)-acceptable data repositories in Appendix D of SPD-41a. Through these efforts, we will establish requirements for archive(s) or repositories of record for higher-level data products. In addition, the PSD recognizes that there are not suitable archive(s) or repositories for all data generated by PSD-funded projects (e.g., model-derived data), and that the Planetary Data System (PDS) review process may not be necessary for all data products. The PSD Planetary Data Ecosystem (PDE) team is investigating current resources, data repositories, and tools available within SMD, PSD, and PDS, and is determining the infrastructural needs of the planetary data community to be in compliance with SPD-41a. Our long-term goal is to provide clear guidelines that describe archive(s) or repositories of record for all data types generated using PSD funding, and including higher-level data products, so that the scientific community and general public can find, access, and reuse all data collected and generated through PSD funded efforts.

Status: In Progress

Recommendation 41 - NASA should establish guidelines for preserving high-level data sets of interest that are not appropriate to PDS archiving. Designate data repositories that comply with FAIR (Findable, Accessible, Interoperable, Reusable) data principles.

FY23 Response: The Planetary Science Division (PSD) recognizes that not all high-level data sets are appropriate to archive with the same level of documentation and ancillary information required for mission-collected data in the Planetary Data System (PDS). Related to Recommendation 29, the PSD Planetary Data Ecosystem (PDE) team is developing an inventory of PDE elements, using the Planetary Data Ecosystem Independent Review Board (PDE IRB) documentation as the foundation, to define the current, funded scope of the PDE, and identify unmet community needs. In addition, we are defining criteria for a PSD-funded repositories based on 2022 guidance from the White House National Science and Technology Council on *Desirable Characteristics of Data Repositories for Federally Funded Research* and guidelines for Science Mission Directorate (SMD)-acceptable data repositories in Appendix D of SPD-41a. Through these efforts, we will identify methods of archiving and preserving high-level data sets of interest that are available to the planetary community, and including repositories funded by the PSD and other SMD Divisions. We will also evaluate responsiveness of these repositories to Findability, Accessibility, Interoperability, and Reusability (FAIR) principles and Federal and SMD guidance. These efforts will help to inform priorities for PDE management.

Status: In Progress

Recommendation 42 - NASA should develop a comprehensive software preservation and archiving strategy that ensures discoverable, accessible, and usable software tools. The curation of the collection of NASA-funded software products through a designed software node within PDS, a centrally managed catalog, or with another approach will ensure the successful implementation of NASA open-source software policies.

FY23 Response: NASA Science Mission Directorate (SMD) has developed a comprehensive software preservation and archiving strategy that ensures discoverable, accessible, and usable software tools. The SMD Information Policy SPD-41a outlines policy guidelines for developing NASA-funded software openly and requires that software developed using SMD funding shall be made publicly available through methods that are transparent, inclusive, accessible, and reproducible. Restricted software, that is software that is subject to specific laws, regulations, or policies (e.g., Export Administration Regulations (EAR), International Traffic in Arms Regulations (ITAR), intellectual property laws, license restrictions) that would prevent the release of this information, is exempt from the requirements for making software publicly available. In addition, NPR 2210 - Release of NASA Software was updated in June 2023 to respond to community needs for making NASA-developed scientific software publicly available. The Planetary Science Division has not yet addressed the recommendation to provide a designed software node within Planetary Data System (PDS), or a centrally managed catalog, to archive NASA-funded software products, and these discussions are ongoing.

Status: Not Yet Started

Recommendation 43 - NASA should develop requirements for the maintenance of mission data processing pipelines so that non-team members can produce data identical to the output from instrument team processing pipelines.

FY23 Response: The Planetary Science Division recognizes the importance of the maintenance of mission data processing pipelines and the desire for non-team members to produce data identical to the output from instrument team processing pipelines. This recommendation will be addressed in future years.

Status: In Progress

Recommendation 44 - NASA should develop a plan for the preservation of models and modeling data beginning with requirements for how models and modeling data should be preserved and linked to other Ecosystem elements.

FY23 Response: A recognized need across all Science Mission Directorate (SMD) Divisions is guidance, standards, and appropriate repositories for the archival and public release of models and model science data results. The SMD Open Source Science Initiative is beginning cross-divisional conversations regarding how to support the public release of model results (both data and software). These discussions would help Planetary Science Division leverage the experience and expertise across divisions and develop more comprehensive guidelines for the public release of model results. In addition, the development of a modeling annex at the Planetary Data System Atmospheres Node is an early step to have a location to archive Global Circulation Models and other atmospheric modeling results. Additional infrastructure for the public release of model results is needed and cross-divisional discussions will be used to identify potential solutions.
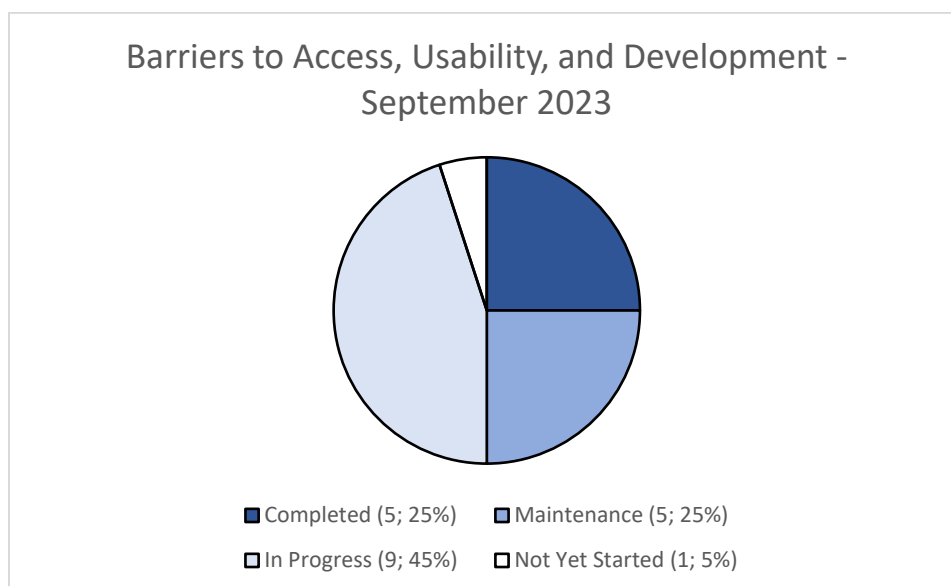
4. Barriers to Access, Usability, and Development

Barriers to Access, Usability, and Development - September 2023

- Completed (5; 25%)
- Maintenance (5; 25%)
- In Progress (9; 45%)
- Not Yet Started (1; 5%)

Figure 4. Chart illustrating the status of the Planetary Science Division response of each recommendation in the category "Barriers to Access, Usability, and Development" as a percentage and based on efforts from April 2021 to September 2023. There are 20 recommendations within this category, and this chart illustrates the number and percentage status for this sub-section of the PDE IRB recommendations.

Status: In Progress

Recommendation 45 - NASA should provide and advertise a better point of entry (or several well-connected portals) to its data, suitable for the broadest range of users looking for planetary data.

FY23 Response: There are several current activities underway to develop a better point of entry to Planetary Science Division (PSD)-funded data and help to make these data more findable and accessible. The Science Mission Directorate (SMD) Science Discovery Engine is a cross-Discipline search capability where all data in the Planetary Data System (PDS) will be indexed, and alongside data from other curated planetary sources within the PSD and SMD Division. This search capability will foster data discoverability and cross-discipline science. In addition, the PDS Engineering Node has re-designed the PDS website and is implementing significant improvements to the PDS website search capabilities aimed at improving the findability of data archived in the PDS across nodes. The new PDS website is planned to be publicly available in the summer of 2024. Finally, SMD is developing the SMD Science Data Portal, which is a data website for public access to SMD-funded science data. The planetary data sites are currently under development.

Status: In Progress

Recommendation 46 - The user search experience needs to be improved across the Planetary Data Ecosystem. PDE elements should partner with a user experience (UX) expert to understand the principles and guidelines for UX.

FY23 Response: The Planetary Science Division is developing both the planetary data site on the Science Mission Directorate Science Data Portal and the new Planetary Data System (PDS) centralized website with user experience (UX) expertise on these web development teams. The PDS Engineering Node's design team has obtained extensive user feedback and performed a thorough review of the public-facing tools for discovering and accessing data archived in the PDS. Through this evaluation, they have designed and are implementing a new and improved, integrated, and modernized user experience through the PDS website that includes advanced search capabilities to improve the findability of data archived in the PDS across nodes. The new PDS website is planned to be publicly available in the summer of 2024.

Status: Completed

Recommendation 47 - NASA should support and encourage expanded use of DOI-like identifiers for data, thereby connecting data at various levels of processing to assist users in locating the best version of a data set for their needs.

FY23 Response: The Science Mission Directorate (SMD) Scientific Information Policy SPD-41a requires that publicly available SMD-funded data collections shall be citable using a persistent identifier (e.g., digital object identifier, or DOI). To support this requirement, SMD provides a means for NASA-funded repositories to generate DOI identifiers for data and software. Astromat uses this service to issue DOIs for all data archived and for registering samples with IGSN. In addition, the Planetary Data System (PDS) now issues DOIs for all data archived using a custom tool that integrates with DataCite.org. See the PDS DOI Policy and how to cite PDS4 data for additional information. The PDS and Astromat archives constitute a majority of Planetary Science Division (PSD) data collected and made publicly available by the PSD. For data and software not archived in the PDS or Astromat, NASA has an agreement with Zenodo, and researchers can generate a DOI and archive data and software within the Zenodo repository.

Status: Maintenance

Recommendation 48 - NASA should continue to support non-planetary data archives and encourage cross-communication between planetary and non-planetary metadata developers.

FY23 Response: The Planetary Science Division (PSD) Planetary Data Ecosystem (PDE) team is developing an inventory of PDE elements, using the Planetary Data Ecosystem Independent Review Board (PDE IRB) documentation as the foundation, to define the current, funded scope of the PDE, and identify unmet community needs. Through this effort, the PSD will identify non-planetary data archives that are relevant to the PDE and that could enable the discovery of data that exists at the boundaries between disciplines and foster cross-disciplinary data analysis. In addition, the PSD PDE team actively participates in the Science Mission Directorate (SMD) Open Source Science Initiative to help foster cross-divisional sharing of knowledge and solutions regarding available data sets, software, and tools. Through these cross-divisional efforts, the PSD engages in cross-divisional communication across SMD through various working groups and reviews data archival and infrastructure related efforts within other SMD divisions. In addition, the SMD Science Discovery Engine is a cross-Discipline search capability where all data in the Planetary Data System (PDS) will be indexed, and alongside data from other curated planetary sources within the PSD and SMD Divisions. This search capability will foster data discoverability and cross-discipline science. In addition, NASA PSD selected a PDE Chief Scientist, Moses Milazzo, in December 2021. The PDE Chief Scientist is also an additional means for communication with the broader community and to gather community feedback.

Status: Completed

Recommendation 49 - NASA should fund the development of more analysis-ready data (ARD) products derived from the lower-level products created by NASA missions.

FY23 Response: NASA is funding and encouraging the development of more analysis-ready data (ARD) products derived from the lower-level products created by NASA missions. Language has been added to the Research Opportunities in Space and Earth Science (ROSES) Planetary Data Archiving, Restoration, and Tools (PDART) solicitation encouraging the submission of proposals to develop ARD products. In addition, the Planetary Science Division (PSD) is currently funding efforts to generate and make publicly available cloud-ready and analysis-read data in the NASA-AWS Open Data Registry (ODR) for highly used instrument data of Mars (see also Recommendation 32). This pilot will help the PSD understand how to better support the delivery of higher-level and analysis-ready data products for geospatial data and will help to inform priorities for Planetary Data Ecosystem (PDE) management. Finally, the Open Geospatial Consortium (OGS) has recently formed an Analysis Ready Data Standards Working Group and includes participation from experts within planetary science. We encourage other interested individuals to participate in this, and similar, community-driven efforts.

Status: Not Yet Started

Recommendation 50 - NASA should develop outreach to user communities within the Planetary Data Ecosystem, assess user needs, and develop focused educational and documentation materials that meet highest-priority needs.

FY23 Response: The Planetary Science Division recognizes the importance of engaged user communities within the Planetary Data Ecosystem (PDE) and developing educational and documentation material to meet user community needs. This recommendation will be addressed in future years.

Status: Maintenance

Recommendation 51 - NASA should continue to foster the development of tools which translate from common planetary formats and standards into broadly used protocols, formats, and standards to enable the adoption of tools and methods in use by other science communities.

FY23 Response: NASA encourages the development of a wide range of tools and fosters the development of such tools through various Research Opportunities in Space and Earth Science (ROSES) solicitations. In addition and through a contract managed by the USGS, the Planetary Science Division (PSD) has collaborated with the open-source project Geospatial Data Abstraction Library (GDAL) to ensure that common planetary data formats and cartographic projections are incorporated into this highly used open source input/output (I/O) software library. This effort enables all software and tools, including many commercial platforms, that use GDAL as the I/O module to automatically provide support and capability for planetary geospatial data. The PSD welcomes and encourages the community to propose to available funding solicitations to address this need.

Status: In Progress

Recommendation 52 - Relevant elements of the Ecosystem should support the delivery of higher-level and analysis-ready data products in well-documented and broadly used protocols and formats, even where those formats might not be appropriate for primary data. This should

include broadening support across the Ecosystem for a wider variety of data and information formats, such as engineering data; data models; sound and imaging data; and physical collections attached to planetary missions.

FY23 Response: The Planetary Science Division (PSD) is currently funding efforts to generate and make publicly available cloud-ready and analysis-read data in the NASA-AWS Open Data Registry (ODR) for highly used instrument data of Mars. This pilot will help the PSD understand how to better support the delivery of higher-level and analysis-ready data products for geospatial data and will help to inform priorities for Planetary Data Ecosystem (PDE) management. Additional efforts to understand how to broaden support for a wider variety of datasets include the planned Extraterrestrial Materials Analysis Group (ExMAG) - Lunar Exploration Analysis Group (LEAG) Specific Action Team to evaluate standards and process for publicly releasing astromaterials laboratory data from OREx and Artemis missions and Science Mission Directorate discussions to better supporting the public release of model data.

Status: Maintenance

Recommendation 53 - NASA and the PDE should ensure that data linkage mechanisms and types are clearly documented with examples.

FY23 Response: Related to Recommendation 47, the Science Mission Directorate (SMD), Planetary Science Division (PSD), and Planetary Data System (PDS) have made significant efforts to encourage and expand the use of digital object identifiers (DOIs), which are a critical mechanism to provide linkage. Scientific Information Policy SPD-41a requires that publicly available SMD-funded data collections shall be citable using a persistent identifier. To support this requirement, SMD provides a means for NASA-funded repositories to generate DOI identifiers for data and software. Astromat uses this service to issue DOIs for all data archived and for registering samples with IGSN. In addition, the PDS now issues DOIs for all data archived using a custom tool that integrates with DataCite.org. See the PDS DOI Policy and how to cite PDS4 data for additional information. The PDS and Astromat archives constitute a majority of PSD-data collected and made publicly available by the PSD. For data and software not archived in the PDS or Astromat, NASA has an agreement with Zenodo, and researchers can generate a DOI and archive data and software within the Zenodo repository. The PSD recognizes the importance of data linkage mechanisms and providing clearly documented examples, and efforts in these areas are ongoing.

Status: In Progress

Recommendation 54 - NASA should find ways that the Ecosystem could include developer advocacy, particularly for the core PDS application program interfaces (APIs).

FY23 Response: The Planetary Data System (PDS) search application program interface (API) was initially released in 2021 and currently contains over 80% of the currently PDS4 data holdings within the NASA PDS and Planetary Science Archive (PSA). This integrated search capability is available now (https://nasa-pds.github.io/pds-api/guides/search.html), with a user guide, numerous tutorials, and links to YouTube video examples. The Planetary Data Ecosystem (PDE) and the PDS is investigating new and innovative ways to use the API, integrate with other PDE elements, and including developer advocacy efforts.

Status: Completed

Recommendation 55 - NASA should expand public participation in scientific research and other crowdsourcing methods as one strategy for providing data labeling essential to ML/AI/AA.

FY23 Response: There has not been significant interest in starting crowdsourcing efforts because additional methods have been developed in the Machine Learning / Artificial Intelligence, Advanced Computing (ML/AI/AA) communities that don not require large labeled datasets for training. Thus, the need in these communities for supporting models that require large training datasets is not as urgent as it was a few years ago. The Science Mission Directorate AI/ML group is developing a Large Language Model (LLM) with IBM. This is not a crowdsource effort specifically, but it is getting the broader science community involved in model validation. We consider this recommendation to be completed at this time and will revisit this suggestion as the ML/AI/AA community evolves. Although NASA Headquarters will not be pursuing this recommendation directly, we welcome and encourage the community to propose to address this need or raise new or additional recommendations through relevant planetary Assessment or Analysis Groups (AGs).

Status: Completed

Recommendation 56 - As they proceed with developing the Planetary Data Ecosystem, NASA should ensure that any Ecosystem assessment group considers the needs of current and potential ML/AI/AA users as part of their work.

FY23 Response: The existing planetary Assessment or Analysis Group (AG), Mapping and Planetary Spatial Infrastructure Team (MAPSIT), is chartered to help "ensure that planetary data are usable for any purpose, now and in the future." This AG will help to advocate for cross-domain needs across the Planetary Data Ecosystem (PDE) and the planetary community and including current and potential Machine Learning / Artificial Intelligence, Advanced Computing (ML/AI/AA) users. In addition, body- and domain-specific AGs may also consider the needs of current and potential ML/AI/AA users as part of their discussions, and independent of MAPSIT. The PDE will also be reviewed periodically (e.g., every 5 years) and evaluating whether and how the needs of the ML/AI/AA communities are being met should be a topic of review.

Status: In Progress

Recommendation 57 - **NASA** should also consider how the relatively nascent planetary ML/AI/AA user community might not be well-aligned with traditional missions, funding opportunities, and user groups and the impact that might have on potential respondents to funding calls.

FY23 Response: Currently, the Planetary Science Division (PSD) is supporting the Machine Learning / Artificial Intelligence, Advanced Computing (ML/AI/AA) communities by funding the generation and public release of dataset processed as Analysis Ready Data. Through participation in Science Mission Directorate (SMD) Open Science working groups, the PSD Planetary Data Ecosystem (PDE) team is also gaining awareness of funding calls and potential collaboration opportunities across SMD. These efforts will provide this community with easier access to data in a format more accessible to their needs, thereby reducing existing barriers to both proposing projects in a more cost-effective manner and completing existing work.

Status: In Progress

Recommendation 58 - NASA should increase the level of funding available to explicitly support software development, either via the existing ROSES programs or via the creation of new programs and clarify its policies for evaluating funding proposals that do not include major components of hypothesis-based science.

FY23 Response: Since the Planetary Data Ecosystem (PDE) IRB, NASA has increased the level of funding available to explicitly support software development and has clarified policies and language for funding solicitation that do not include major components of hypothesis-based science. Beginning in Research Opportunities in Space and Earth Science 2023 (ROSES-23), tool development is again a component of the [Planetary Data Archiving, Restoration, and Tools (PDART)](#) program. Also, three additional ROSES solicitations include opportunities for open-source software and tool development, such as [F.7 Support for Open-Source Tools, Frameworks, and Libraries](#), [F8 Supplemental Open Source Software Awards](#), and [F.15 High-Priority Open Source Science](#). Additional efforts to increase support for software development are being discussed.

Status: In Progress

Recommendation 59 - NASA should establish a mechanism to support the preservation, support, and maintenance of software tools past the expiration of the grants under which they were developed.

FY23 Response: The Planetary Science Division (PSD) is investigating a means to ensure the continued support for software that is infrastructural to the Planetary Data Ecosystem (PDE). To that end, the PSD is discussing potential ways to address funding needs for infrastructural software and tools that the broader community depend on and meet a high standard of policy compliance. We also acknowledge that not all software must be supported beyond the expiration of the grants under which they were developed. In addition, the Science Mission Directorate (SMD) [Science Information Policy SPD-41a](#) now requires that software developed using SMD funding shall be made publicly available through methods that are transparent, inclusive, accessible, and reproducible. This new policy directly addresses the recommendation to preserve software tools past the expiration of the grants under which they were developed.

Status: In Progress

Recommendation 60 - NASA should consider providing options for funding software tools with the proposal requirements and total budget with the scale and scope of typical Guest Investigator or early-career programs.

FY23 Response: NASA is committed to funding software tools at higher levels. Beginning in Research Opportunities in Space and Earth Science 2023 (ROSES-23), tool development is again a component of the [Planetary Data Archiving, Restoration, and Tools (PDART)](#) program and specific language is included to encourage smaller projects (and thus shorter proposal lengths, if appropriate). Also, three ROSES solicitations are available for open-source software and tool development, including [F.7 Support for Open-Source Tools, Frameworks, and Libraries](#), [F8 Supplemental Open Source Software Awards](#), and [F.15 High-Priority Open Source Science](#). We consider this recommendation to be addressed, recognizing that efforts to effectively support software development will be ongoing. Efforts to provide smaller-scale software development funding opportunities to incentivize proposers to request appropriately sized awards and to reduce the effort required to propose for smaller-scale software development projects are being discussed.

Status: Maintenance

Recommendation 61 - NASA should consider, on a case-by-case basis, whether commercial contract bid mechanisms or grant proposal mechanisms would be more appropriate for efficiently filling certain critical Planetary Data Ecosystem software tool needs.

FY23 Response: We acknowledge that some infrastructural software tool needs may be appropriate for other funding mechanisms to ensure that these needs are consistently, effectively, and efficiently met and in a consistent and trusted manner. Through the above-mentioned inventory of Planetary Data Ecosystem (PDE) elements, the Planetary Science Division will identify software or tools that may be infrastructural and explore ways to reliably and ethically fund these services. The evaluation of appropriate funding mechanisms for PDE-related services will be an ongoing effort.

Status: Maintenance

Recommendation 62 - Recognizing that "Software is data, but data is not software" (NASEM 2018 page 2), and in keeping with NASA's open data policies, NASA should ensure that software developed by or for the Planetary Data Ecosystem is as open as possible and only as closed as necessary.

FY23 Response: The Science Mission Directorate (SMD) Science Information Policy SPD-41a outlines policy guidelines for developing NASA-funded software openly and requires that software developed using SMD funding shall be made publicly available through methods that are transparent, inclusive, accessible, and reproducible. Restricted software, that is software that is subject to specific laws, regulations, or policies (e.g., Export Administration Regulations (EAR), International Traffic in Arms Regulations (ITAR), intellectual property laws, license restrictions) that would prevent the release of this information, is exempt from the requirements for making software publicly available. The PSD Information and Data Management Policy supplement to SPD-41a provides additional guidelines and information. Finally, NPR 2210 - Release of NASA Software was updated in June 2023 to respond to community needs for making NASA-developed scientific software publicly available. Through these efforts, significant progress has been made to ensure that software developed by or for the Planetary Data Ecosystem (PDE) is as open as possible and only as closed as necessary. Considering that this recommendation is in reference to policy, we consider this recommendation to be addressed, and with the understanding that discussions with the community are ongoing and future revisions to these policies will be considered. We also acknowledge that appropriate software archives and repositories are also necessary for software to be open, and that concern is expressed in Recommendation 59.

Status: Maintenance

Recommendation 63 - The Planetary Science Division should adopt a single, coherent, open source software policy that applies across all its activities. Ideally, this policy should be a consistent Science Mission Directorate policy. Given that portions of the Ecosystem are outside of NASA's direct control, a single policy across the entire Ecosystem is likely not practical. However, it is appropriate for NASA to use its influence to achieve a high level of software policy consistency across the Ecosystem.

FY23 Response: See response to Recommendation 62. We consider this recommendation to be addressed, and with the understanding that discussions with the community are ongoing and future revisions to these policies will be considered.

Status: In Progress

Recommendation 64 - NASA should seek to expand opportunities for intermediate to advanced technical training in topics related to accessing, using, and processing planetary data.

FY23 Response: As noted for Recommendation 23, the [Topical Workshops, Symposia, and Conferences (TWSC)](#) solicitation invites proposals for events, including asynchronous and virtual workshops and training programs, that would help address this need. Proposal submissions are encouraged to develop needed community training for archival with the Planetary Data System (PDS) and other Planetary Data Ecosystem-related topics. The Planetary Science Division (PSD) has funded meritorious TWSC proposals to develop training in response to community needs and will continue this support as resources allow. For example, In June 2022, [PSD selected a proposal (PI: Dr. David Williams, ASU)](#) to offer a series of Planetary Data Training Workshops that occurred in May and June 2023. Workshops topics include planetary data management, planetary Geographic Information Systems (GIS) training (ArcGIS, open source GIS, and JMARS), Integrated Software for Imagers and Spectrometers (ISIS3) for image processing, SOCET SET-Ames Stereo Pipeline for digital elevation model (DEM) production, and making planetary data available outside of the PDS. These trainings are intentionally targeting an introductory audience. Also, through the [Transform to Open Science Training](#) (F.14 TOPST) ROSES solicitation, [a proposal was selected (PI: Dr. Sierra Brown, Million Concepts)](#) to create a self-paced learning course in open science data, tools, and techniques targeted to learners ranging from interested laypeople to experienced scientists. This course will focus on skills, data, and workflows that are relevant to research in planetary science and astronomy and include: (1) accessing and analyzing publicly available NASA data (including cloud-based datasets), (2) using both general and discipline-specific open-source software libraries for data access, manipulation, analysis, and visualization, (3) creating, managing, and sharing open science workflows. In addition, the Science Mission Directorate Office of the Chief Science Data Office developed [TOPS Open Science-101 curriculum](#), which provides information for topics such as open science, open data, and open software. These education opportunities help to provide a baseline level of information for the community and a foundation onto which more advance topics can be offered in the future.

Status: Completed

Recommendation 65 - NASA should encourage continuing education of members of the planetary science community by making it clear that such costs are allowable on grants for all job categories.

FY23 Response: According to 2 CFR 200.405, specific and relevant training is an allowable cost for grants and cooperative agreements if the proposer can tie the training directly to the proposed project effort. General continuing education is not an allowable cost, as the education opportunity must be directly related to the proposed work effort. Following the proposal review and selection process, documents are submitted to the NASA Grant Officer for review to determine if proposed costs are allowable, allocable, and reasonable for the proposed work. Additionally, for grants and cooperative agreements, the Grant Officer will review the risk posed by applicants as required in 2 CFR 200.205. To complete these required reviews, NASA may request proposers to submit additional documentation.

For additional information on policy that govern Federal awards, see:
- The Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards (2 CFR 200) at: https://www.ecfr.gov/cgi-bin/textidx?tpl=/ecfrbrowse/Title02/2cfr200_main_02.tpl
- The NASA supplement to 2 CFR 200, 2 CFR 1800, at: [https://www.ecfr.gov/cgi-bin/textidx?SID=a742969f637a69b85ae9174705ae9d4a&mc=true&tpl=/ecfrbrowse/Title02/2chapterXVIII.tpl 29](https://www.ecfr.gov/cgi-bin/textidx?SID=a742969f637a69b85ae9174705ae9d4a&mc=true&tpl=/ecfrbrowse/Title02/2chapterXVIII.tpl)

- NASA Grants and Cooperative Agreement Manual at: NASA Grants Policy and Compliance Branch

Within these legal limitations, the Planetary Science Division (PSD) encourages the continuing education of planetary science community and supports and provides education opportunities within the bounds of legal and regulatory statutes. For example, the Science Mission Directorate Office of the Chief Science Data Office developed TOPS Open Science-101 curriculum free of charge, which provides information for topics such as open science, open data, and open software. In addition, the PSD is funding the development of training workshops and curriculum through the Topical Workshops, Symposia, and Conferences (TWSC) and Transform to Open Science Training (F.14 TOPST) ROSES solicitations. See responses to Recommendation 23 and Recommendation 64 for additional detail.

5. Contributors

NASA Planetary Science Division Leadership
NASA Planetary Science Division Planetary Data Ecosystem Team
NASA Planetary Science Division Research and Analysis Team
NASA Planetary Science Division Flight Mission Team
NASA Planetary Data System
NASA Science Mission Directorate Office of the Chief Science Data Officer

Appendix A. Acronym List

AA: Advanced Analytics
AG: Planetary Assessment or Analysis Groups
AHED: Astrobiology Habitable Environment Database
AI: Artificial Intelligence
API: Application Programming Interface
ARD: Analysis Ready Data
ATO: Authority to Operate
AWS: Amazon Web Services
DAP: Data Analysis Program
DEM: Digital Elevation Model
DOI: Digital Object Identifier
DPDG: Data Product Development Guide
dLDD: Discipline Local Data Dictionary
EAR: Export Administration Regulations
ESA: European Space Agency
ESDSWG: Earth Science Data Systems Working Group
ExMAG: Extraterrestrial Materials Analysis Group
FAIR: Findability, Accessibility, Interoperability, and Reusability
HEC: High End Computing
GIS: Geographic Information System
GDAL: Geospatial Data Abstraction Library
HQ: Headquarters
IPDA: International Planetary Data Alliance
I/O: Input/Output
ISIS3: Integrated Software for Imagers and Spectrometers, version 3
ITAR: International Traffic in Arms Regulations
JAXA: Japan Aerospace Exploration Agency
JPL: Jet Propulsion Laboratory
KDP: Key Decision Point (in reference to the planetary mission project management review process)
LEAG: Lunar Exploration Analysis Group
LDD: Local Data Dictionary
LLM: Large Language Models
MAPSIT: Mapping and Planetary Spatial Infrastructure Team
MC: Management Council (in reference to the Planetary Data System or PDS)
ML: Machine Learning
NASA: National Aeronautics and Space Administration
OCIO: Office of the Chief Information Officer
ODR: Open Data Registry
OGC: Open Geospatial Consortium
OSDMP: Open Science Data Management Plan
OSIRIS REx: Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer
PDART: Planetary Data Archiving, Restoration, and Tools
PDC: Planetary Data Cloud
PDE: Planetary Data Ecosystem
PDE IRB: Planetary Data Ecosystem Independent Review Board
PRRSG: Planetary Radar and Radio Sciences Group

PSD: Planetary Science Division
PDS: Planetary Data System
PSA: Planetary Science Archive
R&A: Research and Analysis
ROSES: Research Opportunities in Space and Earth Science
SBN: Small Bodies Node
SPD-41a: Space Policy Directive 41a; NASA's Scientific Information Policy for the Science Mission Directorate
SMD: Science Mission Directorate
TADP: Terrestrial Analog Data Portal (USGS)
TOPST: Transform to Open Science Training
TWSC: Topical Workshops, Symposia, and Conferences
USGS: United States Geological Survey
UX: User Experience, in reference to websites