Evolving Towards Data-Driven Capabilities to enable Planetary Science Research from the PDS. D. Crichton[1], M. Cayanan[1], G. Hollins[1], S. Hughes[1], R. Joyner[1], E. Law[1], J. Padams[1] [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: The NASA Planetary Data System (PDS) captures, archives, and distributes data from robotic exploration of the solar system. In supporting this mission, it has developed an innovative architectural approach called "PDS4" to support the highly diverse set of heterogeneous data from over 600 instruments. The PDS is implemented as a set of distributed archives with different "nodes" managing repositories for this federated system [1]. To enable this federated approach, the PDS uses an information model to drive configuration of its archive and services, enabling it to evolve as data from the mission evolves, as well as the structure of the PDS. This approach has also enabled the PDS to work with and share its standards and architectures with the international community though the International Planetary Data Alliance [2].

The development of PDS4 has not only focused on the construction of compatible archives, but also on increasing access and use of the data in the big data era. As PDS looks forward, it is focused on achieving the recommendations of the Planetary Science Decadal Survey (2013-2022): "support the ongoing effort to evolve the Planetary Data System to an effective online resource for the NASA and international communities" [3]. The foundation laid by the standards, software services, and tools positions PDS to develop and adopt new approaches and technologies to enable users to effectively search, extract, integrate, and analyze with the wealth of observational data across international boundaries.

The Foundation: PDS4 has provided an international foundation for archiving planetary science data, as well as a suite of tools and services for providing stewardship and accessibility to that data:

- **High-level Search**: Various APIs have been developed to access collections and bundles, including PDS Search API [4], PDAP [5], etc.
- **Product-level Search**: Various APIs developed specific to archive/discipline. E.g. PDS Imaging Atlas Search API [6]
- **Access**: Multiple libraries exist for accessing and manipulating PDS4 metadata and products in both Python [7] and Java [8].
- **Transform**: Tool developed to enable transformation to common formats. [9]
- **Visualize**: Basic inspection of PDS4 products included in PDS Inspect Tool [10]

The Future: PDS4 and Stewardship Tools and Services have provided initial functionality and the future foundation for planetary data science discovery. Looking forward, the next generation of tools and services can *harness the power of PDS4 and focus on the development of user-centric services*.

- **Search**: *Integrated* search of PDS4-compliant federated archives
- **Access**: Return every product, including both labels and data, from any PDS4-compliant archive
- **Transform**: Provide standard library of transformations
- **Compute**: Provide standard processing services (e.g., subsetting, coordinate translation, etc)
- **Use**: Support integration with common tools and frameworks
- **Dynamic Tagging and Indexing**: Further enhance discovery and use of data through auto labeling using machine learning feature detection and classification methods based on PDS4 model

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References:

[1] About the PDS. https://pds.nasa.gov/home/about/.
[2] International Planetary Data Alliance. https://planetarydata.org/. [3] Committee on the Planetary Science Decadal Survey, et al. (2011) *Vision and Voyages for Planetary Science in the Decade 2013-2022*. [4] PDS Search Protocol. https://planetarydata.org/projects/active-projects/registration-and-search/pds-search-protocol/pds-search-protocol/at_download/file.
[5] PDAP Search Protocol. https://planetarydata.org/projects/active-projects/registration-and-search/pds-search-protocol/pds-pdap-search-protocol/at_download/file .
[6] PDS Imaging Atlas Search API. https://pds-imaging.jpl.nasa.gov/tools/atlas/api/.
[7] PDS4 Java Tools Library. https://pds.jpl.nasa.gov/tools/about/pds4-tools/.
[8] PDS4 Python Tools Library. https://github.com/Small-Bodies-Node/pds4_tools.
[9] PDS Transform Tool. https://pds.jpl.nasa.gov/tools/about/transform/.

[10] PDS Inspect Tool Repository. https://github.com/NASA-PDS-Incubator/pds-inspect-tool