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# Landsat and the Data Continuity Mission

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# Summary

The U.S. Landsat Mission has collected remotely sensed imagery of the Earth's surface for more than 35 years. At present two satellites—Landsat-5, launched in 1984, and Landsat-7, launched in 1999—are in orbit and continuing to supply images and data for the many users of the information, but they are operating beyond their designed life and may fail at any time.

The National Aeronautics and Space Administration (NASA) and the U.S. Geological Survey (USGS) jointly operate Landsat. The two agencies are developing a follow-on initiative known as the Landsat Data Continuity Mission (LDCM). The LDCM spacecraft (LDCM-1), with its instrument payload, is currently planned for launch in December 2012. NASA completed the Critical Design Review of the LDCM on June 1, 2010, allowing the project to proceed with full-scale fabrication, assembly, integration, and test of the mission elements.

Landsat has been used in a wide variety of applications, including climate research, natural resources management, commercial and municipal land development, public safety, homeland security and natural disaster management. Despite its wide use, efforts in the past to commercialize Landsat operations have not been successful. Most of the users of the data are other government agencies. For that reason, funding a replacement for the failing Landsat orbiters has been a federal responsibility. A number of factors have made it difficult for Congress to assure that the project successfully meets the goal of bridging the impending Landsat data gap.

Of particular concern has been the possibility that the new satellite may not include the capability of receiving data in the thermal infrared spectrum, a capability that is now in Landsat 5 and 7 and which some users have found particularly useful. Funding for a Thermal Infrared Sensing Instrument (TIRS) was uncertain and progress on the instrument delayed during the early years of the mission. However, NASA's FY2009 appropriation included $10 million specifically for TIRS. NASA announced in its FY2011 budget request that TIRS would be developed in time to meet the December 2012 launch date, while noting that because of its late start it required an "aggressive development schedule."

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# Introduction: Continuing Landsat

The U.S. Landsat Mission has collected remotely sensed imagery of the Earth's surface at moderate resolution[1] for more than 35 years.[2] At present two satellites—Landsat-5, launched in 1984, and Landsat-7, launched in 1999—are in orbit and continuing to supply images and data for the many users of the information. A study organized by the Office of Science and Technology Policy (henceforth called the FLI-IWG study) noted in August 2007 that the two satellites "are operating beyond their design lifetimes in degraded status and are subject to failure at any time. Because of fuel limitations, neither satellite is expected to operate beyond 2010."[3] However, the National Aeronautics and Space Administration's (NASA) FY2010 budget request, released in May 2009, said recent analyses "have estimated the Landsat-7 mission should continue to operate through at least the end of 2012."[4]

NASA and the U.S. Geological Survey (USGS) jointly operate Landsat. To maintain a robust archive of Landsat data and imagery,[5] the two agencies are developing a follow-on initiative known as the Landsat Data Continuity Mission (LDCM). The LDCM spacecraft (LDCM-1), with its instrument payload, was initially planned for launch in July 2011, but the current projection is now December 2012.

Landsat has been used in a wide variety of applications, including climate research, natural resources management, commercial and municipal land development, public safety, homeland security and natural disaster management, among others. Landsat stakeholders include (1) investigators in geophysical and atmospheric sciences; (2) decision makers and program managers at NASA, USGS, and other federal agencies, including land management agencies; (3) international government and military decision makers; (4) for-profit enhanced Landsat products distributors; and (5) consumers of commercial land surface imagery and environmental data.

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[1] Moderate resolution land imaging satellites have a resolution between 5 meters and 120 meters. Landsat 5 and 7 have resolution in the optical range of 30 meters.

[2] For a complete history of the Landsat Program, see NASA, "Landsat Then and Now," at http://landsat.gsfc.nasa.gov/about/.

[3] Executive Office of the President (EOP), Office of Science and Technology Policy (OSTP), National Science and Technology Council (NSTC), Future of Land Imaging Interagency Working Group (FLI-IWG), *A Plan for a U.S. National Land Imaging Program*, August 2007, p. 4. Available at http://www.ostp.gov/pdf/fli_iwg_report_print_ready_low_res.pdf. Henceforth cited as the FLI-IWG study.

[4] NASA FY2010 Budget Estimate, available at http://www.nasa.gov/news/budget.

[5] USGS/NASA, Landsat Missions, "NASA Selects Contractor for Landsat Data Continuity Mission Spacecraft," Landsat and LDCM Headlines 2008, April 22, 2008, available at http://landsat.usgs.gov/mission_headlines2008.php.

**Table 1. Characteristics of Space-based Land Imaging Satellites**

| Type of Satellite | Spatial Resolution (meters) | Geographic Coverage Swath per image (kilometers) | Frequency of Repeat Coverage of the Same Location |
|---|---|---|---|
| High-Resolution | less than 5 | 10 to 15 | Months to years |
| Moderate-Resolution | 5 to 120 | 50 to 200 | 15 to 30 days |
| Low-Resolution | greater than 120 | 500 to 2000 | 1 to 2 days |

**Source:** FLI-IWG report, p. 1.

Despite its wide use, efforts in the past to commercialize Landsat operations have not been successful. Commercial users tend to find that high-resolution, narrow coverage is more marketable, as is the data from low-resolution weather satellite images of cloud cover that can show the same location within one or two days. (See **Table 1**.) In contrast, Landsat orbiters cover the globe every 16 days, but many of the images received on the ground are obscured by cloud cover, so that producing a useful image of a particular area requires selecting data from multiple passes. Typically, Landsat's historical data series consist of complete, cloud-free images on a seasonal frequency. Most of the users of the data are other government agencies, or grantees engaged in inherently governmental activities. For that reason, funding a replacement for the failing Landsat orbiters has been a federal responsibility. A number of factors have made it difficult for the Congress to assure that LDCM successfully meets the goal of bridging the Landsat data gap.

### The Landsat Instrument and Functions[6]

Landsat sensors record reflected and emitted energy from Earth in various wavelengths of the electromagnetic spectrum. The electromagnetic spectrum includes all forms of radiated energy from tiny gamma rays and x-rays all the way to huge radio waves. The human eye is sensitive to the visible wavelengths of this spectrum; we can see color, or reflected light, ranging from violet to red.

Today, Landsats 5 and 7 "see" and record blue, green, and red light in the visible spectrum as well as near-infrared, mid-infrared, and thermal-infrared light that human eyes cannot perceive (although we can feel the thermal-infrared as heat). Landsat records this information digitally and it is transmitted to ground stations, where it is processed, and stored in a data archive.

It is this digital information that makes remotely sensed data invaluable. "Observations from Landsat are now used in almost every environmental discipline," explains John Barker, a Landsat 7 Associate Project Scientist.

Landsat data have been used to monitor water quality, glacier recession, sea ice movement, invasive species encroachment, coral reef health, land use change, deforestation rates and population growth. (Some fast food restaurants have even used population information to estimate community growth sufficient to warrant a new franchise.) Landsat has also helped to assess damage from natural disasters such as fires, floods, and tsunamis, and subsequently, plan disaster relief and flood control programs. In addition, the long-term continuity of Landsat allows users to go back in time to monitor changes in the earth's surface.

[6] This description is excerpted from NASA, The Landsat Program, Landsat News, "The Numbers Behind Landsat," which is available at http://landsat.gsfc.nasa.gov/data/. For technical details about the Landsat spacecraft and instrumentation, see NASA, GSFC, The Landsat-7 Science Data User's Handbook, at http://landsathandbook.gsfc.nasa.gov/handbook/handbook_toc.html.

Landsat has never had a permanent agency home at NASA for planning and operation, and the project is small compared to the agency's major space activities. Tight budgets due to funding under continuing resolutions for the last three years have also threatened the project. USGS funding is also limited.

Of particular concern has been the possibility that the new satellite may not include the capability of receiving data in the thermal infrared spectrum, a capability of Landsat 5 and 7 that some users have found particularly useful. NASA has indicated that a Thermal Infrared Sensing Instrument (TIRS) may be included in LDCM-1, but funding for it has been uncertain and progress on the instrument has been delayed. However, for FY2009, the Omnibus Appropriations Act, 2009 (H.R. 1105, P.L. 111-8) included $10 million specifically for TIRS.

# Bridging the Landsat Data Gap

Since the launch of Landsat-4 in 1985, mission payloads have included multiple instruments that capture surface imagery in the visual and near-infrared spectral region and have included sensors that collect environmental data in the infrared spectrum. **Table 2** shows the payloads and types of digital data and imagery acquired from Landsats 1-7, as well as those proposed for LDCM-1.

**Table 2. Landsats 1-7 and LDCM-1 Payloads**

| Mission | Launch | In Orbit | Instrument(s) | Purpose: Data/Imagery |
|---|---|---|---|---|
| ERTS (Landsat) 1 | July 1972 | 2 years | MSS | Land Surface, Resources |
| ERTS (Landsat) 2 | 1975 | 3 years | MSS | Land Surface, Resources |
| ERTS (Landsat) 3 | 1978 | 6 years | MSS | Land Surface, Resources |
| Landsat 4 | July 1982 | 3 years | MSS/TM/TIR | Land Surface, Resources |
| Landsat 5 | March 1984 | 24+ years | MSS/TM/TIR | Land Surface, Resources |
| Landsat 6 | 1994 | launch failure | ETM+[a] | N/A |
| Landsat 7[b] | April 1999 | 8+ years | ETM+ TIRS | Surface Radiance, Ice Sheets |
| LDCM-1 (planned) | 2012 | 5 years | ETM+ -TIRS | Surface Radiance, Ice Sheets |

**Key**: ERTS: Earth Resources Technology Satellite (renamed Landsat in 1975); MSS: Multi Spectral Scanner; TM: Thematic Mapper; ETM+: Enhanced Thematic Mapper; TIR: Thermal Infrared Sensor; LDCM-1: First Landsat Data Continuity Mission Spacecraft.

**Source:** Compiled by CRS from NASA data

a. NASA, Goddard Space Flight Center, "The ETM+ is a fixed position, nadir viewing, 'whisk-broom', multi-spectral scanning radiometer and is capable of providing high-resolution imaging information of the Earth's surface. Radiation in both the visible and infrared regions of the spectrum are detected by the instrument in eight distinct bands. The ETM+ is an improved version of the Landsat 4/5 Thematic Mapper (TM) payloads, but still provides data continuity with all prior Landsat missions." See "ETM+ and the Landsat7 Mission" at http://ls7pm3.gsfc.nasa.gov/mainpage.html.

b. Periodically since May 2003, Landsat-7 has experienced degraded operations, such as scattered data losses and optical equipment problems. Landsat-7 and LDCM would also collect MSS data/imagery as on previous Landsat missions.

Institutional and commercial users of data from the Landsat mission have urged U.S. lawmakers to continue a U.S. Landsat-type capability.[7] Many Landsat stakeholders are increasingly unable to use the data and imagery that are being generated due to the declining operational capacities of Landsats-5 and 7.[8] Their greatest concerns are that if LDCM-1 does not deploy on schedule, and if suitable data-sharing partnerships cannot be forged soon, there is a real danger of gaps in the Landsat data and imagery archive.[9] Information that could be lost, they caution, may include unobstructed visual and near-infrared spectrum records of Earth surface change, such as seasonal vegetation cover, moderate-resolution infrared environmental observations, and remotely sensed land and water resources management data.

## International Alternative Sources

Some Landsat product users have suggested that moderate resolution optical imaging satellites of other nations may supply data to fill the anticipated Landsat gap. A review of this option in the FLI-IWG report indicates that the global coverage of the Landsat orbiters and their ground-based receivers could not be duplicated by foreign moderate resolution satellites, but they could provide a partial, short-term fix to limit losses of some Landsat data and imagery.[10]

A Landsat Data Gap Study team formed by USGS and NASA in 2005 found that no international satellite program, current or planned, has the onboard recording capacity, the direct receiving station network, and the data production systems to routinely perform the full Landsat mission.[11] The Data Gap Study team did conclude, however, that capturing and archiving data from comparable systems could reduce the impact of a data gap. It identified sensors aboard India's ResourceSat satellite and the China Brazil Earth Resources Satellite (CBERS) as the most promising sources of Landsat-like data. USGS is pursuing the options with a Landsat Data Gap Implementation Plan, to identify costs and accessibility and the technical process of integrating data from other sources into the existing framework.[12]

# The Landsat Data Continuity Mission

After some consideration of the possibility of combining the moderate resolution function with weather satellite missions, the Bush Administration decided in December 2005 to continue Landsat instruments as free-flyers (i.e., satellites launched for a single purpose).[13] NASA and the USGS had been working to develop the follow-on program to Landsat-7. This joint initiative became known as the Landsat Data Continuity Mission (LDCM).

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[7] American Society for Photogrammetry and Remote Sensing (ASPRS), *Report to the Future Land Imaging Working Group on the ASPRS Survey on the Future of Land Imaging*, November 6, 2006.

[8] W.E. Stoney, Noblis Inc., *ASPRS Guide to Land Imaging Satellites*, "Optical Satellite Schedules," February 12, 2008.

[9] Scott Goetz, Woods Hole Research Center, "Crisis in Earth Observation," Science (AAAS), vol. 315, no. 30, March 2007, p. 1767, available at http://landcover.usgs.gov/bb_documents/crisis_earth_observation.pdf.

[10] FLI-IWG, op. cit., discusses in Appendix B the options available, including foreign satellite operations.

[11] USGS. "Landsat Data Gap Studies." http://ldcm.gsfc.nasa.gov/about.html.

[12] USGS. "Landsat Data Gap Implementation Plan," Landsat Science Team Meeting, Fort Collins, CO, January 6, 2009.

[13] EOP, OSTP, Memorandum, from John H. Marburger III, Director, "Landsat Data Continuity Strategy," December 23, 2005.

## NASA and LDCM

The main instrument in LCDM-1's payload is the Operational Land Imager (OLI) instrument. A passive (i.e., fixed) imaging radiometer, OLI would capture imagery of the Earth's surface as panchromatic/multi-spectral bands at 30 meters to 15 meters (moderate) resolution. This capability is similar to instruments deployed on Landsat missions 4-7. In addition, a Thermal Infrared Sensing Instrument (TIRS) is being developed, and NASA says the LCDM-1 project is "proceeding down a path as if TIRS will be there."[14]

NASA planned originally to launch LDCM-1, the first U.S. moderate resolution imaging spacecraft to be deployed since Landsat-7, in July 2011. However, a review board found that target "excessively aggressive" and in January 2009 the launch date was changed to December 2012.[15] That new target date could also accommodate NASA's schedule for development and delivery of the TIRS instrument. In September 2008, the LDCM project was approved to advance from Phase A, Concept and Technology Development, to Phase B, Preliminary Design and Technology Completion. On June 1, 2010, NASA completed its Critical Design Review of the LDCM, allowing the project to proceed with full-scale fabrication, assembly, integration, and test of the mission elements, leading to integration and test of the complete observatory.

## USGS and LDCM

The U.S. Geological Survey is responsible for the LDCM Mission Operations Center (MOC) that will be housed within the EROS Data Center in Sioux Falls, SD. USGS is supplying the funds for a five-year $14.5 million contract awarded by NASA, to build a ground data processing center.[16]

USGS officials announced that when procurement of the entire suite of Landsats 1-7 data is complete, the MOC will contain a collective archive of over 35-years' worth of MSS, TM, TIRS and ETM+ imagery, to be accessible free of charge over the Internet.[17] Landsat data and imagery would also be distributed offline at the marginal cost of reproduction and handling for licensed investigators, or at a rate set by USGS for users with commercial applications.[18] Additional data and imagery will be forthcoming from the Landsat-5 and 7 satellites until they cease operating, and eventually from the LCDM and successor missions, if any. These would also be made available under the same terms from the MOC.

[14] "Status of the Landsat Data Continuity Commission," presented by Bill Ochs, LDCM Project Manager, Landsat Science Team Meeting, January 6, 2009; http://landsat.usgs.gov/science_january2009MeetingAgenda.php.

[15] Ibid.

[16] NASA, *The Landsat Program—News*, "NASA Selects the Hammers Co. To Build LDCM MOE," September 17, 2008, at http://landsat.gsfc.nasa.gov/news/news-archive/news_0169.html.

[17] USGS/NASA, *Opening the Landsat Archive/Product Specifications*, April 21, 2009, available at http://landsat.usgs.gov/documents/USGS_Landsat_Imagery_Release.pdf.

[18] USGS Announcement: Landsat Missions, "Opening the Landsat Archive," January 9, 2009 available at http://landsat.usgs.gov/mission_headlines2009.php.

# Landsat/LDCM Funding

## NASA Funding

Development of the LDCM satellite was delayed in part because of funding uncertainties. NASA typically estimates funding requirements for five years, but these projections varied widely from year to year. In addition, various appropriations complications, including the use of continuing resolutions, led to funding the program at less than the requested amount for FY2006 through FY2008. For FY2009, however, the Omnibus Appropriations Act (P.L. 111-8) funded the program at $200.9 million, an increase of $60.5 million over the Bush Administration's request.

For FY2010, the Obama Administration requested $120.6 million for the LDCM project, which was appropriated. The FY2011 request was $156.8 million. NASA's projection of future costs for the program is shown in **Table 3**.

**Table 3. Funding Request for LDCM by NASA**

($ millions)

| 2009 Actual | 2010 Approp. | 2011 Request | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| $200.9 | $120.6 | $156.8 | $157.9 | $69.5 | $3.1 |

**Source:** NASA FY2011 Budget Request.

### TIRS Funding

In the early planning for the LDCM satellite, no provision was made for an instrument that would measure images in the thermal infrared range, although that function is included in the present Landsat-5 and Landsat-7 satellites. Appeals from numerous users of the information in that spectrum sector led NASA to reconsider the possibility of including a Thermal Infrared Sensor (TIRS), and the Congress included $10 million in the FY2009 Omnibus Appropriations bill directly for TIRS.

The infrared instrument is now officially part of the design of LDCM, after it was decided that it could be developed and included in LDCM without delaying the launch of the satellite. NASA includes the "aggressive development schedule" for TIRS as a "project risk" that may require adjustments to meet the targeted launch date.

## USGS Funding

USGS supports data collection and processing from the current Landsat-5 and Landsat-7 satellites, and also funds development of ground facilities to receive and process information from LDCM. For FY2009 USGS received $24.2 million for LDCM, and the same amount for FY2009 and FY2010. For FY2011 USGS requested$37.5 million for LDCM.

# The Future of Landsat

The lack of a permanent agency home for Landsat was a major factor in the impending data gap in the Landsat series, and planning for a follow-on instrument after the five-year-life of LDCM-1 is still in limbo. The FLI-IWG report recommended that long-term responsibility for land imaging, including Landsat planning and operations, be permanently placed under a National Land Imaging Program at the Department of the Interior. Implementation and funding for that program continue to be discussed, but the FY2010 and FY2011 USGS budget documents do not include any substantive reference to NLIP.

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