TRANSITION PLAN

For the

NASA Mars Odyssey Mission
THEMIS Data Node
Arizona State University
Tempe, Arizona

To the

NASA PDS Imaging Node
U.S. Geological Survey
Flagstaff, Arizona
Jet Propulsion Laboratory
Pasadena, California

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Version 1.0

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Table of Contents

Overview

The NASA Planetary Data System (PDS) consists of a set of Discipline Nodes (DN) located at various institutions for the purpose of archiving and distributing planetary mission data within a particular scientific discipline. The Imaging Node (IN) is one such DN, colocated at the Astrogeology Science Center of the U.S. Geological Survey in Flagstaff, Arizona (L. Gaddis, Principal Investigator or PI) and at the Jet Propulsion Laboratory, Pasadena, California (S. LaVoie, Co-Lead). From time to time, the PDS establishes temporary adjuncts to the PDS structure in the form of Data Nodes (dN); these operate for a limited time period (typically spanning the performance period of a NASA mission) on behalf of NASA, a particular flight mission, and PDS to archive and distribute specific data and services (e.g., *PDS Management Council, 2006*). A dN reports to and receives assistance from one of the permanent Discipline Nodes, often under the auspices of a Lead Node that acts as the primary PDS interface to a mission. A formal data archiving plan, prepared prior to data acquisition and archiving by NASA mission archivists with support from PDS, defines generation, validation, and transfer of data and services during and after the mission.

The THEMIS Data Node (TdN) operating at Arizona State University in Tempe, Arizona (P. Christensen, PI), is one such Data Node. The TdN serves data from the Thermal Emission Imaging System (THEMIS) instrument on the NASA 2001 Mars Odyssey mission (ODY; *Arvidson et al., 2001; Arvidson, 2003; Christensen et al., 2003, 2004*). Both the TdN and IN work with the PDS Geosciences Node (GEO) at Washington University, St. Louis, Missouri, (R. Arvidson, PI), the Lead Node for the NASA 2001 Mars Odyssey mission. As an ODY Instrument PI associated with the NASA Mars Exploration Program (MEP), Christensen and his team are held responsive to the MEP Data Management Plan (e.g., *Arvidson et al., 2002*). This plan provides a high-level summary of roles and responsibilities for the generation, validation, and delivery of data products from MEP projects to PDS and to the deep archive at the National Space Science Data Center (NSSDC). The plan also specifies policies and procedures for the timely release and distribution of instrument data and information in a complete, well-documented, permanent archive.

At the end of the ODY mission or another agreed upon time period, the TdN is required by NASA to transfer data, specialized hardware, and associated materials and services to the PDS (IN, in this case; *Arvidson et al., 2001; PDS Management Council, 2006*). The often lengthy time period between initiation of a NASA mission (when a dN is established) and the end of mission (EOM) means that an evolution in data, services, and/or hardware and software capabilities may have occurred, so direct transfer of all of these elements may not be feasible or cost-effective. To document roles, responsibilities and transfer of the final TdN comprehensive archive, a Transition Plan is required to ensure that the transition between TdN and IN archiving and delivery operations occurs smoothly and without loss of data and basic data delivery services.

This Transition Plan (TP) summarizes the data content and services of the THEMIS Data Node and provides a plan and schedule for transferring such data and services to the PDS Imaging Discipline Node. Because the EOM date for the NASA Mars Odyssey mission has yet to be determined, this TP provides a schedule based on the current schedule for the mission and an anticipated EOM date in 2011. The TP may be revised by consent of all document signing parties, with knowledge and/or approval of the Lead Node and PDS management.

Summary of the 2001 Mars Odyssey Mission and its Instruments

The NASA 2001 Mars Odyssey (ODY) mission is part of NASA's Mars Exploration Program, a long-term effort of robotic exploration of the red planet. ODY launched on April 7, 2001 and arrived at Mars on October 24, 2001. ODY included three primary scientific instruments: the Mars Radiation Environment Experiment (MARIE), which measures the near-space radiation environment; the Thermal Emission Imaging System (THEMIS), which maps the mineralogy of the martian surface using a high-resolution camera and a thermal infrared imaging spectrometer; and the Gamma-Ray Spectrometer (GRS), which maps the elemental composition of the surface and determines the abundance of hydrogen in the shallow subsurface.

The THEMIS instrument produces 10-band thermal infrared (6.3 to 15.5 microns) images at ~100 m/pixel spatial resolution and 5-band visible-reflected infrared (0.425 to 0.95 microns) images at ~20 m/pixel (e.g., *Christensen, 2002; Christensen et al., 2003, 2004; Arvidson, 2003*). Odyssey's Primary Science Phase of the mission took place February 2002 through August 2004, and the orbiter began an extended mission on August 24, 2004. The current mission timeline indicates this extended mission will end October 1, 2010, with an additional 6-month closeout phase ending April 1, 2011. A further 2-year extension is anticipated; if approved for NASA funding, this will further extend the EOM to April 2013.

ODY TdN Roles and Responsibilities

The Mars Odyssey Data Generation, Validation and Transfer Plan (*Arvidson, 2003*) states the following PI responsibilities:

1. Generation of high-level mission, spacecraft and instrument documentation, instrument calibration reports, and documentation of software or algorithms used to produce reduced data records (RDRs).
2. Reduction of science packet data to experiment data records (EDRs) and reduced data records (RDRs), including generation of data sets expressed in geophysical units, with associated documentation that determines when and where the data were acquired and for what purpose.
3. Access instrument science packets, spacecraft engineering packets, other engineering information and data, and SPICE kernels generated by ODY Data Administration and archived by the Jet Propulsion Laboratory's Navigation and Ancillary Information Facility (NAIF), for use in EDR and RDR generation.
4. Generation and validation of PDS compliant archives containing Odyssey EDRs and RDRs, software, algorithms, documentation, and ancillary information.
5. Delivery to the community of validated, PDS compliant ODY archives.
6. Generation of deep archive volumes for permanent storage at the National Space Science Data Center to be delivered via PDS IN.

More explicit functional requirements for data archiving, also agreed to by the TdN (*Arvidson, et al., 2001; Gaddis and LaVoie, 2005; MSFF, 2006)*, are summarized in part below (with more recent revisions noted in *italics*):

- Plan a PDS-compliant science data archive and create the required Data Product Software Interface Specification (SIS) and Archive Volume SIS documentation.

- Work with PDS to ensure that the planned archives will be of scientific use to the community, including appropriate reviews by PDS personnel and representatives of the user community.
- Generate standard data products as defined in the SISes.
- Organize data products into archives with supporting documentation, software, and other information.
- Validate the data products and archives according to Science Data Validation Team, ODY Project, and PDS standards.
- Deliver at least 3 copies of each archive on physical media to PDS for long-term archiving at PDS and NSSDC, as described in the Archive Plan, according to an agreed-upon schedule. *(Note that the requirement for three copies has changed due to the electronic nature of many deliveries.)*
- Incorporate into archives, as appropriate, standard products generated under Data Analysis Programs.
- Provide support to users with help from Imaging, the 'parent' node.
  - Answer questions by phone and email, with screening by Imaging if desired.
  - Help users identify, locate, and download data of interest, e.g., by providing online search tools.
  - Generate special products upon request as resources allow.
- Deliver catalog information for ingestion into the PDS high-level catalog.
- Support query methods and interfaces between TdN and Central *(now Engineering)* Node online systems.
- Plan and implement the orderly transition of TdN data sets and services to the Parent Node at the end of the performance period.
- Write archives to an approved archive storage media. The archives on physical media will be validated by the Central (now Engineering) Node for final acceptance. *(Note that this requirement has been replaced by electronic data transfer and archive validation is performed by the Imaging Node.*)

TdN Data Products

The THEMIS Data Node (TdN) has set a high standard for data providers by providing efficient access to archived data, sophisticated online data visualization and delivery services, and data processing tools to provide high-level scientific data products. Archive data products produced by TdN and delivered to PDS are described in ***Table 1***.

Table 1. THEMIS data products and volumes that are part of the formal PDS archive.

Data Product	Description	Volume of Data (TB) (incl. 10/1/09 delivery)	Reference Document
VIS-EDR	RAW image QUBES at visible wavelengths, stored as 8-bit images with attached label containing identification and observation parameters	0.58 TB	THEMIS Standard Data Product SIS (Murray, 2009a)
IR-EDR	RAW image QUBES at thermal infrared wavelengths, stored as 8-bit images with attached label containing identification and observation parameters	1.2 TB	THEMIS Standard Data Product SIS
VIS-RDR	Radiometrically calibrated QUBES at visible wavelengths, stored as 16-bit images with attached label containing identification and observation parameters	1.1 TB	THEMIS Standard Data Product SIS
IR-RDR	Radiometrically calibrated QUBES at thermal infrared wavelengths, stored as 16-bit images with attached label containing identification and observation parameters	2.2 TB	THEMIS Standard Data Product SIS
VIS-ABR	Visible apparent brightness records stored as 8-bit images with attached label containing identification and the geometric parameters calculated for the center of the observation	0.54 TB	THEMIS Standard Data Product SIS
IR-BTR	Infrared brightness temperature records stored as 8-bit images with attached label containing identification and the geometric parameters calculated for the center of the observation	0.17 TB	THEMIS Standard Data Product SIS
VIS-GEO	Geometrically corrected visible 16-bit images	2.2 TB	THEMIS Geometric Processing User's Guide (Murray, 2009b)
IR-GEO	Geometrically corrected infrared 16-bit images	2.4 TB	THEMIS Geometric Processing User's Guide
IR-PBT	Infrared projected brightness temperature 16-bit images, projected equivalent of IR-BTR products	~0.19 TB	THEMIS Geometric Processing User's Guide
	Total Volume (TB)	**10.58**	

*Note: Additional files such as browse images and interim calibration files and data are typically delivered to PDS, but these are not part of the formal archive.

PDS IN THEMIS Data Products

The IN is a curator of NASA's digital image collections from planetary missions. IN provides online access (http://pds-imaging.jpl.nasa.gov) by the NASA planetary science community to the digital image archives, ancillary data, software tools, and technical expertise necessary to fully utilize the vast collection of digital planetary image data. All of the THEMIS data archive volumes are held at IN/USGS, including a copy of the raw-spacecraft packets (SFDU) and the THEMIS index files. IN/JPL also provides a search capability for THEMIS data products and provides links to these products via the ASU Data Node archive (e.g., http://img.pds.nasa.gov/). Updates to the THEMIS archive collection occur electronically and/or by large-capacity, portable disk drives (i.e., 'data brick') on a regular schedule during the ODY mission (every 3 months). As described in the TdN and the IN Disaster Recovery Plans (*Murray, 2007*; *PDS Imaging Node, 2009*), procedures are in place for all THEMIS data, software and delivery capabilities to be restored and made available promptly in the event of a disaster. No physical transfer of storage drives containing THEMIS data volumes between the TdN and IN is deemed necessary at EOM. A full copy of the complete, final THEMIS data archive will be delivered electronically (possibly via 'data brick') by IN to the NSSDC upon completion of the ODY mission.

THEMIS Data Access and User Services

Numerous data search and retrieval tools exist to provide access to THEMIS archive products. Among these are Google Mars (http://www.google.com/mars/) and MarsoWeb (http://www.marsoweb.nas.nasa.gov), both provided by non-PDS groups and considered outside the scope of this plan. Major tools provided by the TdN and PDS entities (primarily IN and GEO) to support the THEMIS data archive are summarized in ***Table 2.*** Tools and/or services that emphasize mission operations or provide non-essential archive support capabilities are beyond the scope of this plan and are highlighted in bold italics in ***Table 2***. Actions needed to maintain primary data access and continuity of user services are shown at right in ***Table 2.***

Transitioning TdN Data and Services to IN

As stated in the Data Nodes: Principles and Practices White Paper (*PDS Management Council, 2006*):

> 'Dissolving a data node requires transfer of data node holdings to the DN on or before the negotiated completion date. Dissolution and transfer must be completed with minimal interruption of services to users. The services (if any) which the dN will continue after dissolution of the data node will be described. The data transferred will meet PDS standards. There may be hardware and software issues in some transfers in addition to the data'.

And, as noted in the Functional Requirements for GRS and THEMIS PDS Data Nodes, R. Arvidson, et al., August 27, 2001 (*Arvidson et al, 2001*):

> 'A search tool is definitely necessary for users of THEMIS products. The minimum capabilities should be to search by time and location to identify and download a set of products. Other desirable capabilities include searching by other parameters in the team's THEMIS database, image display, plotting, and correlation with other data sets (possibly from other missions, e.g. MGS MOC, TES, and MOLA). Whatever tools are provided must be able to be transferred to the Imaging Node when the THEMIS Data Node is dissolved.)'

This Transition Plan document responds to these and other noted references in presenting the transition of the TdN to the IN at the end of the performance period.

Table 2. Summary of TdN, Mars Space Flight Facility (MSFF), and PDS and/or NASA data products, access services and/or capabilities. Products in bold italics below are considered to be beyond the scope of this document and no actions are planned to address them.

Function	TdN Product	IN Product	Other PDS or NASA Product	Differences & *Notes*	Actions	Due
Access tool: Includes a collection of global maps (albedo, shaded relief, elevation) of Mars showing layered footprints of all released images from THEMIS (IR and VIS) and other Mars mission instruments (MRO/CTX, MRO/HiRISE, MGS/MOC, Viking Orbiter). This tool allows the user to select footprints and displays component images of the map. Limited filtering of images is done on the basis of release year of daily images, time of day, and camera. Thumbnail images linked to an image information page are displayed. The image page has context information and allows the user to download images in PNG, JPG and TIFF formats.	Mars Global Image Galleries ('Maps of All Images')	Planetary Image Atlas (Atlas) Map-a-Planet (MAP) Planetary Image Locator Tool (PILOT)	GEO's Mars Orbital Data Explorer (Mars ODE)	Atlas uses two Mars basemaps (MOC, MDIM) for multi-instrument searches (IR, VIS, MOC, CTX, HiRISE, VO), does not display image footprints. MAP provides global maps (MOLA, MOC, TES albedo, MDIM), does not display or provide access to archived images or footprints. PILOT shows layered image footprints and image information for THEMIS IR, CTX, HiRISE, MOC, and VO, uses THEMIS and MDIM21 basemaps.	IN to modify Atlas' Mars Map interface (via an interface to the onMars server) to display footprints, populate the results tab. **No TdN action planned.**	EOM
Access tool: Provides a collection of scientific data as global Mars maps (simple cylindrical, 1 to 256 ppd) from THEMIS and other Mars mission instruments. Global maps/mosaics for >27 layers can be downloaded (typically in PNG format); addition of several hundred more is planned: A wide variety of scientific image products derived from THEMIS and other Mars data are available.	Mars Global Data Sets (MGDS)	Map-A-Planet (MAP) Data Portal		MGDS provides access to many more co-registered map layers, but only in PNG format MAP serves 9 co-registered cartographic maps in multiple formats (PDS, ISIS, raw, tiff, gif, jpeg).	IN to add map layers to MAP. IN to update Data Portal to include archived and published global Mars maps. **No TdN action planned.**	EOM
Analysis tool: Provides access to infrared laboratory and field spectra of a variety of geologic materials. Provides detailed descriptive information for each spectrum. Allows user to plot spectra and view spectral information for different minerals from Actinolite-Zincobotryogen (A-Z). (http://speclib.mars.asu.edu/)	***Thermal Emission Spectral Library***		GEO's CRISM Spectral Library	*Pending continuation of funding by NASA, MSFF expects to continue to maintain this tool for use by NASA-funded researchers.* CRISM Spectral Library provides access to visible and near-infrared (not infrared) spectra.	NASA provides fiscal support for maintenance of this library at MSFF if the capability is desired. **No TdN or PDS action planned.**	
Access tool: A text- and form-based extensive search tool for identifying and accessing data from multiple Mars missions for performing comparative analyses. Data served include CRISM, CTX, HiRISE, HRSC, MOC, OMEGA, THEMIS and Viking Orbiter.	Mars Image Explorer (MIE)	Planetary Image Atlas (Atlas)	GEO's Mars Orbital Data Explorer (Mars ODE)	MIE provides context map image with image footprint overlay, allows stretching and specific band selection of THEMIS products. Atlas does not provide image footprint overlay.	IN to modify Atlas to**:** -Display context map image with footprint overlay, -Allow user to display and download specific stretch and band of data product. **No TdN action planned.**	EOM

Function	TdN Product	IN Product	Other PDS or NASA Product	Differences & *Notes*	Actions	Due
Processing tool: A web-based, interactive tool and the primary THEMIS mission data processing software package for producing THEMIS data products. It is a request-driven tool providing data output such as map-projected images, derived parameters such as emissivity, temperature, radiance, etc., and performing stretches on the data. (http://thmproc.mars.asu.edu/) (*Murray, 2009a, b*)	THEMIS Processing tool (THMPROC)			*Pending continuation of funding by NASA, MSFF expects to continue to maintain this tool for use by NASA-funded researchers.* *USGS provides ISIS 2 and 3 freeware (Gaddis et al., 1997; Anderson et al., 2004) with THEMIS geometric data processing capability and some derived parameter map derivations.*	NASA provides fiscal support for maintenance of this tool at MSFF if the capability is desired. IN to work with MSFF & seek NASA funds to add THEMIS calibration & other basic functions to ISIS 3. **No TdN action planned.**	EOM
Data products: Files used in calibration of visible data.	Calibration files			A complete, current set of calibration files is kept at TdN. Interim versions are included with regular deliveries to PDS and are held at both USGS and JPL.	IN to capture final calibration files upon delivery to PDS. Include on archive volume in format usable by THMPROC and ISIS 3. **No TdN action planned.**	EOM
Processing tool: Software tool with 426 specific functions; a spectral math engine & image processing tool for detailed analysis of multi- and hyper-spectral data. DavinciWiki is a tool to organize and provide documentation and examples for core Davinci as well as other useful user defined and modular functions. Each of these functions is grouped in one or more categories that help describe how the function can be used. (http://davinci.asu.edu/index.php/Main_Page)	***Davinci & DavinciWiki***			*MSFF expects to continue to maintain this tool for use by NASA-funded researchers.* *Davinci is a research tool that has instrument-specific software not found in other NASA-funded image processing packages (e.g., ISIS 3, VICAR).*	NASA to provide funding for maintenance of this tool at MSFF if the capability is desired. **No TdN or PDS action planned.**	
Access tool: An ASU-developed, Java-based software tool used as a geographical information system that allows easy access to a variety of Mars mission coregistered data layers, along with usage tutorials. Used for mission planning and scientific data analysis by several NASA missions, including Mars Odyssey, Mars Global Surveyor, Mars Reconnaissance Orbiter, and Lunar Reconnaissance Orbiter. Simultaneously displays multiple datasets (e.g., maps, image footprints, numerical data products, etc.) and supports numerous data layers (map, stamp, groundtrack, lat/lon grid, nomenclature, region of interest, THEMIS planning, THEMIS mosaic, shape, TES and 3D viewer). Non-proprietary, open source version available (http://jmars.asu.edu/).	***Java Mission-planning and Analysis for Remote Sensing (JMARS)***		USGS's Planetary GIS Web Server (PIGWAD) JPL's onMars Server	*Mars Space Flight Facility expects to continue to maintain this tool for use by NASA-funded researchers.* PIGWAD is an online GIS support tool and service that provides many Mars image layers and tutorials for accomplishing some of the analyses. Supports use of ***other*** visualization and analysis clients (some free, some not). onMars is a data server that provides visualization and access to many Mars image layers. Supports use of ***other*** visualization and analysis clients.	NASA provides fiscal support for maintenance of this tool at MSFF if the capability is desired. PDS does not provide the mission planning and analysis tools of JMARS. Many available (open source and closed) tools can provide the analysis capabilities using data from existing and planned servers. **No TdN or PDS action planned.**	

TdN and PDS IN Transition Plan and Timetable

In addition to the primary copy of all THEMIS data archive volumes at TdN, copies are held at both IN/USGS (primary copy) and at IN/JPL (secondary copy). Updates to the THEMIS archive collection at all three facilities will continue to occur regularly throughout the remainder of the ODY mission. Procedures are in place for all THEMIS data, software and delivery capabilities to be restored and made available promptly in the event of a disaster (*Murray, 2007*; *PDS Imaging Node, 2009*).

Table 2 shows a relative timetable for transition of primary THEMIS data access services provided by TdN to PDS. PDS and TdN staff will work together to ensure that primary TdN services are either maintained at ASU or will be replicated by existing or planned services within the PDS. In some cases, continuation will require additional funding. An informal readiness review will be held between the TdN and IN at least 6 months prior to the dissolution of the TdN to ensure that data are available and access services are in place and remain ready for community use. Prior to completion of the transition, notices will be placed on both TdN and IN websites and other appropriate sites and venues, informing the community of the availability of updated THEMIS services at the IN.

As of the date of this document (*April 2010*), the ODY mission funding is scheduled to end in a little over a year: the first extended mission ends October 1, 2010, allowing for an additional 6-month closeout phase for the science teams and extending the performance period to April 1, 2011. Recently a new, two-year extension was granted by NASA to the ODY Project to extend operations to April 1, 2013. Any required updates to this Transition Plan will be made within 12 months of EOM.

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