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# The Imaging Node for the Planetary Data System

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**Abstract.** The Planetary Data System Imaging Node maintains and distributes the archives of planetary image data acquired from NASA's flight projects with the primary goal of enabling the science community to perform image processing and analysis on the data. The Node provides direct and easy access to the digital image archives through wide distribution of the data on CD-ROM media and on-line remote-access tools by way of Internet services. The Node provides digital image processing tools and the expertise and guidance necessary to understand the image collections. The data collections, now approaching one terabyte in volume, provide a foundation for remote sensing studies for virtually all the planetary systems in our solar system (except for Pluto). The Node is responsible for restoring data sets from past missions in danger of being lost. The Node works with active flight projects to assist in the creation of their archive products and to ensure that their products and data catalogs become an integral part of the Node's data collections.

## 1. Introduction

The overarching goal of the Planetary Data System (PDS) Imaging Node is to enable the planetary science community to perform digital image processing and analysis in support of scientific research at their home institutions as well as through the PDS. In achieving this goal, the Node provides the community with (1) direct and easy access to the digital planetary image archives, (2) ancillary data such as camera calibration and related viewing and camera geometry, (3) digital image processing and analysis tools, (4) expertise and guidance necessary to understand the image collections, and (5) on-line remote-access search and retrieval tools for acquiring and ordering image data products. The image data collections housed at the Node, now approaching a terabyte in volume, provide a foundation for remote sensing research for virtually all the planetary systems in our solar system (except for Pluto). The image data sets available through the Node, summarized in Table 1, include data from NASA's *Mariner* 9 and 10, *Viking*, *Voyager*, *Magellan*, and *Galileo* missions and from the joint Department of Defense and NASA *Clementine* mission. Future data sets to be incorporated by the Node will come from NASA's *Galileo* (observations of the Jovian system), *Mars Pathfinder*, *Cassini*, and *Mars Surveyor* missions.

Imaging Node activities can be divided into three categories: user services, data restoration, and mission interface work. To support user services, the Node distributes mission data products to the community, provides software capabilities to process the data, performs special processing requests, and provides search and retrieval catalogs for the Node's archives of image data products. The Node has taken advantage of recent advances in Internet services, such as World Wide Web (WWW) browsers, to provide remote access to the data collections (see Section 4). In the last 5 years since 1990 the Node has processed more than 1900 data requests and has distributed more than 5 terabytes of image data on CD and magnetic tape media and electronic transfer over the Internet. Since the Node's Internet services became available on-line in 1995, more than 3500 people from 40 countries have used the services.

The Imaging Node has participated in restoration activities for the *Viking* and *Voyager* image data sets. Prior to the restoration efforts, these data sets were organized and stored on 9-track tape media with access available only to a select few NASA-supported scientists. The data were stored in formats unique to each mission with no software tools available to access the data. As a result of the restoration efforts for these data sets, the Node produced CD-ROM volume sets for wide distribution to the science community. Software tools for access to the data and simple image display programs that operate on PC DOS, Macintosh, and Sun UNIX systems accompany the archives.

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**Table 1.** Data holdings at the Imaging Node

| Mission | Target(s) | Data set description |
|---|---|---|
| *Clementine* | Moon, Earth | Experimental Data Record (EDR) of raw images Data stored on 88-volume CD-ROM set containing 1.9 million images. Images acquired in 12 spectral bands from the ultraviolet to the thermal infrared. |
| *Galileo* | Earth, Moon, Venus, Gaspra, Ida (with future observations of Jovian System) | SSI Raw Experimental Data Record (REDR) of raw images from SSI camera. Current data set exists on 15-volume CD-ROM set. Image acquired in spectral range violet to near infrared. |
| | | NIMS EDR of raw images. Data stored on a single CD-ROM. A second volume in preparation for Earth-2, Gaspra, and Ida encounters. In nominal instrument mode, data acquired in 204 spectral channels. |
| *Magellan* | Venus | Mosaicked Image Data Record (MIDR) of SAR image mosaics available at the Node through WWW access. |
| | | F-MAP series comprised of 75 m resolution image mosaics currently with 45 volumes produced. The final data set will reside on 170 CD-ROM volumes. |
| | | Original Data Record (ODR) and SAR EDR data sets are fundamental data products produced by the mission. Processing of the ODR ($\sim$1700 CD-WO volumes) and SAR EDR (on $\sim$10,000 magnetic tapes) is supported by SAR Processing Sub-Node. |
| *Voyager I* and *II* | Jupiter, Saturn Uranus, Neptune, and moons | EDR data set of raw images. Data stored on a 24-volume CD-ROM set. Wide-angle and narrow-angle images acquired in spectral ranges from ultraviolet to orange wavelengths. Data production will be completed in 1996. |
| | | QEDR (Quick Engineering Data Record). Data set includes mission cruise data not captured on EDR data archive in original format provided by mission. Available by special request. |
| *Viking I* and *II* | Mars, Phobos, and Deimos | EDR data set of raw images from *Viking Orbiter* cameras. Data set resides on 46-volume CD-ROM set of more than 50,000 images. Images acquired in spectral ranges violet to red. |
| | | EDR data set of raw images from *Viking Landers* Images available at the Node through WWW services |
| | | Mars Mosaic Digital Image Model (MDIM) and Digital Terrain Model (DTM) on 14-volume CD-ROM set. Contains a global digital image mosaic of Mars at 1/256 pixel$^{-1}$, selected color mosaics, and a DTM at 1/64 pixel |
| *Mariner* 10 | Mercury, Venus, and Moon | EDR data set of raw stored on images CD-WO media and available at the Node by special request. Spectral images acquired in ultraviolet to orange wavelengths. |
| *Mariner* 9 | Mars, Phobos, and Deimos | EDR data set of raw images stored on CD-WO media and available at the Node by special request. Spectral images acquired in violet to orange wavelengths. |

The Node has responsibilities in mission interface activities. The Node works with active flight projects to ensure that the mission data are properly organized, validated, and formatted according to the standards and guidelines of the PDS. Whenever possible, the Node inherits software from flight projects in order to capture and preserve the unique requirements for processing the data. Mission data inevitably require specialized software that address the unique mission and instrument dependent characteristics of the data. Because the Node is fortunate to be affiliated with institutions that continue to have data processing responsibilities to NASA flight projects,

transfer of the mission software is made easier (see Section 4.4 for processing capabilities)

The Imaging Node facilities are located at the Branch of Astrogeology of the U.S. Geological Survey (USGS) and at the Science Data Processing Systems Section of the Jet Propulsion Laboratory (JPL). The **USGS** "Sub-Node" provides the overall leadership and acts as the primary contact for potential users. The JPL Sub-Node serves as the primary interface to the active NASA planetary night projects managed by JPL and leads the development of the Node's remote-access on-line services. Additionally, the Node maintains an SAR Processing Sub-Node, located at the Vexcel Corporation, providing expertise in synthetic aperture radar (SAR) signal processing and sustaining engineering of the *Magellan* SAR processor. In addition to directly serving the science community, the imaging Node acts as the central repository for image data used by the other PDS discipline Nodes. The other Nodes (primarily Geosciences, Rings, and Atmospheres) draw heavily on the image data collections in support of their discipline research activities. The Imaging Node focuses on preserving the image collections and software to process the image data while the science Nodes focus on use of the image data products in support of their individual science discipline.

Potential users interested in learning more about the Node's data services can contact the staff by way of electronic mail ("eeliason@sirius.wr.usgs.gov" or "Sue_Lavoie@iplmail.jpl.nasa.gov").

## 2. Archives of planetary image data

The Node has developed a model for an archive of planetary image data that ensures the effective use and long-term preservation of the data. **In** this model an archive contains the raw image data as acquired by the spacecraft, the derived image data (when available) that have undergone rectification processes, and the supporting elements necessary to make full use of the data, The supporting elements include ancillary data for radiometric and geometric characterization, documentation describing the observational histories and data organization, summary files that index the data, and software to access and process the data, The image data are organized according to the standards prescribed by [he **PDS** (JPL, 1992; Cribbs and Wagner, 1992). The PDS standards provide consistent organization across the image collections and make it possible to develop a common set of software tools and data access methods that operate on the different collections.

The archives of image data are preserved on CD-ROM and CD write-once (CD-WO) media. The CD technology offers highly reliable, cost-effective storage on a compact media with a shelf-life measured in decades. The CD-ROM media, with relatively high initial startup costs but low replication costs, remains the most cost-effective media for data sets with wide distribution potential. CD-WO media, with low initial startup costs but moderate cost per volume, is useful to store anti distribute data with limited distribution potential. The CD media, **in** use **With** the ISO 9660 Data Standard (ISO, 1987), is readable on virtually all modern computer platforms.

### 2.1. *Raw image data products*

The primary data for an archive are the collection of raw images as acquired by the spacecraft. These data provide the foundation for all image processing applications and remote sensing investigations The raw images are pristine in the sense that they contain the artifacts anti the radiometric and geometric characteristics of unprocessed and uncorrected data. Radiometric and geometric correction anti cosmetic cleanup algorithms are intentionally not applied to the data. These techniques render irreversible operations on the image data that would prevent improved corrections from being applied at a later time. Understanding the observational geometry and radiometric properties of an imaging system is an evolving process involving extended post-mission investigations. For example, cartographic-quality digital image maps become possible only after significant geodetic analysis. Thus, preservation of the original unprocessed data is imperative so advanced techniques can be applied to the data in future applications. The raw image data products are useful to those investigators willing to understand and use the elaborate radiometric and geometric techniques for correcting the data.

### 2.2. *I)('ritc)(ii t}I([{j]'( ic[l(ip ro(/11([.%*

Derived image data products, typically of widest interest to the science community, have undergone processes of image rectification (Bernstein *et al.*, 1971). These processes produce images that are "ideal". The pixel values of an image have been converted to radiometric units, geometric processing has been applied for removal of optical distortion and projection to map coordinates, and photometric modeling has been applied to normalize image brightness to standard illumination geometry. Derived images are useful to the community because specialized instrument-dependent processing. cartographic reprojection, anti geodetic analysis have already been applied to the data. General image processing packages. widely available, can be used to visualize and enhance the image products. The potential disadvantage of the derived data is that advanced geometric and radiometric calibration, determined perhaps after years of investigation, may not have been available when the data products were produced

### 2.3. *Browse images*

Browse images provide an important component of an image archive because they facilitate rapid viewing of the image collection and allow a researcher to conduct a visual search for images of interest. If a browse image shows a potentially interesting scene, the full image can be viewed for more detailed inspection. Browse images are reduced

in size from the original image by averaging "$n \times n$" pixel neighborhoods and storing the average as a single pixel. Because browse images are subsampled versions of the original image, they occupy only a small amount of space on the storage media (2 4%). The browse images are distributed as an integral part of the archive and have been provided on the *Clementine*, *Viking*, *Voyager*, and *Magellan* image collections.

### 2.4. *Geometric elements*

The geometric elements are an essential part of the archive because they contain the necessary information to fully characterize the geometric properties of the imaging system and viewing geometry of an observation. These data are essential to geodetic, cartographic. and photometric applications. The geometric elements are organized according to the SPICE (Spacecraft, Planet, Instrument, C-matrix, and Event) kernel concepts adopted by the Navigational Ancillary Information Facility (NAIF) Node (Acton, 1996). For imaging systems the SPICE data include ephemerides of the spacecraft and target, instrument pointing information, mounting offsets between imaging instruments, camera focal lengths, spatial sampling rate, optical distortion coefficients, and other parameters needed to transform line and sample locations of an image to a vector of camera-fixed coordinates.

The Imaging Node acts as the repository for improved SPICE kernel data derived from cartographic and geodetic applications. I'reducing cartographic-quality image data products requires improvements in the geometric elements ofthe image observations. In cartographic applications. images are tied to one another by selecting control points on the surface that are common to the images. These control points are then used to update the SPICE kernel data to force the same control points on different images to have the same position on the planet. The camera pointing matrix is usually the parameter that is updated to force the geometric location of images to match. T he updated SPICE information is maintained as an integral part of' the archive so future image processing applications can make use of the improved geometric control.

### 2.5. *Radiometric element*

The radiometric elements, stored as part of the image archive, characterize the radiometric properties of an imaging system and make it possible to perform colorimetric and photometric analysis. The radiometric elements include the observational sequences, such as prelaunch flat-field observations acquired under controlled laboratory conditions and inflight dark-field and flat-field observations. Calibration correction files are included and contain the dark current and shading corrections for conversion to absolute radiometric units. The camera modes, temperatures, exposure times, filter-wheel positions, and other parameters that affect the calibration of an image accompany the image data products.

### 2.6. *Catalog elements*

The archive includes catalog elements organized as summary tables describing the camera characteristics and viewing geometry of the images in the archive. These summary tables are used to search the archive for pertinent image data. For example, the catalog elements could be loaded into a database application for search and retrieval of' the data products. The summary table is organized as a flat file: each row is an entry that describes an image, and each column is a parameter that describes information about the image. The summary tables describe the location of the file in the archive (file name, directory location. and volume), camera settings and modes (temperature of the focal plane, sensitivity settings. and exposure time, etc.), and searchable geometric parameters (latitude and longitude positions of the four corners of the image, subspacecraft latitude and longitude. sol:ir-incidence. emission, and phase angles, etc.). Because the geometric definition of. an observation evolves over time, the geometric elements found in the summary tables may represent the approximate viewing of an image scene and are intended for image search and retrieval. The primary geometric elements used in the processing of an image should always be extracted from the most up-to-date SPICE kernels.

### 2.7. *Documentation*

Documentation, stored as computer readable fields in the archive, includes mission, spacecraft, and instrument reports. such as calibration reports, flight operations and science team reports. and mission history, The documentation is critical for the preservation of the knowledge of a mission after the end of active flight operations. The documentation focuses on details of the mission that would not typically be available through published literature.

### 2.8. *Software*

An important element of the archive is software that provides processing capabilities which address the unique data and instrument-specific aspects of the image collection. Without these elements, it would be difficult for the science community to access and use the images. Software in this category include programs for image decompression, radiometric correction, and geometric characterization. The archive contains executable modules for computer systems commonly used by the science community (e.g. PC DOS, Macintosh, and UNIX systems) and source code files so programs can be adapted to other computer platforms.

## 3. Mission products

The Imaging Node's data holdings, described in the sections below and summarized in Table 1, are available for

distribution to the science community. The image collections come from the *Mariner* 9 and 10, *Viking I* and *II*, *Voyager I* and *II*, *Magellan*, *Galileo*, and *Clementine* missions. Additionally, the Node maintains image processing software tools and the necessary ancillary data that support the image processing of the image collections (see Section 4.4).

### 3.1. *Clementine*

The *Clementine* mission is a joint Department of Defense and NASA mission with goals of testing small spacecraft, subsystems, and sensors in the deep space environment and of providing a significant science return (Nozette *et al.*, 1994). *Clementine*, launched on January 25, 1994, from Vandenberg Air Force Base, undertook a 2 month mapping mission of the Moon and imaged 100% of the lunar surface in 12 spectral bands from the ultraviolet to the thermal infrared, The main instrumentation on *Clementine* consists of five cameras, one with a laser-ranging system. The cameras include an ultraviolet visible (UV-VIS), a long-wavelength infrared (LWIR), a laser-ranger (LIDAR) high-resolution (HIRES) camera, and a near-infrared (NIR) camera. The star-tracker cameras, used primarily for spacecraft navigation, occasionally were used to acquire wide-angle observations of the Moon and Earth. Although the spacecraft had a malfunction that prevented its rendezvous with the Geographos asteroid, the lunar mapping phase of the mission proved highly successful. The spacecraft, in a polar orbit configuration, acquired more than 1.9 million images of the lunar surface during the systematic mapping phase. The image resolutions range from ~100 m per pixel at periapsis (-28 latitude for the first month's observations and +28 latitude for the second) to ~300 m per pixel at the lunar poles. The archive of *Clementine* raw image data products exists on 88 CD-ROM volumes (Eliason and Malaret, 1995). The 1S1S system (see Section 4.4), distributed through the Imaging Node and available to the science community, provides a processing capability for the *Clementine* data collection.

### 3.2. *Galileo*

The *Galileo* Solid State Imaging (SSI) experiment (Belton *et al.*, 1992) utilizes a high-resolution imaging system with an 800 × 800 pixel array charge-couple detector. The eight-position filter wheel allows the imaging system to acquire spectral images in the range 0.375 (violet) 1.100 (near infrared) $\mu$m. The camera is approximately 100 times more sensitive than those used by the *Voyager* mission. The SSI REDR CD-ROM archive (JPL, 1993) of raw images is stored on 15 volumes. Volumes 1-6 store Earth-1, Moon, and Venus encounter observations and volumes 7-15 store Earth-2 and Gaspra encounter observations. Later volumes will include SSI data acquired during the Jupiter orbiting phase of the mission. The VICAR system (see Section 4.4) offers full processing capabilities for the SSI REDR data set.

The *Galileo* Near Infrared Mapping System (NIMS) (Carlson *et al.*, 1992) is an imaging spectrometer covering the wavelength region 0.7-5.2 $\mu$m with a spectral resolution of 0.025 $\mu$m beyond 1 $\mu$m and 0.0125 $\mu$m below 1 $\mu$m, yielding 204 spectral elements in a nominal operating mode. The NIMS EDR CD-ROM archive (Mehlman *et al.*, 1993) of raw data currently exists as a single volume storing the observations from the Venus, Moon, and Earth-1 encounters. Volume 2 stores the observations for the Earth-2 and Gaspra encounters. Later volumes will include NIMS data acquired during the Jupiter orbiting phase of the mission. The raw instrument data, organized by spacecraft clock sequence and not directly viewable by standard image display programs, requires the ISIS or VICAR systems for geometric registration of the spectral bands, radiometric rectification, and image analysis.

### 3.3. *Magellan*

The ODR (Original Data Record) and SAR/EDR (Engineering Data Record) data sets from the *Magellan* mission to Venus (Saunders *et al.*, 1992) represent the largest holdings maintained by the Node. The ODR data set, transferred to CD-WO media by the Data Distribution Laboratory at JPL, is stored on ~1700 volumes. The SAR EDR data set is contained on ~10,000 magnetic tapes with plans of transferring the collection to CD-WO media to ensure its long-term survival. The ODR data set, capturing the spacecraft's high-rate telemetry stream, was recorded at the Deep Space Network receiving stations and shipped to JPL for processing. The ODR tapes were processed by the *Magellan* high-rate processor, which removed redundant tape-recorded and station-overlapped data, frame-synchronized and time-ordered the data, separated the SAR data from altimetry and engineering data, and selected the highest quality data available for inclusion on the SAR/EDR data set. The SAR/EDR, with data organized in range-doppler form, was provided to the *Magellan* SAR Data Processing Subsystem for transformation into full-resolution basic image data records (F-BIDR), which are in sinusoidal map projections and form the basis for mosaicked image products. The SAR Processing Sub-Node maintains a processing capability to recreate and produce improved F-BIDR data products from the ODR and SAR EDR holdings. Correcting the known errors found in the spacecraft ephemerides and pointing angles, and updating the Venus topographic model used in the systematic processing of the F-BIDRs can improve the radiometric, geometric, and stereo-viewing quality of the SAR images.

The *Magellan* F-MAP, produced by the USGS on behalf of NASA's Planetary Geology and Geophysics Program (USGS, 1994), is a global image mosaic at 75 m pixel⁻¹ resolution covering 1)2% of the surface. The F-MAP data set offers advantages over the mission-produced full-resolution mosaic products (F-MIDR) because the F-MDIR products, also at 75 m pixel⁻¹ resolution, cover just 25% of the surface of Venus. The F-MAP was produced by digitally mosaicking the *Magellan* Full-Resolution Basic-Image Data Record (F-BIDR) strips

into 12 map quadrangles which in turn are divided into 2 tiles. Additionally, the F-MAP products have improved mosaic "seam removal" algorithms applied to the data. The F-MAP uses the left-looking SAR observations. When completed, the F-MAP CD-ROM collection will contain approximately 170 volumes. Production of an F-MAP series from right-looking and stereo-look angle data will be produced in the coming years. These additional data will total about 100 volumes and will increase the global coverage to over 98%, including 17% stereo-pair coverage.

### 3.4. *Voyager*

The *Voyager I* and *II* EDR image archive contains the raw images acquired during the spacecrafts' encounters with Jupiter, Saturn, Uranus, and Neptune. The image observations are from the spacecraft' narrow-angle and wide-angle vidicon camera systems (Benshe and Jepsen, 1978). The cameras are equipped with a filter wheel housing eight spectral filters ranging from ultraviolet to orange. The *Voyager I* and *II* EDR image archive currently exists on 24 CD-ROM volumes (Eliason *et al.*, 1988), with additional volumes in preparation at the JPL Sub-Node for completing the Saturn encounter data collection. The initial 12-volume set, produced by the *Voyager* Project, contains the complete image collections for Uranus (volumes 13) and Neptune (volumes 9 12), and a "best of" image set for Saturn (volumes 4 and S) and Jupiter (volumes 6 8). The Imaging Node has continued the production of the CD-ROM volume series by completing the Jupiter encounter data (volumes 12 24). The CD-ROM volume set of the complete Saturn encounter data will be completed in 1996,

### 3.5. *Viking*

The Node, through its data restoration efforts at the USGS and Washington University, has produced the *Viking Orbiter* image data collections housed on CD-ROM media (Guinness *et al.*, 1990). The *Viking Orbiter I* and *II* spacecrafts, in orbit about Mars from 1976 through 1980, each housed a Visual Imaging System (VIS) comprised of two identical vidicon cameras (Benshe and Thorpe, 1976; Wellman *et al.*, 1976; Klaasen *et al.*, 1977). The VIS cameras contained a filter wheel mounted with five color filters ranging from blue through red wavelengths. The raw image data collection, consisting of approximately 50,000 images, is available on a 46-volume set.

A cartographic digital data base of Mars, compiled by the USGS (Batson, 1987) and available through the Imaging Node, is housed on a 14 CD-ROM volume set (Eliason *et al.*, 1991). The data base is based on a controlled digital image mosaic produced from geometric projection of radiometrically corrected and photometrically modeled *Viking Orbiter* images. The data base is the product of an exhaustive Mars cartography project from data acquired by the *Viking Orbiter* VIS cameras. It includes a global image mosaic at a resolution of 1/256 pixel$^{-1}$ (231 m) on volumes 1 6, a digital topographic model (Wu *et al.*, 1982) of the entire planet at a resolution of 1/64 pixel$^{-1}$ (about 1 km) on volume 7, and a series of multispectral image mosaics at 1/64 pixel$^{-1}$ on volumes 8 13. A companion CD-ROM, volume 14, contains specially processed color images of Mars in the GIF image format.

### 3.6. *Mariner* 9 *and* 10

The *Mariner* 10 mission (Danielson and Klaasen, 1975), the first multiplanet mission carried out by a single spacecraft, was equipped with a n;lrrow-angle vidicon framing camera capable of acquiring spectral images ranging from ultraviolet to orange wavelengths. An auxiliary wide-angle optical system, accessed through a filter wheel configuration, was additionally available for observations. *Mariner* 10 returned more than 12,000 images of Mercury, Venus, and the Moon. *Mariner* 10's three Mercury encounters acquired about 3000 scientifically useful images with resolutions of up to 120 m. About 40 °/O of the surface of Mercury was photographed at better than 2 km resolution. The *Mariner* 10 EDR data collection, stored on CD-WO, is available by special request to the Node.

The *Mariner* 9 mission conducted a one-year intensive orbital reconnaissance of Mars from November 1971 to October 1972 (Masursky *et al.*, 1972). The spacecraft was equipped with wide-angle and narrow-angle vidicon cameras. Although the wide-angle camera was equipped with a filter wheel capable of acquiring spectral images from violet to orange wavelengths, the filter wheel functioned for only part of the mission. Approximately 7500 images of Mars and its moons (Phobos and Diemos) were acquired during the course of the mission. The *Mariner* 9 EDR collection, stored on CD-WO media, is available by special request to the Node. Although the *Viking Orbiter* data offers higher quality (image data with better signal-to-noise ratio) anti better image resolutions, the *Mariner* 9 data set can offer a valuable resource for temporal studies of the planet.

## -1. User services and support

The primary goal of the Imaging Node is to enable the science community to perform digital image processing and analysis in support of planetary scientific research. To this end, the Node distributes mission data products to the community, provides software capabilities to process the data, performs special processing requests on image data products, and provides a search and retrieval catalog of the Node's archive of image data products. In addition, the Node provides technical support to the community in processing of the image data products.

### 4.1. *On-line services*

As the quantities of data that are received and archived from planetary missions increases the Node must continue

**Table 2.** WWW services at the Imaging Node URL: http: cdwings.jpl.nasa.gov PDS

| Feature | Description |
|---|---|
| What's New | A log of additions and changes to the informational pages and (Jn-line data. |
| Image Browsers | Point-and-click interfaces acquire data products and browse the image collection. |
| Node Data Sets | Description of data sets available through the node and method tor acquiring them, including links to on-l ine image browsers and CDs when available. Also includes links to other on-line informati on and resources. |
| on-line Catalog | What is included in the catalog, how to set up your system 10 connect to it. and an electronic connection. |
| On-line CD-ROMs | A list of the CD-ROMs available in the jukeboxes, including links to access Index Files and acquire data files. |
| Software | [formation about and links to useful software to support access and analysis of the data products. |
| Data Request Form | Order form for data, information, and special request processing. |
| Node Personnel | A list of node contacts. |
| Server Statistics | A compilation of number and location of users accessing the WWW pages. To date approximately 3500 people from 49 different countries have accessed the Node's server. |

to develop improved tools for providing ease of access to that data and its ancillary information for use by the science and educational community. Until recently, access to this data was limited to distributions of CD-ROMs. special requests to be filled by Node personnel, and available papers and documents. The tremendous growth in the use of the Internet, the WWW, and NCSA Mosaic and Netscape Communications Navigator browsers has changed methods for data distribution. Through the use of the HyperText Markup Language (}{ TM L), WWW interface routines developed here at the Imaging Node, and several CD-ROM jukeboxes capable of storing hundreds of CDs on-line, the Node has developed a WWW home page with several linked pages that provide data set anti ancillary information, as well as the ability to browse data sets and automatically (requiring an absolute minimum level of operational resources) obtain data of interest,

Although distribution of large data sets with wide community interest will continue to be distributed on CD-ROM media, the Node intends to build upon the on-line services during the next several years as our emphasis shifts from distribution on physical media to remote access for all of our services. Dedicated computer systems at the USGS and JPL (Sun workstations with jukeboxes) will support these functions.

-$.1,1. *WWW home page.* The PDS has selected NCSA Mosaic as its WWW information browser application anti has developed some standards for home pages, so as users navigate through the various parts of the distributed system they are presented with a common look and feel. 1 he home page provides a general overview of the node with links to additional pages containing the imaging node specific information and services show o in Table 2.

Although the Node physically resides in Arizona and California with a sub-node in Colorado, and each supports dill'c'r~.nt services, this is of no concern to the user. "[' he user simply accesses the single Imaging Node h ome page, se lects the services and data of int~'rest, and the WWW browser does the rest. The Uniform Resource Locator (URL) for the Imaging Node is http: cdwings.jpl. nasa.gov, PDS/.

4.1.2. *Point-and- click approach 10 acquiring data products.* The node recently acquired several CD-ROM jukeboxes and now maintains significant collections of CD-ROMS on-line. While these resources are in themselves useful. and raw data can be accessed from them, it was recognized that the development of intuitive, user-friendly interface was essential if these collections were to be readily accessible.

Rather' than requiring researchers to know in advance the location on CD-ROM of a particular image they are interested in, image browsers were developed to determine this for them. This was done by utilizing the "forms" capability of most WWW browsers to accept user-provided criteria and input them to a program. The Node's *Magellan* and *Viking Lander* image browsers present the user with a global picture of the planet or, in the case of *Viking Lander*, the total field of view of the imaging instrument. The user indicates the location of interest by "clicking" with a moose button on this "imagemap". The type of product (full resolution. compressed once, etc., for *Magellan*, or raw, derived, etc. for *Viking Lander*) can also be indicated on this form. This information is then fed to a routine which takes the information, calculates the coordinates on the planet that the user selected. and determines the product name for the desired image, the location on CD-ROM of that product, accesses that product from the CD -ROM, and displays a 256 x 256 pixel "browse" version of this image. At this point. the user may choose either to download the entire image (or, in the case of *Magellan*, a sub-select image of the 56 "tiles" that make up the browse image) at full or reduced resolution, in PDS, VICAR, FITS, GIF, TIFF , JPEG, or PICT format. Since these conversions are performed on computers at the Node's facilities, they are not limited by the speed of the user's computer. This also eliminates the

need for users to obtain image conversion software of their own.

The image browser also provides the user with supplementary information about the image chosen, such as the product name or picture identification number, its location on CD-ROM, and its size and format, etc. In the future, this list will be extended to include such items as relevant feature names, and the product names of corresponding images from other data sets, and it will link directly into the on-line catalog. Extensive supplementary resources and information are also linked to the browsers, including help files that explain the different kinds of data, related data sets and how to acquire them, and on-line versions of project documentation. The image browsers are accessible through the Imaging Node home page.

4.1.3. *On-line catalog.* An essential part of the Image Archive is the on-line catalog. The catalog describes the camera characteristics and the viewing and spacecraft geometry of all the images in the archive, thus enabling the user to search for and extract products based on this information. During active mission operations, flight projects develop and maintain these mission catalogs, and at the conclusion of the mission, the catalog is transferred to the Node and adapted for use by the science community.

Currently, the Node supports an on-line catalog describing its *Magellan* SAR/EDR and ODR, *Viking* EDR, and an International Astronomical Union (IAU) Gazetteer of planetary nomenclature of the solar system's solid bodies. The *Magellan* portion of the catalog was populated through a series of deliveries from the *Magellan* Project's Data Management and Archive Team (DMAT) and validated through an inventory and contents verification process. The *Viking Orbiter* catalog information was derived from mission catalogs, Supplementary Experiment Data Records (SEDRs), and EDRs. The gazetteer was populated with the position and characteristics of all planetary features approved by the IAU. Users can access the catalog through a remote login to a Node Sun workstation or through a WWW browser.

Development is underway on an integrated catalog and data archive system utilizing CD-ROM jukeboxes, WWW browsers and tools, and image browsers. This will allow users to remotely search the catalog for desired data products, view the "browse" version of those products, and then retrieve them over the Internet (or for large numbers of products, place an electronic order to be filled and delivered on tape or CD). The first object to be supported through this new integrated system will be *Clementine*, *Viking Lander*, and *Voyager*. These will be followed by *Galileo*, *Viking Orbiter*, *Mariner* 9, and *Mariner* 10. The Node will continue to support the remote login interface to our catalog for a time, but it is anticipated that ease of use of the new system will render it undesirable and obsolete in the future. Additional information for the catalog can be accessed through the Imaging Node home page. Telnet access to the catalog can be arranged by contacting the Imaging Node personnel.

### 4.2. *Data set distribution*

Large volume data distribution to the science community is accomplished primarily using CD-ROM media because it remains the most cost effective approach. The Node maintains distribution lists for the CD-ROM data sets it distributes. These lists are created by canvassing the NASA science community before new products are available, so most users do not have to explicitly order them. Those in the NASA community not on existing lists can contact the Node for individual products. The Node relies on the National Space Science Data Center (NASA Goddard Spaceflight Center, Greenbelt, MD 20721, U.S.A.) for distribution to the broader audience of the general .S. community and international researchers.

Distribution of individual data products or sub-sets of data sets are made either automatically via the WWW home page (as described above), copied to a Node computer for electronic transfer, or copied to media and shipped to the requester

### 4.3. *Special processing requests*

The Node performs special processing requests for the NASA science community. This service allows users to acquire specialized data products tailored to their processing and analysis requirements. Special processing includes radiometric and geometric corrections on unprocessed images, mosaics of selected areas, and other enhancement techniques. Another form of special processing, provided by the SAR Sub-Node, is the reprocessing and conversion of *Magellan* SAR EDR data into full resolution basic image data records (F-BIDRs). Products can be made available in digital or hardcopy form. Due to budgetary limitations, this service is limited to relatively small requests.

### 4.4. *Software support*

Without processing capabilities that address the unique data and instrument-specific aspects of the images, it would be difficult for the science community to access and analyze the planetary data sets. The Node provides these capabilities for use by the community through either full processing systems or special purpose software.

4.4.1. *Full processing systems: ISIS, VICAR, PICS, MCIDAS.* The Node provides to the science community a variety of image processing software options that support the planetary image collections. These systems, obtained by contacting the Imaging Node, include PICS (Planetary Image and Cartography System), VICAR (Video Image Communication and Retrieval), ISIS (Integrated Software for Imaging Spectrometers), and McIDAS-eXplorer. Research and development is ongoing at the Node to develop more precise, efficient, and sophisticated tools for image analysis. As these become available they are distributed as part of the ISIS and VICAR systems. Although the development and maintenance costs for these systems are primarily funded through other projects, the Node supports the distribution of and technical advice for these systems.

PICS is a mature system originally developed by the

U'S( iS to support the *Mariner* 9 and *Viking* missions. The PICS system, running solely under the VAX VMS environment, supports full radiometric, geometric, and cartographic processing for the *Mariner* 9 and I (). *Viking*, *Voyager*, *Galileo*, and *Magellan* missions. The system will eventually be phased out once its full functional capabilities arc available in the ISIS system.

The ISIS system was co-developed by the USGS, JPL, UCLA, and the University of Hawaii. ISIS. initially developed to support the *Galileo*/NIMS and AVIRIS experiments, provides full processing capabilities for imaging spectrometer data. The system, designed to be portable across multiple computer platforms, currently runs under SunOS, UNIX and VAX/VMS environments and, in the future, will be available for DECAlpha/OSF1 systems. ISIS has been expanded to support the radiometric. geometric, and cartographic processing for the *Clementine* mission and will be further expanded to support *Galileo* 'SS 1, *Viking*, *Voyager*, and *Mariner* 9 and 10.

The VICAR system has evolved over more than 20 years of JPL planetary mission support. VICAR is designed to facilitate the acquisition, processing, and handling of data produced by a variety of science instruments (e.g. imaging, plasma wave and imaging spectrometers, radar-). Capabilities include image navigation, radiometric, geometric and cartographic processing, instrument calibration. and data compression. The system is currently being made portable to a variety of computer platforms, including VAX/VMS, DECAlpha/OSF1, and UNIX on SunOS, Sun Solaris, and Silicon Graphics workstations. The *Viking*, *Voyager*, *Magellan*, *Galileo*, *Mars Pathfinder*, and *Cassini* mission imaging data are supported under VICAR.

McIDAS-eXplorer, developed by the University of Wisconsin- Madison, provides the ability to interact with satellite data for geophysical applications such as multi-spectral imagery, surface network data, and atmospheric soundings. Tools include geometric and radiometric calibration. filtering. navigation and cartographic projections. multispectral classification, time series analysis, area anti distance measurements, and cross section display. McIDAS-eXplorer runs under X-Windows on Silicon Graphics, Sun, and Hewlett Packard workstations.

4.4.2. *Special purpose software*. Special purpose software has been developed for use with products generated by and made available through the Node. *Magellan* EDR-to-F-BIDR conversion software (UNIX SAR Processor) is available through the SAR Processing Sub-Node. Simple tools necessary for access. display, anti decompression of data are included on published CD-ROMs, and as these data sets are put on-line and accessible through jukeboxes, the software are also made available through the Node's WWW Software Page. Decompression software, as executable modules and source code, exist on the *Viking*, *Voyager*, and *Clementine* archives of raw image data products. The CD-ROM image data products additionally contain simple display software. The National Institute of Health (NIH) Image program is available for the display of PDS image data products for Macintosh systems. The IMDISP display package, developed by JPL, provides an image display capability for PC Dos computer systems.

## 5. Future activities

The explosive growth of the Internet and WWW services offers the opportunity to provide access to more data by more of the community for less money than ever before. With the shift from distribution on physical media to remote access. all members of the planetary science community and the public can now obtain data immediately anti at no cost.

Consistent with this better faster- cheaper trend, the focus of the Node's activity over the next several years will be to build upon our user-friendly WWW-based integrated catalog and data archive system. We are excited by the challenges and opportunities ahead. Steps involved in building upon the WWW-based system include:

- Extensively interlining the catalog with the image browsers so that researchers can access such important information as sun angle, spacecraft range, camera filters, and other data vital to image interpretation.
- Developing image browsers and loading catalog information for *Clementine*, *Voyager*, *Galileo*, *Viking Orbiter*, *Mariner* 9 and 10. and eventually *Cassini*.
- Providing access to related data sets, such as the *Magellan* F-MAPs, 3D rendered images, movies of planet surfaces, and other specially processed images of wide community interest.
- Interlinking the Node's integrated system with that of other PDS Discipline Nodes to enable access and use from the Imaging Node to other Nodes, and vice versa.

In parallel with this development, the Node will continue to work with active missions (currently *Galileo*, *Mars Pathfinder*, and *Cassini*) to assist in the creation of (heir archive products and to ensure that their products and catalogs become a part of the Node's integrated system at end of mission. Past mission data sets, including *Lunar Orbiter* and *Mariner* 9 and 10, will be reviewed, and determinations will be made as to the need for and priority of restorations.

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