Requirements for a Landsat Data Continuity Mission

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Landsat Data Continuity Mission requirements rest on science, societal benefits, heritage, public law, Executive Office direction, and an eye to the future.

A Landsat Data Continuity Mission (LDCM) will advance the legacy of the Landsat program with the intent of serving science and society. The performance of the Landsat 7 satellite system, the predecessor to the LDMC, has set a standard with respect to rigorous calibration, an enlightened data policy, and global data collection. LDCM requirements advance this standard in accordance with public law, current technology, and Executive Office direction. The LDCM will provide a core capability that serves as a foundation for a global land observing system.

Introduction

The United States (and the rest of the world) require a Landsat Data Continuity Mission (LDCM) to succeed the Landsat-7 satellite system. Driven by population growth and developing technologies, the land surface of the Earth is changing at rates unprecedented in human history with profound societal consequences. The requirements for LDCM reflect basic needs to characterize land cover type, rates of change, and ecological health for Earth's land and coastal areas. In part these are articulated in the Strategic Plan for the U.S. Climate Change Science Program (CCSP), which calls for continued collection of global moderate- and high-resolution satellite data, and quantification of rates of global land-cover change to support research into climate change (U.S. Climate Change Science Program, 2003). In addition to scientific research, the Landsat program serves a large community within Government and private industry, including natural resource monitoring, agribusiness, forestry, and military planning. Each of these communities brings its own set of priorities to the mission.

Background

The current Landsat program is unique in its capacity to provide medium resolution intra-annual and inter-annual observations of the global land surface from space. No other satellite system is operated to collect even annual global coverage at this scale. No other nation maintains a multi-decadal record of land observations in an archive providing non-discriminatory data access to the general public. This capacity is now diminished by the Landsat-7 Enhanced Thematic Mapper Plus (ETM+) scan line corrector failure and by ageing subsystems aboard the Landsat-5 satellite. The LDCM is needed to renew the capacity for global land observations.

Landsat 7 Legacy

The Landsat-7 satellite system has set high standards for its successor mission. Responsibility for the Landsat program transferred from a commercial entity back to the United States Government with the development and launch of Landsat 7. In that transition the government embraced several new practices to more fully serve the public. These new practices include:

- Rigorous on-orbit calibration and performance monitoring of the ETM+ (Markham *et al.*, 2004). The inclusion of an Image Assessment System within the Landsat-7 ground system enables this practice and makes calibration and characterization a routine part of mission operations for the first time. The ETM+ is the best calibrated sensor of the Landsat series, resulting in the most accurate image products with respect to radiometry and geolocation. ETM+ data serve as a reference to which observations from other satellite sensors are compared.
- A strategy for capturing seasonal coverage of the global land mass into a U.S. archive. This strategy, implemented by a Long-Term Acquisition Plan (Arvidson *et al.*, 2006), realizes the satellite system potential as a global survey mission and may ultimately have the greatest impact.
- A data policy that lowers the data cost and removes the licensing restrictions imposed on Thematic Mapper (TM) data during the commercial operations of Landsat 4 and Landsat 5. The policy now applies to all Landsat data held in the United States Geological Survey (USGS) archive. The lower prices and unencumbered sharing of Landsat data increase the public's return on investment for the Landsat program (Green, 2006).

Landsat 7 leaves a legacy of rigorous calibration, enlightened data policy, and global survey operations for the LDCM to emulate.

LDCM Development

In addition to the Landsat-7 legacy, LDCM requirements derive from public law, from technology demonstrations, and from direction provided by the Executive Office of the President. The Land Remote Sensing Policy Act of 1992 (U.S. Congress, 1992) initially guided the development of specifications. The Advanced Land Imager (ALI) launched aboard the Earth Observing-1 (EO-1) spacecraft in 2000 demonstrated the capabilities of new technologies possibly applicable to the LDCM. Recent memoranda from the Executive Office of the President (White House) Office of Science and Technology Policy (OSTP) provide further direction. This paper discusses these drivers of current LDCM requirements.

The Land Remote Sensing Policy Act of 1992

The Land Remote Sensing Policy Act of 1992 (U.S. Congress, 1992) initiated formulation of the LDCM. The Act directs Landsat Program Management to study options for a Landsat 7 successor mission that "adequately serve the civilian, national security, commercial, and foreign policy interests of the United States" and that "maintain data continuity with the Landsat system." The Act defines data continuity as data "sufficiently consistent (in terms of acquisition geometry, coverage characteristics, and spectral characteristics) with previous Landsat data to allow comparisons for global and regional change detection and characterization." Landsat Program Management currently consists of an inter-agency partnership between the National Aeronautics and Space Administration (NASA) and the Department of Interior (DOI) / USGS per an amendment to a Presidential Decision Directive (The White House, 2000). LDCM requirements derive essentially from Landsat Program Management interpretations of the phrases "adequately serve" and "sufficiently consistent" in the 1992 Act.

Figure 1. Rapid growth of Shenzhen, China between 1988 (top) and 1996 (bottom) shown in Landsat 5 TM images (courtesy of NASA GSFC Science Visualization Studio).

The Advanced Land Imager

The 1992 Act also directed Landsat Program Management to "incorporate system enhancements, including any such enhancements developed under the technology demonstration program under section 303, which may potentially yield a system that is less expensive to build and operate, and more responsive to data users." The Advanced Land Imager (ALI) aboard EO-1 constitutes the principal instantiation of the demonstration program. Launched on November 21, 2000, EO-1 is designed to demonstrate new technologies for land imaging (Ungar et al., 2003). It includes three sensors: the ALI, a Landsat-like multispectral imager; Hyperion, a hyperspectral imager; and a hyperspectral Atmospheric Corrector. As of mid-2006 over 46,000 ALI and Hyperion images had been collected and archived at the USGS Center for Earth Resources Observation and Science (EROS).

The ALI offers an important demonstration of technologies that could be applied to the LDCM. Unlike the Landsat TM or ETM+ whiskbroom scanners, ALI is a push-broom imager. ALI visible and near infrared detectors are constructed from silicon, while short wave infrared (SWIR) detectors are constructed from mercury-cadmium-telluride (HgCdTe) photodiodes, thus allowing higher ambient operating temperatures (approximately 220 K) compared to the TM/ETM+ SWIR bands that use indium- antimony (InSb) photodiodes cooled to 91 K. Individual detectors are organized into a series of overlapping sensor chip assemblies (SCAs) that extend across the focal plane in the cross-track direction. Each SCA contains 320 separate multispectral detectors. Since ALI is a demonstration mission, only one-fifth of the focal plane was populated with four SCAs, giving an image swath width of 37 km.

ALI collects image data for nine multispectral bands (with 30 m ground sample distance) and one panchromatic band (with 10 m ground sample distance). The ALI push-broom architecture offers greater dwell time and significant radiometric improvement over TM or ETM+. At 5 percent of maximum radiance, the ALI signal-to-noise ratios (SNRs) range from 100-300, while the ETM+ only manages SNRs of 15-50 (Lencioni et al., 2005). The simpler, push-broom architecture, combined with the use of passive cooling, allows ALI to give improved radiometric performance at substantially lower volume, mass, and power consumption than ETM+. Several studies have now been published comparing the performance of ETM+ and ALI for remote sensing applications. Without exception, these studies find that ALI offers improved ability to classify images, detect land cover change, and map environmental features and conditions.

Conclusion

NASA and DOI/USGS are now embarked on the third (and hopefully!) final implementation strategy for the LDCM. The previous implementation delays will most likely result in a Landsat data gap. Some users are already hindered by the Landsat 7 ETM+ scan line corrector failure. The impending gap should not serve as justification for compromising LDCM requirements. As the Landsat 7 demonstrated, there are considerable advances that can be achieved in land imaging if we build upon previous successes. The Landsat-7 mission advanced the practice of land imaging and set a standard for the LDCM. Likewise the LDCM needs to serve as a foundation upon which to build the future of land imaging.