Progress Report

International Planetary Data Alliance

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Acronyms and Abbreviations

ARAS	Armenian Astronomical Society
ASI	Italian Space Agency
CNES	National Centre for Space Studies, France
CNSA	China National Space Administration
COSPAR	Committee on Space Research of the International Council for Science
CSIC/INTA	Centro de Astrobiologia, Instituto Nacional de Tecnica Aeroespacia, Spain
CSIC-UVA	Centro de Astrobiología, Unidad Asociada, Spain
DLR	German Aerospace Center
EMM	Emirates Mars Mission
ESA	European Space Agency
ETH	Swiss Federal Institute of Technology
FMI	Finnish Meteorological Institute
GIS	Geospatial Information System
IAP	Institute of Atmospheric Physics, Czech Republic
IAS	Institut d'Astrophysique Spatiale, Orsay, France
IASF	Istituto di Astrofisica Spaziale e Fisica Cosmica, Italy
IKI	The Space Research Institute of Russian Academy of Sciences
INTA	Instituto Nacional de Técnica Aeroespacial, Spain
IPDA	International Planetary Data Alliance
IPGP	Institut de Physique du Globe de Paris
ISRO	Indian Space Research Organization
IVOA	International Virtual Observatory Alliance
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
KARI	Korea Aerospace Research Institute
LATMOS	Laboratoire Atmosphères, Milieux, Observations Spatiales, France
MASCOT	Mobile Asteroid Surface Scout (DLR & CNES)
MMO	Mercury Magnetospheric Orbiter (Japan)
MPS	Max-Planck-Institute for Solar System Research, Lindau, Germany
MPO	Mercury Planetary Orbiter (ESA)
NASA	National Aeronautics and Space Agency
PDAP	Planetary Data Access Protocol
PDS	NASA Planetary Data System
PDS4	Version 4 of PDS standards maintained by JPL and utilized by the IPDA
PSA	ESA Planetary Science Archive
SEI	Space Exploration Institute, Neuchâtel, Switzerland
SwRI	Southwest Research Institute, USA
UAE	United Arab Emirates Space Agency
UKSA	United Kingdom Space Agency

Introduction

In the mid-1980s, as NASA planetary exploration expanded, it became apparent that a national archive that could handle digitized data was needed. NASA launched the Planetary Data System (PDS) in 1989 after considerable planning and development. Because most of the early planetary data originated from NASA missions, the international scientific community became familiar with PDS standards. Thus, when the European Space Agency (ESA) began producing planetary science data they adopted components of the PDS standards and developed the Planetary Science Archive (PSA). This occurred under version 3 (PDS3) of the PDS Standards.

The PDS and PSA worked closely together to develop standards and share data. As additional agencies began developing unique missions of interest to the international community, two needs were identified: increased cooperation and collaboration to facilitate access to the individual archives, and modernization and implementation of standards.

A group of individuals involved in mission archiving within the international planetary community met in 2006 to develop a mechanism for enhancing international access and collaboration.[1] The goal of this meeting was to develop an approach that would:

- Give scientific communities world-wide access to data archives built upon similar standards,
- Reduce cost of archiving and distributing science data by collaborating and sharing standards,
- Ensure reusability of science data across agency/mission/instrument boundaries,
- Coordinate archiving processes and plans,
- Improve and increase access to tools and services offered.

Aware of budgetary constraints and leery of inefficient committee structure, the group agreed to establish the International Planetary Data Alliance (IPDA) as an organization with minimal structure and open to all agencies that are involved in planetary exploration. The charter of the IPDA is available at https://planetarydata.org/about/charter/charter.

Only two formal structures are recognized within the IPDA: the Steering Committee that is comprised of two members from each member agency, and a technical advisory group whose members assist in refining and accomplishing defined goals.

A chair and deputy chair are selected for two-year terms from the Steering Committee members. The activities of the IPDA are determined during the annual face-to-face meeting where specific needs and goals are identified. Projects are identified and defined to address these goals. Each individual project is defined in scope and duration, and a project leader is designated and given the responsibility of recruiting the necessary team members. A given project addresses components of the IPDA development that are usually needed by volunteering participants at their home sites; thus, their involvement provides a direct benefit to them and their institution. The project leader is responsible for assuring that the project is progressing. The project activities are carried out by email and progress is reported during several teleconferences that are held during the calendar year and at the annual face-to-face meeting. When a project is completed it is assessed and modified or accepted into the IPDA framework.

[1] "Developing a Core Set of Data Standards for the IPDA", Concept White Paper, January 2007.

Current Membership includes:

Armenian Astronomical Society (ArAS)
China National Space Administration (CNSA)
European Space Agency (ESA)
German Aerospace Center (DLR)
Indian Space Research Organization (ISRO)
Italian Space Agency (ASI)
Japan Aerospace Exploration Agency (JAXA)
National Aeronautics and Space Administration (NASA)
National Centre for Space Studies (CNES)
Russian Space Research Institute (IKI)
United Arab Emirates Space Agency (UAE)
UK Space Agency (UKSA)

In 2010, it was recognized that the PDS3 lacked the capability to support planetary data archiving and interoperability at an international scale. As a result, PDS4[2] was co-developed with the international community to enable a standard structure for building compatible archives. While a significant amount of data is captured under PDS3[3], all members of the IPDA are now implementing PDS4 on missions.

The IPDA is recognized by the Committee on Space Research (COSPAR) as the official body for definition of planetary science archive standards (see Appendix A). Within this framework the IPDA accepted the NASA PDS4 standards in 2012 as a starting point to develop an international framework for efficient sharing of archived data.

The Mission of IPDA

The mission of the IPDA is to facilitate global access to, and exchange of, high quality scientific data products managed across international boundaries. Implementation involves collaborative efforts to construct national compatible archives and shared tools and software services. To achieve this, the association has formulated the following goals:

- Support construction of compatible archives
- Support sharing of tools and software services
- Facilitate global access to, and exchange of, high quality scientific data products managed across international boundaries

IPDA Progress

The alliance's progress in achieving these goals is as follows:

Goal #1 - Support construction of compatible archives

IPDA endorsed PDS4 as the archiving standard for planetary data in 2012. Members continue as active participants in development and coordination of the PDS4 standard. Implementation (or planned implementation) of common PDS4 archive standards across

[2] PDS version 4 (PDS4) provides a modern set of data standards and software services to enable access and interoperability at an international scale. (https://pds.nasa.gov/pds4/about/)

[3] For example, NASA has captured data from nearly 600 instruments in PDS3.

agencies for mission archiving involve the following agencies: ESA, IKI, ISRO, JAXA, KARI, NASAS, UAE.

See Appendix B for description of missions utilizing PDS4 standards.

Goal #2 - Support sharing of tools and software services

Sharing of tools between agencies has increased with PDS4. For example, the PDS4 validation tool is used by several IPDA members, resulting in improved interoperability of data between agencies and robust testing the tool itself. Another example is the Tool Registry that acts as a virtual clearinghouse of planetary data-related tools produced by a variety of providers worldwide.

Goal #3 - Facilitate global access to, and exchange of, high quality scientific data products managed across international boundaries

Given the large archives of PDS3 data, the IPDA has enabled interoperability between member agencies providing search and access to both PDS3 and PDS4 data. At present, REST based access services are in place between ESA, ISRO, and NASA. In addition, high level search between ESA and NASA is in place accessing both PDS3 and PDS4 archives. Projects are underway to develop citation linkage with publications and to create bridges between IPDA and the IVOA (International Virtual Observatory Alliance).

Future Challenges

IPDA projects have produced substantial progress in working toward the group's stated goals. Nevertheless, a number of challenges have been identified that need attention.

Goal #1 - Support construction of compatible archives

- Improved support and documentation including tutorials for implementation
- Guidelines on how to build high quality archives (e.g., what to include and peer review process)

Goal #2 - Support sharing of tools and software services

- Registry for GIS technologies and tools as suggested at the Planetary GIS meeting, e.g., services registry
- Coordinated tool development across international boundaries.

Goal #3 - Facilitate global access to, and exchange of, high quality scientific data products managed across international boundaries

- API access to archives
- Open Planetary Data Access Protocol (PDAP) services at JAXA
  - PDAP evolution
  - Improved web mapping services
- Integrate ISRO data into international search and access
- Product level search and access across agencies
- Integrate access with computation
- Expanded interoperability across space sciences

Current Activities

Following review of ongoing progress for the currently defined projects at the July 2017 Steering Committee meeting in Berlin, IPDA members identified the following projects as areas of study for the coming year:.

- PDS4 Implementation Project
- Data Access Protocols
- Registry and Search
- IVOA Interoperability Project
- Data Citation

See Appendix C for descriptions and participating agencies.

Conclusion

The IPDA has made significant progress in the adoption of common standards, the development of compatible archives, and the establishment of open access policies. The efforts of IPDA, in working together, led to a common standard realized through the shared development of PDS4. Based on PDS4 progress, the IPDA sees discoverability, seamless access to data holdings, and increased tool support for using high quality peer reviewed data across international archives as key foci for the future of the IPDA.

Appendix A: The Committee on Space Research (COSPAR) Resolution

The **International Planetary Data Alliance (IPDA)** was recognized by the Committee on Space Research (COSPAR) (See https://cosparhq.cnes.fr/) as the official body for definition of planetary science archive standards." Commission B at the 37th COSPAR Assembly in 2008 approved of the following resolution.

Taking into account that:

1. It is in the general interest of the planetary science community that data archives be made as widely accessible as possible,
2. Existing technology via the World Wide Web supports efficient and cost effective access.
3. Sustained sequential missions by specific agencies are rare and limitations imposed by gaps in temporal coverage, spatial resolution and frequency coverage can be partially overcome by sharing of international databases.
4. The scientific yield that can be achieved through open international access and collaboration will be greatly enhanced.

COSPAR recommends that:

1. The IPDA continue its efforts to extend interoperative capabilities and common access tools and to develop sufficient commonality in the IPDA data model to achieve interoperability and ease of scientific use from public planetary science archives.
2. Data obtained with publicly funded planetary and lunar missions be similarly formatted, based on the common data model, including metadata, to make them scientifically valuable.
3. All scientific data from planetary and lunar missions be promptly made publicly available, consistent with individual agency policies on validation periods and periods of exclusive use.
4. Funding agencies provide encouragement and adequate support to enable data produced by instruments and missions they fund to be deposited in recognized archives.

Appendix B: Missions and Data Providers Adopting PDS4

The following summaries present an overview of all the missions that are currently developing databases that will utilize PDS4 standards to enhance international access. A brief summary of instrument types and involvement of space agencies are included.

ESA – The European Space Agency

ExoMars Trace Gas Orbiter is currently in the aerobraking and calibration phase and the science phase of the mission is scheduled to begin in March 2018. The mission will search for methane and other trace atmospheric gases that could be the result of biological activity. The craft was designed by ESA while Roscosmos provided the launch. The science payload includes: The Nadir and Occultation for Mars Discovery (NOMAD) developed by Belgium with two IR and one UV channel and the Atmospheric Chemistry Suite (ACS) and a Russian Fine-Resolution Epithermal Neutron Detector (FREND) developed by Russia with 3 IR channels designed to observe during solar occultations at the parts-per-billion (ppb) level. A Swiss Colour and Stereo Surface Imaging System (CaSSIS) high-resolution color stereo camera is included.

ExoMars Rover and Surface Platform will deliver a European rover and a Russian surface platform to Mars with the primary goal of finding organic material. The rover will look for and sample optimal sites to perform mineralogical and chemistry analysis. Instrumentation will include a panoramic camera (UK), an IR spectrometer (IKI), a close-up imager (SEI), a ground-penetrating radar (LATMOS), a neutron spectrometer (IKI), a multi-spectral imager inside the drill (IASF), a visible and IR mineralogical imager (IAS), a Raman Spectrograph (CSIC-UVA), and organic molecule analyzer (MPS). The surface platform managed by Roscosmos and IKI will remain stationary and investigate the surface environment at the landing site. The main goals of the surface platform are detailed imaging of the landing site, climate monitoring, and atmospheric investigations. The Surface platform instrumentation will include a radio science experiment (Belgium); a habitability, brine irradiation and temperature package (Sweden); a meteorological package (IKI, FMI & INTA); a wave analyzer module (IAP); and the following instruments from IKI : a magnetometer , a set of cameras to characterize the landing site, an IR Fourier spectrometer, an active neutron spectrometer and dosimeter, a multi-channel diode-laser spectrometer, a radio thermometer for soil temperatures, a dust particle size/impact/atmospheric charging instrument suite, a seismometer, and a gas chromatography-mass spectrometry for atmospheric analysis.

BepiColombo – This mission consists of two spacecraft: the Mercury Planetary Orbiter (MPO), supplied by ESA, and the Mercury Magnetospheric Orbiter (MMO), contributed by JAXA (see JAXA). The two craft will be carried to Mercury by a single transfer module to be launched on October 2019 and following an extended gravity assist orbit path will reach science orbit in March 2026. The MPO will carry a laser altimeter, an accelerometer, a magnetometer, radiometer and thermal IR spectrometer, a gamma ray and neutron spectrometer, and x-ray spectrometer, a UV spectrometer, a mass spectrometer, cameras and solar monitoring detectors and a radio science experiment. ESA and JAXA are working closely together to assure that the adaptation of PDS4 to BepiColombo mission is optimized.

Juice - Jupiter Icy Moons Explorer – is a large class mission that will be launched in 2022 to arrive at Jupiter in 2030 and enter orbit around Ganymede in 2033 after observing Jupiter, Europa and Callisto. The science objectives for Ganymede and to a lesser extent for Europa and Callisto are: Characterization of subsurface water reservoirs, the internal mass distribution and the magnetic field, mapping of the surface and characterization of the physical properties of the surface and a study of Ganymede's tenuous atmosphere. Instrumentation includes: JANUS, a high-resolution camera (ASI); MAJIS, a visible and IR spectrometer (CNES); UVS, an UV imaging spectrograph (SwRI); SWI, a Sub-millimeter Wave Instrument (MPS); GALA, a laser altimeter (DLR); RIME an ice-penetrating radar (ASI); J-MAG, an magnetometer to study subsurface oceans (UKSA); PEP, a suite of six sensors to study the Jupiter magnetosphere and its interactions with the Jovian moons (SNSB); RPWI to characterize the plasma environment (SNSB); 3GM, composed of a Ka transponder and an ultrastable oscillator to measure the gravity field of Ganymede (ASI); and PRIDE, a Planetary Radio Interferometer & Doppler Experiment (NOW and NSO).

ISRO – Indian Space Resource Organization

Chandrayaan-2 - India's second mission to the moon to be launched in early 2018 consists of an orbiter, a lander and a rover. The primary goal is to test the soft landing capabilities, as well as the semi-autonomous movement of the Rover. The scientific payloads onboard the Orbiter, Lander and Rover are expected to perform mineralogical and elemental studies of the lunar surface. The orbiter will carry a terrain mapping camera, a neutral mass spectrometer, an imaging IR spectrometer, L and S band synthetic radar and a soft x-ray spectrometer. The lander will deliver the rover but will have no scientific activities. The rover will pick up and analyze soil and rock samples using a laser induced breakdown spectroscope and an alpha particle induced x-ray spectrometer. The rover will carry a camera module that will allow semi-autonomous operations.

JAXA - The Japan Aerospace Exploration Agency

Hayabusa-2 - The craft was launched on December 3, 2014 and will arrive at a C-type asteroid, 162173 Ryugua, in July 2018. It will collect samples for one and half years before returning to Earth around the end of 2020 to release a re-entry capsule containing the asteroid samples. The craft is equipped with an ensemble of remote sensing instruments to characterize the asteroid and facilitate sampling. They include optical navigational cameras, a near-IR spectrometer, a thermal-IR imager and a laser altimeter as well as a gravity experiment. Sampling will be carried out by a small rovers and a lander, the Mobile Asteroid Surface Scout (MASCOT) that carries instruments for multi-wavelength sensing and lifts off the asteroid to sample another region. MASCOT was provided by DLR and CNES. Hayabusa-2 will also carry a small explosive penetrator and a small deployable camera to observe the impact. The freshly exposed material will be characterized.

BepiColombo – A joint ESA JAXA mission, composed of two orbiters, is aimed at carrying out a comprehensive study of Mercury: Mercury Planetary Orbiter (MPO) by ESA to characterize bulk and surface properties of the planet and Mercury Magnetospheric Orbiter (MMO) by JAXA to study the magnetic field, atmosphere, magnetosphere, and inner interplanetary space. The two will be launched together and utilize Moon, Venus, and Mercury gravitational shifts to attain orbit. On reaching orbit they will separate and carry out coordinated observations. MMO instrumentation includes a magnetometer, a particle wave experiment, a plasma wave instrument, a sodium atmosphere spectral imager and a dust monitor.

KARI - Korea Aerospace Research Institute

KPLO (Korea Pathfinder Lunar Orbiter) will orbit the Moon in a 100-km-high, polar orbit for one year, permitting a complete survey of the lunar surface. The orbiter will carry the following instruments: LUTI, a high resolution camera to characterize landing site selection for future KARI robotic missions; PolCam, a polarimetric camera to characterize lunar regolith and space weathering processes; KGRS, a gamma ray spectrometer to map major elements (Mg, Ni, Cr, Ca, Al, Ti, Fe, Si, O, U, He-3) and water; and KMAG, a magnetometer to provide a 3-D map of lunar magnetism. In addition, KARI offered NASA space on the craft and ShadowCam has been selected. This highly sensitive camera will map reflectance of shadowed regions to search for frost or ice deposits, and obtain quality imaging of shadowed lunar regions.

NASA - The National Aeronautics and Space Administration

LADEE (Lunar Atmosphere and Dust Environment Explorer) was the first PDS4 mission. It was a short lunar mission that gathered information about the lunar atmosphere, conditions near the surface and distribution of lunar dust. It carried a UV-visible spectrometer, a mass spectrometer, a dust experiment and a lunar laser communications demonstration.

MAVEN (Mars Atmospheric and Volatile EvolutioN) is a mission aimed at giving insight into the history of Mars' atmosphere and climate, liquid water and planetary habitability by determining how volatiles from the Martian atmosphere have escaped into space over time. It carries a UV spectrometer, a mass spectrometer, accelerometers, a magnetometer and a suite of detectors to measure the solar wind environment and it's interaction with the upper atmosphere.

OSIRIS-REx (Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer) will travel to Bennu, a near-Earth asteroid, and bring a small sample back to Earth. It carries a suite of cameras, visible and IR spectrometer and an altimeter and x-ray spectrometer. International partners include the Canadian Space Agency, France's Centre National d'Études Spatiales (CNES) and Japan Aerospace Exploration Agency (JAXA).

InSight (Interior exploration using Seismic Investigations, Geodesy and Heat Transport) will study the Martian interior to understand the processes that shaped the planets of the inner solar system. The payload consists of two instruments: the Seismic Experiment for Interior Structure (SEIS), provided by CNES, with the participation of IPGP, ETH, Imperial College, and JPL; the Heat Flow and Physical Properties Package (HP^3), provided by DLR; and a wind and temperature sensor package provided by CSIC. In addition, the spacecraft communication system will be used to provide precise measurements of planetary rotation.

Mars 2020 Rover will seek evidence of past life. It will collect samples of soil and rock, and cache them for return by a future mission. The rover will carry a remote sensing panoramic camera; a second instrument to provide imaging, chemical composition analysis, mineralogy and seek organic compounds in rocks and regolith from a distance with CNES is making a significant contribution to this instrument and the Mars Environmental Dynamics Analyzer (MEDA) containing sensors for temperature, wind speed and direction, pressure, relative humidity, and dust size and shape, supplied by CSIC/INTA. For close-up analysis there will be an X-ray fluorescence spectrometer and a Raman scanning spectrometer. In addition, the rover will carry MOXIE, an exploration technology investigation that will produce oxygen from martian atmospheric carbon dioxide.

Europa Clipper will place a radiation-tolerant spacecraft into orbit around Jupiter to perform an ongoing sequence of Europa flybys. The science payload will include cameras and spectrometers to produce high-resolution images and composition measurement. The mission will carry an ice penetrating radar in an attempt to determine the thickness of the moon's icy shell and to search for possible subsurface lakes. A radiometer will map the surface seeking warmer possible upwellings. A magnetometer will measure the strength and direction of the moon's magnetic field, which would allow scientists to determine the depth and salinity of its ocean. Gravity measurements will help define the extent of a subsurface ocean. The team includes members from the following institutions: The team includes members from the following institutions: the universities of Paris-Sud and Nantes of France, Dresden, Stuttgart and Cologne of Germany, Trento and Rome La Sapienza from Italy, Oxford and Imperial College from Great Britain, Oulu from Finland and Bern from Switzerland as well as Le Centre National de la Recherche Scientifique, Institute de Planetologie et d'Astrophysique de Grenoble, German Aerospace Center, and the Swedish Royal Institute of Technology.

Lucy will be the first mission to study the Trojan asteroids that are trapped in Jupiter's leading and following Lagrangian Points and believed to be fossil remnants of early solar system formation. Thus, the mission was named for Lucy, a fossilized skeleton of an early human ancestor. From 2025 to 2033 the craft will visit 6 Trojan locations using three instruments: a high-resolution visible imager, an optical and near-infrared imaging spectrometer, and a thermal infrared spectrometer.

Psyche is a mission that will explore 16 Psyche, the largest known M-type asteroid. Psyche is believed to be an exposed fragment of a nickel-iron core of an early planet, one of the building blocks of our solar system. Instrumentation includes: a multispectral imager, a gamma ray and neutron spectrometer, a magnetometer and an X-band gravity science investigation.

Providers of higher order data products. Motivated by increasing pressure for the results of federally supported research to be more publically accessible and to encourage the development of derived products to enhance access to mission results, NASA provides opportunities for individual scientists to propose to develop archival products to be deposited in the PDS in PDS4 format. At present, more than 40 selected proposals are active. In response the PDS is developing online tools to assist individuals in understanding PDS4 and to develop cost-effective data management plans and, if selected, to design and create products that adhere to PDS4 standards.

Migration of PDS3 holdings to PDS4. Increasing stability and utility of PDS4 has led NASA to begin migration of PDS3 holdings into the PDS4 format. This will be a multi-year activity with high value data sets being the first to be migrated. The migration will include enhancements to both metadata and data formats, where needed. Migration will be managed by the PDS Discipline Nodes.

UAE – United Arab Emirates

HOPE or **Al-Amal** will be launched in 2020. Hope will study climate throughout daily and seasonal cycles – it will be Mars' first true weather satellite. It will study the effects that events in the lower atmosphere can have in the upper atmosphere days or weeks later. The probe will orbit the Red Planet until at least 2023, with an option to extend the mission until 2025. The data will be freely shared. Instrumentation will include a multi-color camera and UV and IR spectrometers.

Appendix C: Development of IPDA Projects

Since the formation of the International Planetary Data Alliance (IPDA) in 2006 the Steering Committee has defined projects to be selected, monitored their progress and, when necessary, established an additional group to carry out an assessment to recommend termination, enhancement or new directions. The Steering Committee selects the team leaders and they develop their team from qualified people within the individual member agencies.

The earliest efforts centered on setting up communication structure, developing web pages and logos and beginning efforts to gain recognition by the Committee on Space Research (COSPAR) which led to recognition as follows; "COSPAR resolves that there is a need for common data standards and tools to enhance international access to data acquired by planetary and lunar missions and that the International Planetary Data Alliance (IPDA) be recognized as the lead organization to coordinate efforts to achieve this".

The first projects began in 2007. These included standard definitions, assessment of the NASA Planetary Data System standard data model, data dictionary modeling, and interoperability (based on ESA/PSA and NASA/PDS accessing the Venus Express data and JAXA led Small-Body Interoperability Demonstrator and Query Model projects). As these efforts progressed and were completed or morphed into more defined topics, additional projects were added. In addition to the individual interoperability projects, a basic ESA led effort, the Planetary Data Access Protocol (PDAP) project, was introduced to standardize metadata access to archives.

More recent projects included components developed from the initial projects as well as specific topics that included:

- Guidelines for an archiving process and a common basis for peer reviews
- Suggestions to a desired component of interagency official Memos of Understanding to define data content and standards
- Architecture and Standards Definition
- Information Model and Data Dictionary Development
- PDAP development for standard API access to metadata in archives
- Archiving Guide
- IPDA Registry and Search Implementation
- Planetary Geographic Information System
- Planetary tools registry
- A PDS4 prototyping project
- Interoperability project dealing with Hyabusa/JAXA and Chandrayaan-1/ISRO

Current projects include a major implementation project **- The PDS4 Implementation Project**, a major project to capture recommendations and requirements for using the PDS4 standard (see below); **Data Access Protocols**, an extension of PDAP; **Registry and Search**, development of registration and search infrastructure to enable cross-agency search; **IVOA Interoperability Project**, an International Virtual Observatory Alliance/IPDA interactions project dedicated to reinforcing the interoperability between the IVOA and IPDA infrastructures; and **Data Citation**, aimed at establishing a standard that utilizes the Digital Object Identifier (DOI) system that is in common use by peer-reviewed scientific journals.

The PDS4 Implementation Project

The purpose of this project is to capture recommendations and requirements based on the preparation and implementation of PDS4 by authorities/institutions outside NASA. The project is expected to support several international agencies that are implementing PDS4 systems and data. A number of previous IPDA projects have morphed into this project, bringing in additional participants. Current activities include:

- IPDA participation in the PDS4 working group and Change Control Board
- Assessment of changes to PDS4 standards
- Testing of next PDS4 releases
- Defining instrument types
- PDS4 International Status & Implementation
- PDS Review of PSA documentation / implementation
- Geometry & Cartography
- SPICE in PDS4
- Evaluation of PDS4 Tools
- PDS4 Validate Tool

Project Leaders – Santa Martinez, Steve Hughes

Project Members

- ESA/PSA - Santa Martinez, Tanya Lim, Daniela Coia, Sebastien Besse, Alan Macfarlane, I. Ortiz de Landaluce, A. Villacorta, Marc Costa Sitja
- NASA / PDS - Steve Hughes, Tom Stein, Sean Hardman, Mitch Gordon, Jordan Padams; Geometry support: Ed Guinness; Cartography support: Chris Isbell, Trent M Hare
- UK Space Agency - P. Alan
- ISRO - Ajay Prashar, B.G. Krishna, Debajyoti Dhar
- DLR - T. Roatsch
- IPSL/LATMOS - A. Sarkissian
- OBSPM (Observatoire de Paris) - Baptiste Cecconi, Stéphane Erard
- JAXA - Yukio Yamamoto, I. Shinohara
- INAF/IASF - M.T. Capria
- China - Z. Ling
- IKI - Oleg Batanov

Data Access Protocols

The Data Access Protocols project is a series of assessments to determine the role of PDAP (the ESA Planetary Data Access Protocols) within PDS4 and IPDA. Specifically, the project is to: assess the applicability of PDAP to the PDS4 information model scope potential implementation, assess the Europlanet EPN-Core and EPN-TAP (Table Access Protocol) data model within the new Planetary Science Archive data model, and assess EPN-Core and EPN-TAP from a PDS viewpoint.

Project Leaders – Isa Barbarisi, Sean Hardman, Baptiste Cecconi

Registry and Search

The PDS4 project has developed a registration and search infrastructure to enable cross-agency search of planetary data. This infrastructure is currently deployed at the PDS Engineering Node (http://pds.nasa.gov) and provides catalog-level search across PDS3 data sets and PDS4 bundles for both NASA PDS and ESA PSA archival data. This project will continue to extend the implementation and deployment of this infrastructure to ensure the search services can be populated and utilized by other IPDA-member agencies (e.g., ISRO Chandryaan-1 data). This project builds on the results from the previous IPDA-sponsored registry projects.

Project Leaders – Dan Crichton, Sean Hardman

IVOA Interoperability Project

The IVOA/IPDA interactions project is dedicated to reinforcing the interoperability between the IVOA (International Virtual Observatory Alliance) and IPDA infrastructures. The IVOA defines interoperability standards mainly driven by astronomy science cases. Some IVOA standards are also used in other disciplines and in particular for some planetary science related projects (e.g., Europlanet developments. In this context, closer collaboration between the two alliances (IPDA and IVOA) could be envisaged to determine if there are some common interests, possibility of knowledge sharing and eventually re-use of interoperable standards that might require slight adaptation to cover both disciplines.

In exploring a possible IPDA/IVOA areas for collaboration, the most obvious opportunity for collaboration is around data access/usage, particularly around specific planetary science disciplines where there is a connection between data capture in planetary science archives and those captured in astronomy archives. However, it is clear from the past experience, and from the points listed in this document, that some standards from IVOA can be used in a larger scope than its initial specification.

Topics under consideration by the project include:

- Standard list of coordinate systems and reference frames
- Standardization of observation geometry
- Link with Europlanet developments
- Extension of IVOA cone search to moving targets
- Standard list of ground based observatories
- Standard list of space based missions
- Link with ESO planetary images (same with HST database or else)
- Cross-matching of registries
- Promoting and extending SAMP (Simple Application Messaging Protocol)
- Extending IVOA data models and semantics to planetary sciences
- Proposing new serialization examples in IVOA standards for format used in planetary sciences
- FITS keyword standardization for planetary targets
- Implementation of IVOA standards in MPC
- Exoplanets

Project Leaders – Baptiste Cecconi, Christophe Arviset, Maria-Teresa Capri, Dan Crichton

Data Citation

The Data Citation project is aimed at establishing a standard that utilizes the Digital Object Identifier (DOI) system that is in common use by peer-reviewed scientific journals. This work will support all IPDA member agencies as none currently has a data citation standard in place.

Project Leader – Dan Crichton