Landsat Science Team Meeting Summary

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Meeting Overview

The Landsat Science Team sponsored by the U.S. Geological Survey (USGS) and NASA met June 12-14, 2007, at Oregon State University in Corvallis, OR. **Warren Cohen** [U.S. Forest Service (USFS)] hosted the meeting. The goal of the meeting was to discuss the scientific and engineering issues associated with ensuring the success of the Landsat Data Continuity Mission (LDCM). The specific meeting objectives offered by **Tom Loveland** [USGS—*Landsat Project Scientist, USGS*] and **Jim Irons** [NASA Goddard Space Flight Center (GSFC)—*LDCM Project Scientist, NASA*] were to:

- Review the status reports of key Landsat 1-7 and LDCM topics.
- Review and receive Landsat Science Team input on LDCM requirements with particular emphasis on the ground system.
- Discuss issues identified during the January 2007 Landsat Science Team meeting.

The meeting agenda and presentations are available at *ldcm.usgs.gov/june2007MeetingAgenda.php*.

Summary of Status Reports

Bill Ochs [NASA GSFC—*LDCM Project Manager, NASA*] and **Mike Headley** [USGS—*LDCM Project Manager, USGS*] provided reports on the status of LDCM planning and implementation. The NASA and USGS team is working toward a launch readiness date of July 2011.

Ochs provided an update on the status of the procurement of launch and space segment elements. The evaluation of proposals for the Operational Land Imager (OLI)—the next generation sensor—is in the final stage and an award is expected by mid-July, 2007[1]. Ochs stated that the spacecraft accommodation study is underway with an award expected in late-2007. He also said that the launch vehicle Request for Proposals had been released and an award was planned for late this summer. Regarding the mission operations element, a statement of work has been released for industry comment and current plans are for award of contracts by mid-2008.

An outcome of the January 2007 Landsat Science Team meeting was a strong statement of support for adding a stand-alone thermal imaging capability to the LDCM. Ochs said that the team's letter has generated more discussion on the importance of this capability and support is gaining momentum. However, no firm commitments have been made.

Headley summarized three topics associated with USGS ground system planning and implementation: (1) USGS acquisition strategy and procurement status; (2) ground system concept review results; and (3) ground system requirements review plans. The ground system includes the flight operations and data processing and archive segments, as well as interfaces to the International Cooperators Network (i.e., Landsat ground stations) and the Landsat user community. Requests for proposals for key elements, including the ground network, flight operation team, mission operations center, and archive and user portal elements will be released throughout 2008. The collection planning (i.e., long-term acquisition plan), image processing and infrastructure elements will be developed by USGS Earth Resources Observation Systems (EROS) technical services support contractors. Details on the USGS ground systems acquisition strategy are available at— *ldcm.usgs.gov/acquisitionStrategy.php.*

Headley also reported that the ground system concept review was held in February 2007 and provided a means to gauge progress toward the upcoming ground system requirements review. The result of the concept review was the identification of issues needing further policy or scientific, technical, or engineering clarification. Key issues included LDCM standard product definition and access strategies, acquisition strategies, support of the International Cooperators Network, and backup archive concepts. The resolution of the issues is an important preparation step for the September 2007 ground system requirements review. The requirements review will assess the readiness to begin the ground system design and will address the maturity and completeness of segment level and overall ground system requirements.

Rachel Kurtz [USGS—*Acting Landsat Acquisitions Manager*] provided an update on activities associated with Landsats 5 and 7 and the Landsat archive. Landsat 5 and 7 are functioning although both have experienced periodic problems. Landsat 7 data are being acquired routinely for the global land surface but the data are affected by the 2003 scan-line corrector (SLC) failure that results in data gaps in each scene. Landsat 5 acquisitions continue over areas of the globe where

[1]On July 16, 2007, NASA announced that Ball Aerospace and Technologies Corp. of Boulder, CO was selected to develop the OLI.

direct broadcast of acquisitions to ground stations are possible. As a 24-year-old mission, there are a number of technical problems that periodically disrupt Landsat 5 operations but team engineers have been very successful in correcting or managing problems associated with power supply, transmitters, and star trackers. Engineering studies indicate that both satellites have sufficient fuel to continue operations into 2011.

Kurtz reported that there are now more than two million Landsat scenes spanning 1972–2007 in the USGS archive. The USGS is developing plans to make all Landsat data more accessible. As a first step, all Landsat 7 data from 2003–present (i.e., SLC-off era) over the United States are being made available via the web at no cost to users. The data are terrain corrected and are in a Universal Transverse Mercator (UTM) projection. Results from the pilot phase of this initiative will be used to determine the next steps in expanding web access to additional Landsat data.

Jeff Masek [NASA GSFC—*Deputy LDCM Project Scientist*] gave an update on the NASA-USGS Mid-Decadal Global Land Survey (MDGLS) initiative. The MDGLS is a continuation of the Landsat *GeoCover* orthorectified global data set (1975, 1990, and 2000 epochs) and will add global Landsat and other moderate resolution data from 2004–2007 to the *GeoCover* archive. This effort is in support of Climate Change Science Program requirements, will support global assessments of landscape dynamics, and will serve as a pilot project for routine global monitoring in the LDCM era. The first phase of the MDGLS is the acquisition of Landsat 5 and 7, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and Earth Observing-1 (EO-1) imagery. This effort is progressing and the USGS is initiating the second phase, data processing. All acquisitions will be processed to *GeoCover* standards—i.e., orthorectified, terrain corrections, 28.5-m resolution, and Universal Transverse Mercator (UTM) projection. Orthorectified data sets will start becoming available in 2008. NASA planning is underway to advance the third phase of the activity, which involves the development of global land cover change products.

Ray Byrnes [USGS—*Liaison for Satellite Missions*] gave an update on the progress of the Landsat Data Gap Study Team. The team's objective is to identify, assess, and recommend alternative data sources that can best provide recurring global land observations, sufficiently consistent in terms of acquisition extent, frequency, and quality, as that of the Landsat Program. Based on recent investigations, the team concludes that:

- The Landsat Program is unique and serves as the most consistent single source of systematic, global land observations but that alternate sources can reduce the impact of a Landsat data gap.
- Data quality of potential candidate systems is unverified; however, based on preliminary analysis, India's ResourceSat and China/Brazil's Earth Resources Satellite (CBERS) are the leading candidates for reducing the impact of a Landsat data gap.
- There are technical challenges associated with receiving and archiving data from new source(s), data characterization and cross-calibration, and differentiating land cover change from multiple disparate sources.

The Landsat Data Gap Study Team is now developing plans for filling the data gap should Landsat 5 and 7 fail prior to the launch of LDCM.

Ray Byrnes and **Ed Grigsby** [NASA Headquarters—*Landsat Program Executive*] updated the team on the status of the Office of Science and Technology Policy, Executive Office of the President study on *The Future of Land Imaging*. The study is complete and publication of findings is pending[2]. The report calls for the establishment of a National Land Imaging Program (NLIP), led by the Department of the Interior, and endorses a strong U.S. role in moderate resolution Earth imaging.

Ron Beck [USGS—*Program Information Specialist*] and **Anita Davis** and **Laura Rocchio** [both at NASA GSFC—*Education and Public Outreach*] provided overviews of their respective Landsat-related outreach activities. Beck emphasized USGS efforts to provide science support to the public policy process. Davis and Rocchio presented activities associated with formal and informal education, news stories, and partnerships. NASA and the USGS, with National Science Foundation support, are involved in the Integrated Geospatial Education and Technology Training (iGETT) program that is geared toward faculty at two-year colleges.

Following the programmatic status reports, the 18 Landsat Science Team members provided brief summaries of their research activities that are related to LDCM.

Rick Allen [University of Idaho] summarized research on his development of operational evapotranspiration (ET) algorithms. Specific elements of this research include the development of a model for calculating surface energy balance for ET mapping (METRIC) at Landsat scale resolution, the interoperability of Landsat data and ET with other satellite system data and resolutions, and the use of ET to calibrate reflectance-based procedures.

[2] This report was released on August 14, 2007.

Sam Goward [University of Maryland, College Park (UMCP)] provided an update on his work to improve the Long-Term Acquisition Plan (LTAP) that governs the global collection of Landsat data. He concluded that LTAP-7 used for Landsat 7 acquisitions has provided good global coverage on a quarterly basis but that there now needs to be improvements covering key areas such as the boreal and tropical regions.

John Schott [Rochester Institute of Technology] is investigating the potential for using LDCM for Great Lakes water resources assessment. Preliminary results show that the OLI blue band will be useful in the retrieval of suspended materials, and that the addition of 12-bit quantization offers significant advances associated with water constituent retrieval.

Jennifer Dungan on behalf of **Rama Nemani** [Both with the NASA Ames Research Center] presented research focused on developing an operational capability to produce vegetation green leaf area index (LAI) from Landsat data by adapting a physically based approach conceived and implemented by the Moderate Resolution Imaging Spectroradiometer (MODIS) Science Team. Dungan's discussion addressed the importance of understanding measurement errors and uncertainties.

Prasad Thenkabail [International Water Management Institute] reviewed the status of the Global Irrigated Area Map, an initiative to map irrigated lands across the globe. A 10-km resolution global map of irrigated lands was produced using Advanced Very High Resolution Radiometer (AVHRR) and MODIS data, and research is underway to develop a global 30-m map using Landsat data.

Charlie Walthall on behalf of **Martha Anderson** [Both with the U.S. Department of Agriculture Agricultural Research Service] reported on research for mapping drought and evapotranspiration using Landsat and Geostationary Operational Environmental Satellite (GOES) thermal imagery. They are developing a multi-satellite drought product that ranges between 30-m and 10-km resolution and also developing techniques to sharpen thermal band imagery to shortwave band resolutions.

Lazaros Oraiopoulos [University of Maryland Baltimore County] summarized his research on cloud detection and avoidance. The work is assessing MODIS cloud climatology as an input to the LTAP, transferring the lessons learned from MODIS cloud detection research to LDCM, and evaluating automatic cloud cover assessment algorithms.

Jim Vogelmann [Science Applications International Corporation (SAIC)/USGS Earth Resources Observation System (EROS)] is studying strategies for monitoring forest and rangeland change using Landsat and alternative sources of satellite data. The research is evaluating *at-sensor* reflectance data as a function of seasonality for assessing landscape-level trends between 1988 and 2006.

Eilieen Helmer [U.S. Forest Service (USFS)] is investigating tropical forest monitoring using cloud-free image mosaics. In her research, Helmer is filling cloud gaps with models that normalize inter-date differences with mutually clear pixels. She has found that regression tree normalization more closely matches inter-date image differences than results using other approaches.

Mike Wulder [Canadian Forest Service] is engaged in research geared toward conversion of Landsat imagery into resource management information. In his investigations, he is conducting cross-sensor change detection, comparing Landsat 7 SLC-on / SLC-off data for change detection, monitoring insect disturbance and recovery, grizzly bear habitat monitoring and modeling, and generation of national fragmentation products.

Feng Gao [Earth Resources Technology, Inc.] is developing a consistent Landsat data set from Multispectral Scanner (MSS), Thematic Mapper/ Enhanced Thematic Mapper Plus (TM/ETM+), and international data sources for land cover change detection. This involves processing moderate resolution data sources into a consistent orthorectified surface reflectance data set, testing consistent surface reflectance data set for land-cover change detection, simulating Landsat surface reflectance using MODIS and Landsat data, and evaluating the potential for using data for filling a possible Landsat data gap.

Dennis Helder [South Dakota State University] is developing a strategy for a systematic radiometric calibration approach for LDCM and the Landsat archive. His approach involves: (1) consistent calibration of the Landsat archive through use of pseudo-invariant sites; (2) techniques for relative gain calibration/correction of large linear arrays; and (3) vicarious calibration of LDCM and Landsat TM/ ETM+ instruments.

Eric Vermote [UMCP] is conducting research that leads to a surface reflectance standard product from LDCM and supporting data. The strategy calls for the development of an operational, globally applicable, sharable, and fully automated approach for integration into the LDCM processing chain.

Randolph Wynne [Virginia Polytechnic Institute and State University] presented a status report on his research on the use of Landsat data for forest

science and management, with particular focus on the southeast United States and forest industry. Wynne is developing approaches for mapping areas of rapid forest change, assessing forest carbon management, rating southern pine beetle hazards, and monitoring reforestation of abandoned mine lands.

Curtis Woodcock [Boston University—*Landsat Science Team Leader*] reported on his research to understand SLC-off *gap filled* data. Woodcock is documenting the magnitude of errors (i.e., differences between observed and synthetic values) and is using *variograms* to estimate the magnitude of errors. He also updated the team on planning to expand land cover mapping and land-change assessments to the globe.

As the meeting host, **Warren Cohen** [USFS] and his Oregon State University and USFS colleagues organized a comprehensive summary of their remote sensing research activities. Topics included carbon balance assessments, national parks monitoring, land cover dynamics including forest disturbance and regrowth, sampling strategies, and validation.

Technical Issues Discussions

The USGS, NASA, and Landsat Science Team members assessed a series of requirements concepts issues associated with ground systems plans. There are several important issues that must be resolved in advance of the upcoming ground systems requirements review.

Doug Daniels [Aerospace Corp.] and **Jim Nelson** [SAIC/USGS] provided an overview of efforts by the USGS to resolve ground system requirements design issues that were raised during the winter 2007 ground system concept review. The issues discussed were:

Data acquisition scheduling—The USGS plans to support up to five priority and off-nadir acquisition requests per day. While these types of requests are important, it is also important that the long-term global acquisition plan be maintained in order to consistently extend the global Landsat record. The USGS agreed to develop a *white paper* on recommended acquisition priorities for review by the Landsat Science Team and the USGS and NASA mission operations groups.

Bulk data access and distribution—This issue deals with the provision of very large amounts of Landsat images (more than 400 per transaction) to high volume data users. There are no clear precedents for estimating the impact on planned electronic delivery systems. The USGS LDCM team proposes that at launch, a manual capability be used to address bulk data access on a case-by-case basis, and that more robust capabilities be established as experience is gained in the post-launch era.

Data products—The USGS plans to produce a single standard LDCM Level 1T (L1T) product that is precision and terrain corrected with top-of-atmosphere correction. The products will be made available via the web at no cost to users. The Landsat Science Team will contribute to the identification of possible higher level products including surface reflectance transformations, cloud-reduced composites, and multi-temporal data cubes.

Applying the USGS cost of fulfilling user requests (COFUR) policy—The current COFUR policy states that data must be provided at no more than cost of fulfilling user requests. Plans to distribute a single LDCM standard product at no cost are consistent with the current guidelines.

User registration—In order to understand the demographics and requirements of LDCM users, the USGS will require users accessing web-enabled products to provide basic demographic and applications information. The USGS plans to keep the registration process simple in order to reduce impacts on users.

Calibration and validation—LDCM data will be routinely evaluated in order to maintain and report image quality data to users. Current USGS plans call for: (1) cross calibration to Landsat 7 ETM+ data; (2) characterization of the on-orbit radiometric, spatial, and geometric performance of the LDCM sensors and data; (3) assessment of image data quality throughout mission life; and (4) derivation and application of calibration throughout mission life. In addition, the USGS will develop a strategy to reprocess data as appropriate.

International Cooperators Network roles and participation—Historically, a network of international ground stations have directly received Landsat data over their areas of interest. For LDCM, the USGS recommends a hybrid strategy that retains the current network model, provides direct downlink as the primary data delivery mechanism, and includes internet and a high capacity media delivery option that delivers archive and L1T data from the U.S. archive holdings.

Data processing and archive continuity of operations—The issues involve the form of the backup archive and the length of time that should be planned to rebuild processing and archive systems in the event of the loss of system capabilities. Plans are to establish a low-cost off-site tape archive for data and critical system software, documentation, and calibration/validation parameters. In addition, capabilities to rebuild the ingest and archive functions within 90 days is needed.

Latency and availability—This governs the length of time users must wait for data. Plans are that U.S.

priority acquisitions be available for distribution within six hours of acquisition and global priority scenes will be available within 12 hours of observation. All other scenes will be available for search and order within 24 hours of observation.

John Dwyer [SAIC/USGS] added a detailed discussion of LDCM standard product plans. The planned L1T standard product uses a single fixed recipe that was developed based on discussions and recommendations with data users and a review of historical image ordering preferences. The planned specifications are:

Parameter	Specification
Pixel Size	14.25m pan, 28.5m VNIR
Media Type	Download (no cost) – no plans for other media
Product Type	L1Gt or L1T (decision pending assessment of ground control point needs)
Output Format	GeoTIFF
Map Projection	Universal Transverse Mercator
Datum	WGS84
Orientation	North up
Resampling	Cubic convolution
Geometric Accuracy	~12m circular error (90%) global

The products will continue to be based on the World Reference System-2 scene structure. The relief displacement will be based on the best available digital elevation models (DEM).

Dwyer also led a short discussion about the potential for generating user-specified products from LDCM and other Landsat data. Currently, the USGS does not plan to produce additional products but offered to consider recommendations from the Landsat Science Team.

Landsat Science Team Working Group Recommendations

The final day of the meeting was devoted to working group discussions. At the end of the meeting, each working group presented recommendations to NASA and the USGS. The working groups and conclusions each offered include:

Instrument Engineering

The image engineering working group led by **Dennis Helder** and **John Schott** addressed issues associated with LDCM calibration/validation, development reviews, and the status of the thermal instrument.

Specific recommendations from this group include:

- Yaw maneuver capabilities should be a calibration requirement for the instrument and spacecraft and should be factored into the LTAP.
- Access to flight hardware (i.e., engineering samples of key system components) and initial burn-in data on detectors and/or filters should be considered.
- Landsat Science Team engineering representatives should participate in critical instrument reviews.
- Calibration continuity for the entire Landsat archive is needed. This strategy should involve the use of pseudo-invariant (i.e., desert) sites.
- While the status of the thermal instrument on LDCM is still unknown, early consideration of instrument registration issues should be addressed.

Data Products

This working group led by **Warren Cohen** is dealing with the types and characteristics of Landsat data products in the LDCM era. Recommendations from this working group include:

- The L1T standard product should include top-of-atmosphere (TOA) reflectance processing. Provision of ancillary information and tools that permit users to convert TOA reflectance to surface reflectance should be considered.
- There should be more consideration for providing Level 0 or similar products.
- The LDCM standard product should include a public domain DEM. However, the terrain correction process should use the best available DEM.
- Spatially explicit, pixel-level quality assurance information, should be provided.
- There should be more consideration of the potential for creating user-specified data products.
- The processing used to generate LDCM standard products should be applied to all archived Landsat data. This is critical for enabling an in-depth understanding of global land surface changes.

Mission Operations

This working group led by **Sam Goward** is focusing on issues associated with ensuring the collection of global coverage that meets the mission's science objectives. Goward provided a summary of the key capabilities and needs of the LTAP and presented the following working group recommendations:

- Analysis of the potential impacts of the LDCM off-nadir imaging capabilities on the LTAP is

needed. A plan for referencing off-nadir non-World Reference System-2 scenes in the Landsat metadata archive must be developed.
- Improving the seasonality of global acquisitions is important. This should include incorporation of the location of irrigated areas in deserts and use of continuous variable normalized difference vegetation index inputs.
- Cloud screening without thermal infrared data will be problematic. Additional investigation of cirrus-clearing strategies is needed.

Future Missions, Outreach, and Advocacy

This working group met informally to discuss long-term opportunities and Landsat Science Team outreach and advocacy functions. Opportunities identified include opening access to the Landsat archives and the role of science associated with NLIP implementation.

Final Recommendations and Next Steps

The Landsat Science Team reviewed the working group reports and concluded that the primary outcomes of the meeting were the validation of the recommendations associated with the ground system requirements, and the identification of new opportunities for expanding access to Landsat data. Given the encouraging movement toward the formation of a new National Land Imaging Program, the Landsat Science Team outlined a broad goal and two objectives that should be considered by the leadership of the National Land Imaging Program. The team recommended that **b*y the launch of the LDCM in mid-2011, all the existing imagery collected by prior Landsats be consolidated in the U.S. archive and made equally accessible as LDCM imagery.*** The Team identified two steps needed to achieve this goal.

The first step is to consolidate past images collected by Landsat satellites in the U.S. archive at the USGS EROS. Only approximately half the images collected by Landsat satellites to date are safely archived in the U.S. The other images are in archives managed by foreign receiving stations. These holdings are not necessarily in secure archives and it is likely that there are holdings in danger of being irrevocably lost. The best solution to this problem is to bring copies of these foreign holdings into the USGS archive.

The second step is to make the existing Landsat images as accessible as the LDCM images. The recent history of the Landsat Program has shown that improved access to Landsat imagery enhances its value to society. The explosion in the use of Landsat data after the *GeoCover* datasets were made freely available has demonstrated that free access to the imagery leads to creative and productive new uses. To maximize benefit from the LDCM, it is necessary for the existing images within the U.S. archive to be equally accessible as the LDCM images and in formats compatible for use with LDCM images.

The Landsat Science Team sent a letter to the Department of the Interior, USGS, and NASA leadership regarding these recommendations.

Because of the importance of Landsat archive issues to the overall success of LDCM, the team concluded that the winter Landsat Science Team meeting should concentrate on the goal and objectives concluded during the Corvallis meeting. In order to have access to the full range of USGS Landsat archive expertise, the next meeting is tentatively set for January 8-10, 2008, at USGS EROS near Sioux Falls, SD. ■

NSIDC Media Advisory: Fall 2007 Arctic Sea Ice News Launched

The National Snow and Ice Data Center has launched our second annual news and commentary Web site as we follow the Arctic sea ice melt season. From August 10, 2007, through the end of the summer melt season, we will post updates as events warrant. To find out the latest sea ice conditions and to read press information, visit the site at *nsidc.org/news/press/2007_seaiceminimum/20070810_index.html.*

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