

2004 Landsat Updates

February 2004

USGS Announces New Product Line

The Landsat Project at the U.S. Geological Survey (USGS) EROS Data Center (EDC) in Sioux Falls, South Dakota has been taking steps to increase the utility of the Enhanced Thematic Mapper Plus (ETM+) data that includes non-functional Scan Line Corrector (SLC) artifacts. The SLC on the Landsat 7 ETM+ instrument failed May 31, 2003.

A technique to estimate radiometric values in Landsat 7 data gaps has been selected, and the resulting new products will be available to customers in June 2004. In the planned products, the gap pixels are replaced with data from a previously acquired SLC-on scene that is registered and histogram-matched to the SLC-off image. The histogram matching technique is a localized linear transform performed in a moving window throughout the missing pixels.

In March 2004, the current ETM+ SLC-off product will be available to the public with a user-selectable amount of interpolation to replace missing gap pixels. The USGS is continuing to research other methods of providing better gap pixel estimates/merged data products and will continue to provide information resulting from this work as it becomes available. A sample product, with a comparison with the degraded data, further information, and regular updates on the planned product release can be found at http://landsat7.usgs.gov/slc_enhancements/.

This image is a preview of the new Gap-Filled products that will soon be available from the USGS EDC. The left image is from path 39 row 37, acquired over the Salton Sea in southern California on 9/17/2003, and shows the scan gaps caused by the failed SLC. The right image represents the same data, but with the gaps filled by histogram-matched data acquired 9/14/2002 over the same area.

Status of the Landsat 5 X-Band Transmitter Investigation

The Landsat 5 Flight Operations Team (FOT) has recently completed the testing and assessment of the X-band transmitter performance and, in particular, the Traveling Wave Tube Amplifier (TWTA). An over-current protection circuit for the TWTA has tripped on multiple occasions since last summer. In mid-January, a technical peer review was held with communications experts to present the history, symptoms, theories, testing, and analysis of the observed TWTA behavior. The outcome of this review included a proposed new operating profile for the x-band transmitter that will have a direct impact on the science data mission.

These results will be presented to the Landsat Flight Systems manager who will produce a proposal for a new mission concept of operations for Landsat 5 that will be presented to USGS Landsat Project Chief. A final decision will then be made on the operations profile the mission will adopt for the future.

NASA's Commercial Remote Sensing Program Released Two New Landsat 7 Products

Through cooperative efforts between National Aeronautics and Space Administration (NASA) and the commercial remote sensing community, the USGS EDC released two new Landsat 7 products on December 23, 2003. The Landsat orthorectified ETM+ imagery and Landsat orthorectified Pan sharpened ETM+ Imagery data sets joined the Landsat

orthorectified TM imagery data set, which was used as to establish the baseline for these two new products. Together, these products form a suite of quality-screened, high-resolution satellite images with global coverage over the Earth's landmasses, which will provide users with remote sensing data for tracking change over much of the Earth. The Earth Satellite Corporation, Rockville, Maryland, in cooperation with NASA and the USGS, provided the "orthorectification" process used to enhance the quality of the remote sensing data by using geodetic and elevation control data to correct for the positional accuracy and relief displacement of the imagery. For further information:

<http://edcimswww.cr.usgs.gov/pub/imswelcome/>

April 2004

Landsat 7 Completes Five Years of Observations

It is worth noting that, on April 15, 2004, Landsat 7 completes five years of operation and will have completed the original planned mission life. In spite of difficulties, Landsats 5 and 7 continue to provide useful observations of a changing planet.

USGS Announces New Product Line

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The U.S. Geological Survey (USGS) Landsat Project at the EROS Data Center (EDC) in Sioux Falls, South Dakota has been taking steps to increase the utility of the Enhanced Thematic Mapper (ETM+) data that includes non-functional Scan Line Corrector (SLC) artifacts. The SLC on the Landsat 7 ETM+ instrument failed May 31, 2003.

In the initial Gap-filled product release, the gap pixels are replaced with data from a previously acquired SLC-on scene that is gistered and histogram matched to the SLC-off image. The histogram matching technique is a localized inear transform performed in a moving window throughout the missing pixels. Pricing for the new products has not yet been determined and will be announced at a later date. A sample product along with further information can be found at http://landsat7.usgs.gov/slc_enhancements/.

User Selectable Interpolation Now Available for Landsat 7 SLC-off Scenes

The USGS has recently released ETM+ SLC-off products to the public with a user-selectable amount of interpolation to replace missing gap pixels. Allowable interpolation values range from 0 to 15 pixels, with each pixel representing 30 meters. The default value for interpolation is 2 pixels, which is the heritage value for Level 1G processing of previous Landsat 7 SLC-off data. A sample product along with further information can be found at http://landsat7.usgs.gov/slc_enhancements/.

Landsat 7 ETM+ Dataset Transition

As of March 31, 2004, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data will no longer be available for search and order through the Land Processing Distributed Active Archive Center (LP DAAC) and the Earth Observing System (EOS) Data Gateway (EDG). All orders submitted to the LP DAAC prior to this date will be filled, provided payment is received within a reasonable amount of time. Search, browse, and order capability for most of these datasets will be migrated to the U.S. Geological Survey's Earth Explorer (<http://earthexplorer.usgs.gov>) on March 31, 2004.

This change is driven by long standing agreements to transfer land remotely sensed data from the National Aeronautics and Space Administration (NASA) to the USGS for long-term archiving, as well as specific agreements made between NASA and the USGS for management of the Landsat Project. Both agencies are working to make the transfer as seamless to the user as possible and to continue the current high level of service.

Although the method of data access will change, there will be no other change to the processing, format, or other details of the products. Level 1 and Level 0 products that were previously available through the EDG will now be accessed through Earth Explorer (<http://earthexplorer.usgs.gov>) or the Global Visualization Viewer (GloVis)<http://glovis.usgs.gov>). Level 1 products, will continue to be available through both processing systems currently in use (Level 1 Product Distribution System (LPGS) or National Landsat Archive Production System (NLAPS)), with the temporary exception of floating scenes. Until a search and order capability for floating scene products is released on Earth Explorer, all floating scene and multi-scene orders must be placed by contacting USGS EDC Customer Services and will be processed only through the NLAPS processing system and will be processed only through the NLAPS processing system.

(<http://edc.usgs.gov/includes/contactform.html>)

If you have any questions, please contact USGS EDC Customer Services (1-800-252-4547, 605-594-6151)(<http://edc.usgs.gov/includes/contactform.html>).

June 2004

Landsat Product Price Adjustment

The U.S. Geological Survey (USGS) is reducing the price of Landsat 7 scenes with gaps in data resulting from a satellite anomaly in May of 2003. Scenes that contain gaps in data will be reduced from \$600 to \$250. A new product being offered for \$275 will have the gap areas filled in with Landsat 7 data acquired prior to the Scan Line Corrector (SLC) failure at a similar time of the year. The two scenes are geometrically registered, and a histogram matching technique is applied to the fill pixels that provide the best-expected radiance values for the missing data.

The new product represents an effort by the USGS Landsat 7 Project at the USGS EROS Data Center (EDC) in Sioux Falls, South Dakota, to increase the utility of the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data affected by the non-functional scan line corrector. The USGS is continuing to research methods of providing improved data products and will continue to provide information resulting from this work as it becomes available.

A sample product, with a comparison of the degraded data, further information, a complete list of the new pricing structure, and regular updates on planned product releases can be found at http://landsat7.usgs.gov/slc_enhancements/.

Planned Landsat Product Development

The USGS Landsat Project at the USGS EDC has been taking steps to increase the utility of the ETM+ data that includes non-functional scan line corrector (SLC) artifacts. With the initial gap-filled product released on May 10, 2004, the missing pixels are replaced with data from a previously acquired SLC-on scene that is registered and histogram matched with the SLC-off image. Phase 2 of SLC product improvements will combine one or more SLC-off scenes into an SLC-off/SLC-off gap-filled product using a similar registration and histogram matching technique. Delivery is expected by the end of 2004 with a price of \$300. This product will overcome the temporal issues associated with the Phase 1 SLC-on/SLC-off gap-filled product. The Earth Explorer ordering interface will guide the

user through the ordering process of choosing appropriate SLC-off scenes to generate their gap-filled product. A sample product along with further information can be found at <http://landsat7.usgs.gov/sampleproducts.php>.

Landsat Mission Operations Center

Since November 2000, Honeywell has provided spacecraft flight operations and ground systems sustaining engineering support for the Landsat 7 satellite. The USGS recompeted this contract and on May 16, 2004, awarded the new 8-year contract to the incumbent, Honeywell. The Landsat 7 Mission Operations Center (MOC) is located at National Aeronautics and Space Administration's (NASA's) Goddard Space Flight Center (GSFC) in Greenbelt, Maryland. Additionally, Honeywell maintains a backup MOC at their facility in Columbia, Maryland.

Landsat 7 Attitude Control System, Gyro 3

On April 7, 2004, the Landsat 7 Precision Attitude Determination System (PRADS) initiated an automatic reset. A PRADS reset is an autonomous self-preserving action that the satellite takes when it loses confidence in where it thinks it is pointed in relation to star observations. It is not uncommon for a PRADS reset to occur once or twice a year due to periods of too few identifiable stars or a misidentification of a number of stars. Between April 7th and May 5th a total of 14 PRADS resets occurred, indicating a significant and anomalous change in the spacecraft's Attitude Control Subsystem (ACS).

Starting on April 7, the Flight Operations Team (FOT) responded to this anomaly with a thorough review of all satellite systems that could impact attitude pointing. The only suspicious telemetry related to the gyro 3 motor current and a coincident change in the biases calculated for gyros 1 and 2. (The Landsat 7 spacecraft carries three gyros in its Inertial Measurement Unit (IMU); two are required to maintain precision attitude control.)

The FOT had been closely monitoring unstable motor currents from gyro 3 for more than a year with no apparent impact to the stability and operation of gyros 1 and 2. The recently observed perturbation of these gyros' performance during gyro 3 'noisy' periods indicated a new 'cause and effect' relationship. The FOT compiled data from the anomaly investigation and forwarded it to the spacecraft manufacturer and personnel from several missions with similar gyros. The FOT soon received concurrence from these sources that the degraded performance of gyros 1 and 2 resulting in the PRADS resets was most likely caused by the mechanical vibration of a debilitated gyro 3. The FOT and subject matter experts further stated that if gyro 3's erratic behavior was affecting gyros 1 and 2, cumulative damage could result.

Based on the evidence presented and recommendations of both the FOT and spacecraft manufacturer, the USGS Flight Systems Manager directed that gyro 3 be powered off on May 5. The shut down procedure occurred without incident resulting in an immediate and positive response to the performance of gyros 1 and 2 as indicated by telemetry. Since May 5, there have been no additional PRADS resets.

Landsat 5 Modular Power System, Battery #1

On May 21, 2004, Landsat 5's Battery #1 was removed from the Modular Power Subsystem (MPS) main power bus following an anomaly of the enable/disable charge relay. The nominal configuration of the charge relay is in the closed position for each of Landsat 5's three batteries so that they can supply power during spacecraft eclipse (night) periods. On Thursday, May 20, 2004, the FOT noted that the charge relay for Battery #1 was not operating consistently; maintaining an open circuit after having been commanded to close the circuit. Battery #1 has exhibited anomalous performance for 7+ years, more so over the past two months. With the apparent charge relay failure, the Flight Systems Manager ordered the relay commanded open and permanently removed from the main power bus.

Even with the shut down of Battery #1, Landsat 5's two remaining batteries have sufficient capacity to continue the mission with no impact to operations. The mission can operate with only one functional battery.

Landsat Technical Working Group (LTWG)

The Landsat Technical Working Group (LTWG) Meeting #13 was held in Cordoba, Argentina from April 26-30, 2004. Thirty-nine participants representing 12 countries attended the conference. The meeting provided an opportunity for the U.S. Landsat Project staff to present the current status of both the Landsat 5 and Landsat 7 missions along with a description of the events that have occurred since the last working group meeting held in June 2002. There were several in-depth presentations on development of new gap-filled products to mitigate the effect of the failed ETM+ scan line corrector. At the meeting, the USGS distributed the source code for the latest version of its Landsat Product Generation System (LPGS) containing the phase-1 gap-filling capabilities.

The next meeting with the International Cooperators (ICs) will be the Landsat Ground Station Operators Working Group (LGSOWG) to be held in Chang Mai, Thailand the week of November 1, 2004. The next Landsat Technical Working Group meeting will be held in the Washington, DC area in April-May of 2005.

August 2004

Landsat Data Retrieval System

The Landsat data archive, reaching back to 1972, largely exists on aging analog tape media retrieved and handled manually for product requests. The Landsat Archive Conversion System (LACS), which began operations in June 2004, will convert analog data from these tapes to digital data stored in automated near-line silo. LACS also significantly automated the processes of collecting new Landsat 5 data from the satellite and placing those data in the archive. The process previously took approximately 24 hours from the time of data collection until it became available for customers to order. With LACS, this process takes only 3 hours.

Historic data archive (left) and automated silo storage (right) located at the EROS Data Center (EDC).

Planned Landsat Product Development

Since release of the Phase 1 Landsat 7 Scan Line Corrector (SLC)-off gap-filled product in May 2004, the U.S. Geological Survey (USGS) Landsat Project has been taking steps to increase the utility of the Enhanced Thematic

Mapper Plus (ETM+) data that includes non-functional SLC artifacts. The Phase 2 gap-filled product will combine one or more SLC-off scenes into an SLC-off/SLC-off gap-filled product using a similar registration and histogram matching technique as the Phase 1 product. Public release is planned for early October 2004 with a price of \$300. This product will overcome the temporal issues associated with the Phase 1 SLC-on/SLC-off gap-filled product. The scan gap mask files distributed with the Phase 1 product will be enhanced for Phase 2 to better assist the user in determining the source scene for each pixel in the gap-filled scene. The Earth Explorer ordering interface will guide the user through the ordering process of choosing appropriate SLC-off scenes to generate their gap-filled product. A sample product along with further information can be found at http://landsat7.usgs.gov/sample_products.php.

Landsat Program Outreach

The program managers take communications relating to changes in the Landsat Program very seriously. A number of media are being used to communicate changes and keep interested parties informed. Landsat Program staff will be attending a number of technical conferences and encourage visitors to stop by the USGS exhibit booths to learn about the Landsat Program. Recent and upcoming conferences where booths or presentations have been scheduled include: the ESRI conference in San Diego, California in August; IGARRS in Anchorage, Alaska in September; and the fall

technical conference for ASPRS in Kansas City, Missouri in September. As part of the annual ASPRS meeting to be held in Baltimore, Maryland in March 2005, a special session is planned to present the status, current applications of data, and plans for the Landsat Program.

December 2004

ETM+ SLC-off to SLC-off Gap-filled Product

The U.S. Geological Survey (USGS) has completed development of a major new product enhancement for Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data captured after the Scan Line Corrector (SLC) anomaly. Gap-filled product options will now allow the data merge of one or more SLC-off fill scenes for generation of a final gap-free image. Users may select from up to four SLC-off scenes, in addition to an optional SLC-on scene, to create a final data merged product.

The technique used to generate the new product is similar to the previous gap-filled products. The major advantage of this new product is a much improved temporal match of fill scenes used to produce the final image. **The SLC-off to SLC-off product will now allow the use of scenes from consecutive passes to fill the gaps of the target scene.**

The cost of the new SLC-off to SLC-off product option is \$300 per scene. Data products that are generated using only Landsat 7 SLC-on data for the gap-fill (acquired prior to the SLC failure) will continue to be offered at the previous price of \$275 per scene. Standard SLC-off products (with the data gaps included) or SLC-off interpolated products are also available for \$250 per scene.

This new product represents a continuing effort by the USGS Landsat Project at the EROS Data Center (EDC) in Sioux Falls, South Dakota to increase the utility of the Landsat 7 ETM+ data affected by the non-functional SLC. Previously released products designed to compensate for the SLC problem include a fully interpolated option and an SLC-on to SLC-off data merge option. The USGS is continuing to research other methods of providing merged data products and will continue to provide information resulting from this work as it becomes available. For more information on the current Landsat 7 SLC-off product options, detailed information on gap-filled processing, and to download sample products, please visit the Landsat Project website: http://landsat.usgs.gov/slc_off.html

Landsat 7 Gyro Issue

Landsat 7 de-powered one of its gyros on May 5th, 2004, due to anomalous indications of the gyro's behavior. The spacecraft has three two-degree-of-freedom gyros and needs two at any time to maintain attitude control. To mitigate the risks associated with any future gyro failures and to provide options that allow for the longest possible mission-life (reducing the risk of potential data gaps), a team from USGS, NASA, Honeywell, Hammers, and Lockheed Martin was assembled to perform a feasibility study for Landsat 7 operating in what is being termed Virtual Gyro (V-Gyro) mode. In this mode, after the future failure of another gyro, the attitude control system would use the remaining gyro, along with existing onboard instrumentation and new control logic, to maintain attitude control. The team also examined the different levels of attitude knowledge required for various satellite operations modes, namely, ETM+ imaging operations, orbit maneuvers, and Safehold. Of the three, ETM+ imaging operations has the most rigorous requirements for attitude knowledge precision. The team determined that V-Gyro mode can satisfy the attitude control requirements of not only orbit maneuvers and Safehold operations, but also for the more demanding ETM+ imaging mode. There are no indications of any problems with Landsat 7's remaining gyros and therefore the risk of an additional gyro failure is deemed low. The Landsat team continues to work toward the implementation of a V-Gyro, first testing it in the performance of Orbit Maneuvers and the Safehold mode and then as Landsat 7's contingency gyro. Once these capabilities have been implemented, tests of the V-Gyro for the more complicated ETM+ operations mode will be developed, and V-Gyro capability will be inserted into the satellite's control system should future need arise.

LGSOWG Meeting #33

The Landsat Ground Station Operator's Working Group (LGSOWG) meeting #33 was held in Changmai, Thailand the week of November 1-5. The meeting was hosted by the Geo-Informatics and Space Development Agency of Thailand (GISTDA). Representatives were present from 11 organizations representing 9 different USGS Landsat International Cooperators. Discussions covered a range of topics, including: Mission Status of Landsat 5 and Landsat 7, detailed information on the Landsat 7 SLC-off new product lines, with emphasis on the release of the SLC-off to SLC-off gap filled products, information on the status of future Landsat Missions (Landsat Data Continuity), and one-on-one sessions with each International Cooperator (IC) on issues specific to their operation. The next opportunity for International Cooperators and Landsat project personnel to interact will be at the Landsat Technical Working Group (LTWG) meeting #14 to be held in Washington, D.C. USA in the late April /Early May 2005 timeframe. Exact dates should be available in the next newsletter.