2001 MARS ODYSSEY THEMIS DATA ARCHIVE. K. C. Murray, P. R. Christensen, G. L. Mehall, N. S. Gorelick, J. C. Harris, K. C. Bender, and L. L. Cherednik, Arizona State University, Mars Space Flight Facility, P.O. Box 876305, Tempe, AZ, 85287-6305, (asupds@themis.asu.edu).

Introduction: The Thermal Emission Imaging System (THEMIS) onboard the 2001 Mars Odyssey Orbiter began its Primary Mapping Mission in February, 2002; public access to the THEMIS standard data archive began in October, 2002. The archive includes the raw, calibrated, and derived images generated from the infrared and visible observations. THEMIS standard data products are generated by the staff at the Arizona State University Mars Space Flight Facility, and are available at the Planetary Data System (PDS) and ASU-THEMIS internet sites.

Instrument Overview: The THEMIS instrument is a combined infrared (IR) and visible (VIS) multi-spectral imager. The imaging system is comprised of a three-mirror, off-axis, reflecting telescope in a rugged enclosure, a visible/infrared beamsplitter, a silicon focal plane for visible detection, and a microbolometer array for infrared detection. The telescope has a 12-cm effective aperture, speed of f/1.6, and co-aligned VIS-IR detector arrays. A major feature of this instrument is the uncooled IR microbolometer array which can be operated at ambient temperature. A small thermal electric (TE) cooler is used to stabilize the detector temperature to ±0.001 K. The only moving part in the instrument is a calibration flag which allows for thermal calibration and protection of the detectors from unintentional direct solar illumination when the instrument is not in use.

THEMIS IR images are acquired at selectable image lengths and in combinations of ten selectable bands. The image width is 320 pixels (32 km, based on the nominal 400 km mapping orbit) and the length is variable, in multiples of 256 line increments, with a minimum and maximum image length of 272 and 65,296 lines respectively (27.2 km and 6,530 km, based on the nominal mapping orbit). The IR focal plane is covered by ten ~1 µm-bandwidth strip filters (Table 1a), producing ten band images with bands 1 and 2 having the same wavelength range.

THEMIS VIS images are acquired in framelets of size 1024 pixels crosstrack by 192 lines downtrack (18 km by 3.4 km, based on the nominal mapping orbit). The maximum number of framelets that can be collected in an observation is determined by the number of bands selected (Table 1b) and the spatial resolution selected (three summing modes available). The size of an image is given by

$$((1024*192) * \#framelets * \#bands) \div summing^2$$

the total of which must be less than the onboard buffer of 3.734 Mbytes. For example, with no spatial summing (summing=1), either a single-band, 19-framelet (65.6 km) image or a 5-band 3-framelet (10.3 km) image can be collected.

Table 1a & b: THEMIS available bands [1]

INFRARED BANDS		VISIBLE BANDS	
Band Number	Center (µm)	Band Number	Center (µm)
IR-1	6.78	V-1	0.425
IR-2	6.78	V-2	0.540
IR-3	7.93	V-3	0.654
IR-4	8.56	V-4	0.749
IR-5	9.35	V-5	0.860
IR-6	10.21		
IR-7	11.04		
IR-8	11.79		
IR-9	12.57		
IR-10	14.88		

Internal THEMIS data processing may be applied to either image type before storage and data transfer. Onboard data compression is applied to all images before the data stream is downlinked from the spacecraft: IR are compressed losslessly; VIS are compressed either losslessly or lossy. A full description of the instrument system and onboard processing is available in the THEMIS *Space Science Review* paper [2].

THEMIS Standard Data Products: Each THEMIS observation results in either a visible image, an infrared image, or both an infrared image and a visible image with overlapping spatial coverage. Additional infrared images are collected throughout each orbit for calibration purposes. THEMIS standard data products include the raw images (EDR), radiometrically calibrated images (RDR), and derived brightness temperature images (IRBTR & VISABR).

All images are stored in binary format with an attached ASCII label. The four multi-spectral datasets (IREDR, VISEDR, IRRDR, and VISRDR) are stored as PDS SPECTRAL_QUBE objects; the two derived datasets (IRBTR & VISABR) are stored as PDS IMAGE objects [3]. None of the standard data products are projected into a coordinate system, and bands within a single SPECTRAL_QUBE have not been spatially registered.

SPECTRAL_QUBE Object. All multi-spectral THEMIS data products make use of the PDS

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SPECTRAL_QUBE object, adapted from the ISIS cube object and defined in the PDS Standards Reference [3]. A THEMIS QUBE is an array of sample values in three dimensions: two spatial dimensions (samples and lines) and one spectral dimension (bands). This format allows THEMIS data to be simultaneously a set of images (at different wavelengths) of the same target area, and also a multi-point spectrum at each spatially registered pixel in the target area.

A QUBE object has an attached ASCII label and one or more header data objects. Label keywords contain QUBE structure definitions and pertinent observation information. All THEMIS QUBE headers include a header HISTORY object which documents data manipulations of the individual file; all IREDR QUBEs also include a binary telemetry TABLE object within the header.

IMAGE Object. THEMIS brightness products (IRBTR and VISABR) make use of the PDS IMAGE object defined in the PDS Standards Reference [3]. An IMAGE is a two-dimensional array of values organized as line_samples and lines. A THEMIS IMAGE is derived from a single band of an RDR QUBE and has the same dimensions as that band. Each THEMIS IMAGE has an attached label containing IMAGE structure definitions, a summary of observation information, and some basic geometric parameters calculated for the center of the observation. Geometric parameters are based on the Mars IAU 2000 aerocentric model with east positive longitude.

Geometrically Projected Products: The THEMIS team recognizes the importance of geometrically registering and projecting the calibrated data products. THEMIS has contracted with the ISIS team at USGS Flagstaff to adapt their existing software to the THEMIS dataset; both teams are working towards making geometrically projected THEMIS products available as soon as possible.

Applicable Software: The THEMIS team uses the software tools DAVINCI and ISIS to display and analyze the SPECTRAL_QUBEs and IMAGEs, however any software package that understands multi-spectral images should be able to ingest the image structures. DAVINCI is distributed by ASU and is available at http://davinci.asu.edu. ISIS is produced by USGS Flagstaff and is available at http://astrogeology.usgs.gov/Projects/ISIS.

Online Data Distribution: In compliance with the Mars Exploration Program data release policy [4] and the Odyssey Archive Plan [5], THEMIS standard data products will become available through PDS six months after ground receipt of the last raw data within the three month acquisition period. Data releases are scheduled for every three months, starting from October 2002.

THEMIS data will be available online from the 2001 Mars Odyssey Data Archives web site, http://wwwpds.wustl.edu/missions/odyssey [6], or at the PDS THEMIS Data Node, http://themis-data.asu.edu.

References: [1] Christensen, (2001) Calibration Report for the Thermal Emission Imaging System for the Mars 2001 Odyssey Mission. [2] Christensen, et. Al., (Submitted, 2001), The Thermal Emission Imaging System for the Mars 2001 Odyssey Mission, *Space Science Review*. [3] (2002) Planetary Data System Data Standards Reference, Version 3.5, JPL D-7669, Part 2. [4] Arvidson and Slavney (2000), Mars Exploration Program Data Management Plan, http://wufs.wustl.edu/missions/mep/dmp.html. [5] Arvidson (2001), 2001 Mars Odyssey Orbiter Archive Generation, Validation, and Transfer Plan, JPL D-20679. [6] Slavney, et. Al., (2003) 2001 Mars Odyssey Science Data Archives, *LPS XXXIV*.