NASA PLANETARY DATA SYSTEM SUPPORT FOR CARTOGRAPHIC SCIENCES. Trent M. Hare[1], Lisa R. Gaddis[1], Susan K. LaVoie[2], Chris E. Isbell[1], Moses P. Milazzo[1], Samuel J. Lawrence[3], [1]Astrogeology Science Center, U. S. Geological Survey, 2255 North Gemini Drive, Flagstaff, AZ; [2]Jet Propulsion Laboratory, Pasadena, CA; [3]Arizona State University, Tempe, AZ. (thare@usgs.gov).

Introduction: Current data holdings of the NASA Planetary Data System (PDS) total ~1 petabyte (PB) and are projected to reach ~2 PB in the next five years [1]. PDS is dedicated to making these data and information resources accessible, discoverable, and usable by the public and thus it plays a major role in NASA's plan to improve access to data and publications resulting from NASA-funded scientific research [2,3]. Continued availability of data and services as part of the PDS federation holdings fuels scientific discovery, innovation, and entrepreneurship in the United States and among US partners abroad. To meet these objectives, PDS and NASA support the development and delivery of products that are accurately mapped to the surfaces of planetary bodies in three dimensions. Such cartographically precise products form a solid foundation for planetary exploration on which the US and other nations rely for continued success.

The PDS Cartography and Imaging Sciences Discipline Node: Managed at the Astrogeology Science Center of the USGS and partnering with the Jet Propulsion Laboratory, the Cartography and Imaging Sciences Discipline Node (a.k.a. Imaging, http://pds-imaging.jpl.nasa.gov/) curates NASA's larger digital image collections from past, present and future planetary missions. Imaging is partnered with mission-supported data nodes for three of the largest currently accumulating datasets: Mars Odyssey THEMIS (P. Christensen, Arizona State Univ.), Mars Reconnaissance Orbiter HiRISE (A. McEwen, Univ. of Arizona), and Lunar Reconnaissance Orbiter cameras (M. Robinson, Arizona State Univ.).

Imaging provides and supports the digital image archives, ancillary data, sophisticated data search and retrieval tools, and cartographic and technical expertise necessary to develop and fully utilize the vast collection of digital planetary images of many terrestrial planetary bodies, including icy satellites. Imaging science expertise at the node includes orbital and landed camera instrument development and data processing, data engineering and informatics, planetary remote sensing at UV to RADAR wavelengths, and cartographic and geospatial data analysis and product development. Imaging has also hosted Planetary Data Workshops in 2012 and 2015 [4] to promote discussion between data providers, users, and software developers and to provide hands-on training in many of the latest tools and methods for data processing and analysis.

Infrastructure Software: USGS Astrogeology is a major developer of software for cartographic data processing for NASA missions and research programs, including the former Planetary Cartography and Geologic Mapping Program, NASA flight projects, research and data analysis projects, and the PDS.

ISIS: The Integrated Software or Imagers and Spectrometers (ISIS, 5) is a free processing package for working with planetary image data and is designed to operate on two-dimensional images and multi- and hyper-dimensional cubes collected by imaging spectrometers. The power of ISIS is its unique capability for processing data from NASA spacecraft missions such as Voyager, Viking, Galileo, Mars Global Surveyor, Mars Odyssey, Mars Reconnaissance Orbiter, Cassini, Lunar Reconnaissance Orbiter and MESSENGER.

GDAL: The Geospatial Data Abstraction Library (GDAL) is a free translation library for geospatial raster and vector data [6]. GDAL offers powerful capabilities for converting and processing planetary data, including support for map projected PDS data and ISIS cubes. Any application which supports the GDAL library (e.g. Esri Arcmap, QGIS) can now understand these planetary formats. For applications that do not use GDAL, routines released with GDAL can convert PDS and ISIS data into geospatial formats like GeoTIFF, GeoJPEG2000, HDF, FITS and ENVI.

Imaging Node Cartographic Services: In addition to development of products and metadata standards for PDS cartographic products [7,8,9], and frequent consultation with mission and instrument teams and other data providers, Imaging provides several services that support cross-mission searches, cartographic data processing and delivery of geospatially accurate data products as discussed next [http://bit.ly/PdsCIS].

UPC: The PDS Unified Planetary Coordinates (UPC, 10) database standardizes the numerous, disparate planetary orbital datasets into a single coordinate system and simplifies data identification and delivery for users. The UPC has two main parts: 1) a spatial database containing improved geometric and positional information about planetary image data that has been computed using a uniform coordinate system and projection onto a common (preferably 3D) planetary surface shape, 2) a process by which continual maintenance and updates to the content of the database are performed.

PILOT: The Planetary Image LOcator Tool (PILOT, 11; http://pilot.wr.usgs.gov/) is a search tool for the UPC database. PILOT features cartographically accurate image locations and search capabilities using a navigable map, user selectable image constraints (e.g., incidence angle, solar longitude, spatial resolution), and facilitates bulk downloads and/or image processing using POW. Image footprints are displayed on Web Mapping Services (WMS) map layers using a customized OpenLayers planetary interface.

POW: The Map Projection on the Web service [POW, 12; http://astrocloud.wr.usgs.gov/] allows users to convert raw PDS images to science-ready, map-projected products. POW integrates PILOT and the UPC, Astrogeology's in-house planetary cartographic data processing toolset, the ISIS package, GDAL, and the Astrogeology cluster for its processing and delivery needs.

MAP2: Map-a-Planet 2 [MAP2, 13; http://astrogeology.usgs.gov/tools/map] is a major update to the original and popular Map-a-Planet [14] web site. Both services allow global, map-projected image products to be re-projected, stretched, clipped, and converted into a variety of useful image formats. This service leverages the capabilities of the Annex, ISIS, GDAL and the Astrogeology processing cluster.

The Annex: The PDS Imaging Node Annex for Geospatial Products (a.k.a. The Annex, 15; http://astrogeology.usgs.gov/pds/annex) is designed to help planetary researchers to release derived geospatial products created from archived PDS data. Examples of such products are cartographic and thematic maps of moons and planets, local and regional geologic feature maps, topographic and perspective views of planetary landing sites, and tabular data containing unit information derived from planetary data. Many of these products likely have been developed as a result of NASA data analysis programs, often years after active missions (and their archives) have ended.

Planetary Image Atlas: The Atlas (http://pds-imaging.jpl.nasa.gov/Atlas) provides access to the entire collection of IMG data through links to online holdings and data node catalogs [16]. The Atlas uses faceted navigation to support searches on mission name, instrument name, target, product type, lighting geometry meta-data (emission angle, incidence angle, phase angle), lat/lon, time constraints, etc. Every month, nearly 15 terabytes of data are delivered to users across the globe.

Other PDS Science Discipline Nodes: PDS Discipline nodes routinely collaborate within PDS, sharing their expertise, strengths and capabilities across discipline boundaries. In some cases, Imaging products and services provide im-portant elements for services at other nodes. PDS nodes such as Geosciences (R. Arvidson, Washington Univ.), Planetary Rings (M. Showalter, SETI Institute), and the Asteroid/Dust Subnode (E. Palmer, Planetary Sciences Institute) of Small Bodies (M. A'Hearn, Univ. of Maryland) regularly consult with, and rely on, Imaging archived data, documentation, databases and delivery services. For example, the UPC database is used by the Geosciences node to support data searches for products served by their Orbital Data Explorers (http://ode.rsl.wustl.edu/moon/).

External Partners: Imaging readily partners with other facilities, labs and teams, including international teams. For example, at the Jet Propulsion Laboratory, Imaging partners with the Multimission Ground System and Service (MGSS) Office, Machine Learning and Instrument Autonomy Group (MLIA), and Multimission Image Processing Lab (MIPL) to support implementation of a Webification (W10N) specification that is central to the functionality of services for The Atlas [16], the MarsViewer software [17] and the Landmarks Web services [18]. Also, cartographically controlled PDS data [19] are leveraged by numerous NASA-affiliated software and geospatial product distribution systems, including the ASU JMARS software [20], the LROC Lunaserv platform [21], and the Lunar Mapping and Modeling Project data portal [22].

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