Landsat Science Team: 2016 Summer Meeting Summary


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Introduction

The summer meeting of the joint U.S. Geological Survey (USGS)-NASA Landsat Science Team (LST) was held July 26-28, 2016, at South Dakota State University (SDSU) in Brookings, SD. LST co-chair **Tom Loveland** [USGS's Earth Resources Observation and Science Center (EROS)] and **Kevin Kephart** [SDSU] welcomed more than 80 participants to the three-day meeting. That attendance at such meetings continues to increase—likely due to the development of new data products and sensor systems—further highlights the growing interest in the Landsat program. The main objectives of this meeting were to provide a status update on Landsat 7 and 8, review team member research activities, and to begin identifying priorities for future Landsat missions. Meeting presentations are available at *http://landsat.usgs.gov/landsat-science-team-meeting-july-26-28-2016.php*.

Landsat 7 and 8 Status Update

Brian Sauer [USGS EROS—*Landsat Sustaining Engineering Project Manager*] offered an update on the mission status of Landsat 7 and 8. Sauer reported that Landsat 7's duty cycle has been raised to 105%, resulting in ~15 more scene acquisitions per day. On average, Landsat 7 is now acquiring around 470 scenes per day. The USGS is committed to continuity by extending Landsat 7's operational life until the launch of Landsat 9 late in 2020. Once retired, plans are being prepared to use Landsat 7 to test satellite-refueling technology via the NASA Restore-L mission.[1]

The in-orbit performance of Landsat 8 continues to be outstanding, currently acquiring around 740 scenes per day, and several Antarctic and Arctic off-nadir requests have recently been fulfilled with no impact on routine imaging. Operational and data processing solutions have been implemented to mitigate the impact of the anomaly in Landsat 8's Thermal Infrared Sensor (TIRS) scene select mirror (SSM)—see *Landsat 8 TIRS Stray Light Correction* on page 46 to learn more. All affected data have been reprocessed and nominal TIRS data collection and processing have been restored.

Landsat Global Archive Consolidation

Sauer also provided a brief update on the Landsat Global Archive Consolidation (LGAC) effort to repatriate data from international ground stations. He noted the that European Space Agency (ESA) is in the process of delivering to the USGS nearly two million scenes acquired between 1987 and 1999. Around 500,000 of these scenes contain no Payload Correction

[1] Scheduled for launch in 2020, the Restore-L mission uses a robotic spacecraft equipped with the tools, technologies, and techniques needed to extend satellites' lifespans—even if they were not designed to be serviced in orbit. To learn more please visit *https://sspd.gsfc.nasa.gov/restore-L.html*.

The Landsat Science Team.

Data (PCD),[2] so additional development is needed to improve image geometry. Data from Argentina are currently being added to the Landsat archive, with digital ingest expected to be completed by mid-2017.

New Landsat Products and Collections

Sauer also provided an update on the status of the new tiered collection management system being implemented at EROS. Although Landsat data will soon be organized using a three-tiered system (i.e., Near-Real Time, Tier 1, and Tier 2), it is important to note that all data, regardless of geometric or radiometric quality, will still be available to all users. Starting with Collection 1, Landsat 4-5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS) scenes will be assigned to a specific tier. Several changes are being implemented to Landsat Level-1 data products to support this effort, including new Landsat Product Identifiers (a file naming convention), "Collection" and "Tier" designations, metadata changes, and the addition of new supporting files including a Quality Assurance (QA) band, Top of Atmosphere (TOA) angle coefficients, land-based cloud cover scores, and new life-long gain adjustments for TM sensors. TM and ETM+ data for the U.S. are being processed first, from newest to oldest, followed by U.S. OLI/TIRS data, and finally, the rest of the global archived data will be processed. Landsat Multispectral Scanner (MSS) data will be considered after processing for Landsat 7 and 8 are completed. At present, the goal is to finish processing Collection 1 by the end of May 2017. For more information on Landsat Collections, visit *http://landsat.usgs.gov/landsatcollections.php#collection*.

Landsat MSS Improvement Plan

Ron Morfitt [USGS EROS—*Landsat 8 Calibration and Validation Lead*] discussed efforts to improve the Landsat MSS archive, including MSS reflectance-based calibration, adjustment of minimum and maximum radiance values to minimize saturation, updating of gain-trend models, and derivation of a bulk correction factor to minimize attitude bias. Overall, the processing and model updates being implemented will help increase the number—as well as the geometric and radiometric quality—of MSS Level-1T scenes. Currently, the plan is to begin collection-processing for MSS in the summer of 2017.

Landsat 8 TIRS Reprocessing Status

Ron Morfitt also described how image measurements from geometric calibration are being used to correct the SSM issue, which caused TIRS images to be shifted out of alignment with OLI by as much as 500 m (~1640 ft). Overall, the new TIRS processing model is working well, with registration accuracy of around 20 m (~66 ft) when telemetry and calibration data are available.

Landsat 8 TIRS Stray Light Correction

Matt Montanaro and **Aaron Gerace** [both from Rochester Institute of Technology] provided an update on the stray-light correction algorithm being developed for TIRS on Landsat 8. Montanaro explained how stray light entering the optical path from outside the direct field-of-view is causing significant nonuniform banding in TIRS bands 10 and 11. The approach to correct this issue uses TIRS data to estimate the out-of-view signal, based on in-scene statistics. Initial validation results based on comparison with underpass data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra are encouraging. Although more testing is planned over land and low-temperature regions of Antarctica, the LST recommended moving toward operational implementation of the developed stray-light correction algorithm. The current plan is to implement the algorithm during Collection 1 reprocessing, which is slated to begin in the fall of 2016.

Landsat 9 Development Status

Del Jenstrom [NASA's Goddard Space Flight Center (GSFC)—*Landsat 9 Project Manager*] and **Jim Nelson** [USGS—*Landsat 9 Project Manager*] provided an update on the status of Landsat 9, which will be a full Class-B rebuild of Landsat 8. This approach minimizes risk and reduces reviews, which saves both time and money. TIRS2 is being upgraded to a Class B instrument, with additional steps being taken to fix the stray-light issue affecting the Landsat 8 TIRS instrument. As for previous missions, NASA is responsible for the space segment, including instrumentation and launch, and on-orbit checkout, while USGS will develop and manage the ground systems, including data collection, processing, archiving, and distribution. Level-1 science requirements have already been approved by both agencies, and everything is currently on track for a late-2020 launch date. Jenstrom noted that key lessons from the Landsat Data Continuity Mission (LDCM, now called Landsat 8) are being implemented at all project levels.

Landsat 10 Requirements and Capabilities Discussion

The LST initiated discussions that will lead to recommendations for capabilities for future Landsat missions. **Curtis Woodcock** [Boston University—*LST Co-Lead*] led a review and validation of the 2014 LST Landsat continuity statement.[3] The LST members confirmed that continuity was the primary driver of future missions. **Greg Snyder** [USGS Headquarters] reviewed

[2] Payload correction data contain attitude and ephemeris information needed to calculate (i.e., correct) the location of the pixels on the ground. Since the spacecraft moves and rotates somewhat rapidly, these data are needed at a high rate (once per second or more) to position the pixels within the 12 m (~39 ft) geolocation specification.

[3] To read the statement, visit *http://landsat.usgs.gov/documents/LST_Landsat_Continuity_Requirements.pdf*.

USGS's efforts to collect detailed user requirements related to future Landsat mission requirements. **Jeff Masek** [GSFC—*Landsat 9 Project Scientist*] reviewed the status of several technology investigations focused on reducing instrument size and weight. Masek also shared information and updates regarding a 2015 NASA Earth Science Technology Office solicitation for advanced technology demonstrations and long-term technology investment concepts. Awards for the 2015 Research Opportunities in Space and Earth Sciences (ROSES) solicitation were announced in August 2016.[4] **David Roy** [SDSU—*LST Co-Lead*] summarized LST member suggestions on new capabilities needed for Landsat 10 and beyond. Afterward, LST members discussed requirements and capabilities and defined five areas for more detailed study: continuity and backward compatibility with previous Landsat sensors, temporal frequency improvements, spatial and geometric improvements, radiometry resolution and signal-to-noise improvements, and new spectral measurements. Study teams will provide preliminary recommendations at the next LST meeting—see **Conclusion** for details.

[4] To view the announcements, visit *https://esto.nasa.gov/files/solicitations/SLIT_16/ROSES2015_SLIT_A47_awards.html*.

Landsat Science Team Member Presentations

The **Table** below summarizes the presentations given by members of the LST during the meeting. Please refer to the URL in the **Introduction** for more details on each presentation.

Table. Highlights from LST member presentations.

Presenter(s)	Affiliation	Highlights
John Kerekes	Rochester Institute of Technology (RIT)	Provided an overview of a test version of the Digital Imaging and Remote Sensing Generation (DIRSIG) model, a physics-based, scene-simulation tool for studying future Landsat systems.
Nima Pahlevan	NASA's Goddard Space Flight Center (GSFC)	Discussed the use of Landsat 8 and Sentinel 2A in aquatic science applications.
Anthony Vodacek	RIT	Showed how Landsat 8 is being used to monitor cyanobacteria in the U.S. Great Lakes region.
Yongwei Sheng	University of California Los Angeles	Described the use of Landsat 8 for mapping global lake presence and lake-level elevation.
Ted Scambos	University of Colorado	Discussed how more acquisitions and improved radiometric fidelity of Landsat 8 are helping to map ice flow speeds, surface roughness, and surface temperatures in Greenland and Antarctica.
Rick Allen	University of Idaho	Described the challenges and impacts of using Visible Infrared Imaging Radiometer Suite (VIIRS) and Moderate Resolution Imaging Spectroradiometer (MODIS) data to fill in gaps in Landsat evapotranspiration products.
Alan Belward	European Commission Joint Research Centre	Discussed the importance of the Landsat Global Archive Consolidation (LGAC) effort for producing next generation terrestrial essential climate variables.
Jim Vogelmann	USGS EROS	Showed how models fit to all available Landsat data are being used to assess changes in vegetation health.
Leo Lymburner, Adam Lewis	Geoscience Australia	Described Geoscience Australia's efforts to improve atmospheric correction, data integration with other sensors, and time series analysis including interpolation, modeling, and future projection of data.
David Roy	South Dakota State University (SDSU)	Presented a generalized, empirical line method for correcting bidirectional reflectance distribution function (BRDF) effects in Landsat images.
Crystal Schaaf	University of Massachusetts, Boston	Discussed production of a North American surface albedo product from Landsat data. Described ongoing validation of initial albedo maps of the Continental U.S.

Table. Highlights from LST member presentations. (cont)

Presenter(s)	Affiliation	Highlights
Joel McCorkel	GSFC	Presented an overview of the new modeling techniques and lasers being used to improve the sensor model for Landsat 9.
Eric Vermote	GSFC	Discussed the current status and performance of the Landsat 8 and Sentinel 2 surface reflectance algorithms. Results and future directions will be discussed at an upcoming, Landsat/Sentinel 2 atmospheric correction workshop.
Dennis Helder	SDSU	Transferred Landsat 8 TOA alibration back in time to achieve a consistent, reflectance-based calibration of the whole Landsat archive. A summary of final gains and biases from Landsat 8 dating back to Landsat 1 is forthcoming.
Rick Lawrence	Montana State University	Presented an overview of research from the AmericaView group, including evaluation of Landsat 8 surface reflectance for modeling percent mortality from bark beetle outbreaks and mapping dissolved organic matter and chlorophyll concentrations in Minnesota.
Patrick Hostert	Humboldt University of Berlin	Discussed efforts to map forest dynamics in Southern Amazonia using Landsat time series. Focused on the use of temporal filters to develop coherent successional pathways and use of change metrics as classification inputs.
Txomin Hermosilla	Canadian Forest Service (CFS)	Described development of best pixel time series composites for mapping forest disturbance year, agent, and recovery times across Canada.
Mike Wulder	CFS	Showed how Landsat disturbance maps are being used to develop Canada-wide estimates of harvest and wildfire rates and recovery times. Also described a filtering approach to resolve successional transitions in annual land cover maps.
Joe Hughes (for Robert Kennedy)	Oregon State University	Discussed the challenges and opportunities of using Google Earth Engine to map land cover and cause of disturbance. Stressed the importance of quantifying uncertainty both spatially and numerically.
Randy Wynne	Virginia Polytechnic Institute and State University	Reviewed new algorithms and data fusion techniques to improve estimates of forest status and change. Demonstrated a Monte Carlo simulation approach to approximate prediction uncertainty for random forest regression models.
Warren Cohen	U.S. Department of Agriculture (USDA) Forest Service	Presented an approach for improving the radiometric and geometric quality of MSS and other Landsat Level-1G images for use in forest change applications.
Mark Friedl	Boston University	Discussed the use of Landsat data to study seasonal covariation in land surface climate and surface properties in the Boston metropolitan area. Described how the results suggest urban heat islands are one factor causing leaves to emerge earlier and senesce later in cities.
Curtis Woodcock	Boston University	Discussed the importance of using time series change metrics for classification and analysis. Showed how denser time series can lead to better quantification of subtle change events like gypsy moth outbreaks in the eastern U.S.
Feng Gao	USDA Agricultural Research Service	Presented an approach for mapping crop progress and yield at field scale with 30-m Landsat data.

Table. Highlights from LST member presentations. (cont)

Presenter(s)	Affiliation	Highlights
Martha Anderson, Yun Yange	USDA Agricultural Research Service (ARS)	Discussed the use of Landsat–MODIS data fusion techniques to improve daily evapotranspiration models.
Jim Hipple	USDA ARS	Presented an overview of the use of Landsat science products in the USDA ARS national agricultural data warehouse. Also discussed how Landsat data are being used to create mappable reports of crop loss.
Dave Johnson	USDA National Agricultural Statistics Service	Discussed the benefits of combining Sentinel 2A and Landsat data to estimate yields of winter wheat in Kansas.
Ayse Kilic	University of Nebraska	Showed how evapotranspiration time series can be used to estimate turf water conservation in California.

Landsat Advisory Team Update

Kass Green [*Kass Green & Associates*] summarized the activities of the Landsat Advisory Group (LAG), which is part of the Department of the Interior-sponsored National Geospatial Advisory Committee. The LAG is working to finalize a report summarizing feedback from non-federal Landsat users' requirements,[5] and make future recommendations on improving access and use of Sentinel-1 and -2 and data from other small-satellite sensors. Finally, at the request of USGS, the LAG is also updating their 2013 product improvement and cloud computing reports.

Landsat 8 Surface Reflectance Update

John Dwyer [USGS EROS—*Landsat Project Scientist*] provided an update on recent changes to the Landsat 8 surface reflectance algorithm, now referred to as Landsat Surface Reflectance Code (LaSRC) 3.0. Released on June 23, 2016, the updates include use of blue and red bands (instead of deep blue and red) for improved, ratio-based aerosol inversion performance. The previously reported issues of spatial blockiness,[6] particularly around offshore coastal regions, has been resolved by applying the aerosol interpolation at the 30-m pixel level (versus the coarser 0.05° Climate Modeling Grid (CMG) level), and by dropping the land/water mask. Future plans involve conducting a more thorough comparison of Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) and Landsat Surface Reflectance Code (LaSRC) reflectance retrievals, so that compatibility and differences can be documented and shared with users. Dwyer stressed the importance of this information, as users need to know more about how surface reflectance products from different Landsat sensors relate to one another.

[5] Increasing Landsat's temporal acquisition frequency is by far the most requested improvement cited by non-federal users.
[6] Spatial blockiness refers to multi-pixel checker-board patterns resulting from using coarse resolution inputs to atmospherically correct 30-m Landsat pixels.

USGS Land Change Monitoring, Assessment and Projection Update

Tom Loveland discussed the ongoing evolution of the USGS Land Change Monitoring, Assessment and Projection (LCMAP) project. Designed as a modernized, integrated approach to mapping, monitoring, and synthesizing land-use and land-cover change information, LCMAP will use Landsat Analysis Ready Data (ARD) as the foundation to provide a capability to continuously map and monitor changes in land cover across the U.S. **Brian Sauer** provided an update on the status of ARD implementation. The goal is to prioritize the availability of stable and consistent TOA, surface reflectance, and brightness temperature products, thereby enabling users to directly interact with the highest-quality Landsat data with minimal need for preprocessing. ARD data will be generated using Collection 1 inputs, so that changes and updates have a clearly traceable provenance. The plan is to first process data for TM/ETM+/OLI over the U.S., then expand globally—including the addition of MSS data. **Zhe Zhu** [ASRC Federal InuTeq, a USGS contractor] gave an update on ongoing efforts to fine tune the Continuous Change Detection and Classification (CCDC) algorithm to produce annual land-cover and land-cover change maps operationally using Landsat ARD inputs.

South Dakota State University Remote Sensing Activities

Meeting co-hosts **David Roy** and **Dennis Helder** [SDSU—*LST member*] and their colleagues made several presentations showcasing a number of ongoing SDSU research projects that were of interest to the LST. The presentations covered a wide range of topics including: the use of Landsat time series to detect ecological thresholds in West African tropical forests, synergistic use of Landsat and MODIS data to characterize land-surface phenologies in Kyrgyzstan, development of Landsat 8 and Sentinel 2 burned-area products, detecting new pseudo-invariant calibration sites for vicarious calibration of Landsat and other optical sensors, use of Landsat time series to assess vulnerability and response of fragmented forests in the Amazon, and quantification of time series inconsistencies caused by satellite orbital drift.

Conclusion

The 2016 summer LST meeting focused on identifying a number of important priorities to improve several aspects of the Landsat program. LST members offered guidance and recommendations on developing new Landsat products, enhanced synergy with Sentinel-2, and improving the MSS data record. The wide range of science and applications talks given by the LST members highlighted the increased capacity and ambition that may be brought to analyses based upon free and open data, available in an analysis-ready form. The firm cross-governmental support of the Landsat program has empowered the science community while also engendering agency support through an expectation of future access to an uninterrupted and high-quality Earth-observation data stream. The repeated highlighting of the importance of continuity of Landsat measures came from all user communities present or represented at the meeting. With reference to continuity, following initial context setting, team discussions led to identifying key steps toward informing what will become Landsat 10. The discussions regarding Landsat 10 identified a need to determine opportunities to take advantage of new technologies, clearly stressing the importance of measurement continuity across sensors across the Landsat program.

The next LST meeting will be held January 10-12, 2017, at Boston University in Boston, MA. ■

Congratulations William T. Pecora Award Winners

The Earth Observer is pleased to recognize the entire **Tropical Rainfall Measuring Mission (TRMM) Team** and **Curtis Woodcock** [Boston University—*Landsat Science Team Lead*] for receiving the 2016 *William T. Pecora* Team Award and Individual Award, respectively.

For more than 17 years, the **TRMM Team** has conducted innovative precipitation science and has developed widely used applications that have greatly benefitted society. The mission was launched in late 1997 and ended in 2015, and was a joint endeavor between NASA and the Japan Aerospace Exploration Agency (JAXA). The TRMM team met and exceeded their original goal of advancing our understanding of the distribution of tropical rainfall and its relation to the global water and energy cycles. As of May 2016, more than 2700 publications have TRMM in their title according to Google Scholar, and there are more than 25,000 citations of these TRMM papers. By their outstanding efforts, the TRMM team has advanced precipitation science and paved the way for the next generation of precipitation observations.

Curtis Woodcock, a professor at Boston University, has dedicated his career to remote sensing education, research, and service. After joining Boston University in 1984, he co-founded the Center for Remote Sensing and served as chair of the Department of Geography for 13 years. Woodcock has led the Landsat Science Team for nearly 10 years. He has played a key role in opening and expanding the Landsat archive, and he has provided guidance for the USGS initiative to modernize Landsat-scale global land monitoring. His seminal work on scaling and geostatistics continues to influence the way we understand remotely sensed imagery, and his work on land-cover mapping "best practices" unified a scattered academic community. His research over more than 30 years has effectively changed our basic understanding of remote sensing science.

The *William T. Pecora Award* was established in 1974 to honor the memory of William T. Pecora, former Director of the U.S. Geological Survey (USGS) and Undersecretary of the Department of Interior (DoI). Pecora was a motivating force behind the establishment of a program for civil remote sensing of Earth from space. His early vision and support helped establish what we know today as the Landsat satellite program, which created a continuous record of Earth's land areas that has now spanned a period of more than 40 years.

The award is sponsored by DoI's USGS and NASA, and presented annually to individuals and/or groups that make outstanding contributions toward understanding Earth by means of remote sensing. This year's award was presented on September 21 at a special commemorative event, *A Vision to Observe Earth … 50th Anniversary*, held in Washington, DC.

To learn more about this award and this year's group and individual winners please visit *http://remotesensing.usgs.gov/pecora.php*.

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Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the calendars should contain location, person to contact, telephone number, and e-mail address. Newsletter content is due on the weekday closest to the 1st of the month preceding the publication—e.g., December 1 for the January–February issue; February 1 for March–April, and so on.

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