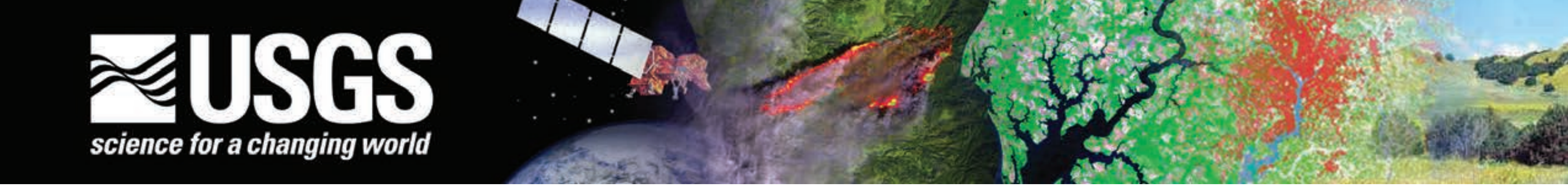

Landsat: A Global Land-Imaging Mission

Across four decades since 1972, Landsat satellites have continuously acquired space-based images of the Earth's land surface, coastal shallows, and coral reefs. The Landsat Program, a joint effort of the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA), was established to routinely gather land imagery from space. NASA develops remote-sensing instruments and spacecraft, then launches and validates the performance of the instruments and satellites. The USGS then assumes ownership and operation of the satellites, in addition to managing all ground reception, data archiving, product generation, and distribution. The result of this program is a long-term record of natural and human-induced changes on the global landscape (see table 1).

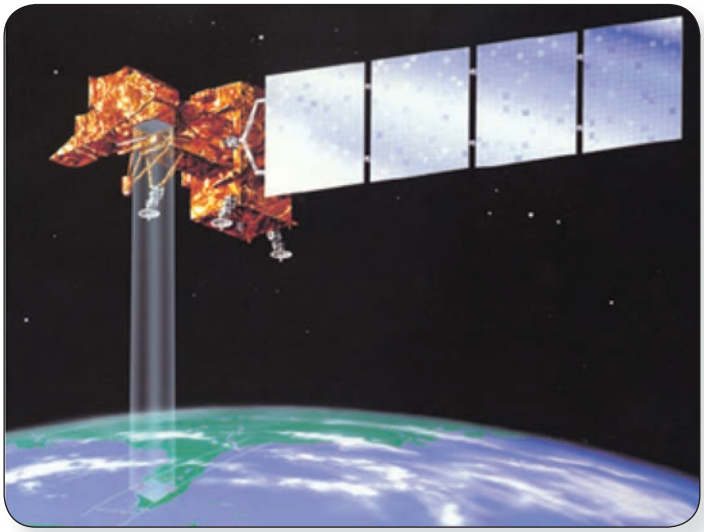

Figure 1. Landsat 7 satellite.

History of the Landsat Program

In the mid-1960s, stimulated by U.S. successes in planetary exploration using unmanned remote-sensing satellites, the Department of the Interior, NASA, and the Department of Agriculture embarked on an ambitious effort to develop and launch the first civilian Earth observation satellite. Their goal was achieved on July 23, 1972, with the launch of Landsat 1, originally named "ERTS" for Earth Resources Technology Satellite. Landsat satellites have since provided worldwide science and resource-management communities with an archive of space-based land remotely sensed data—a valuable resource for people who work in agriculture, geology, forestry, education, regional planning, mapping, and global change research.

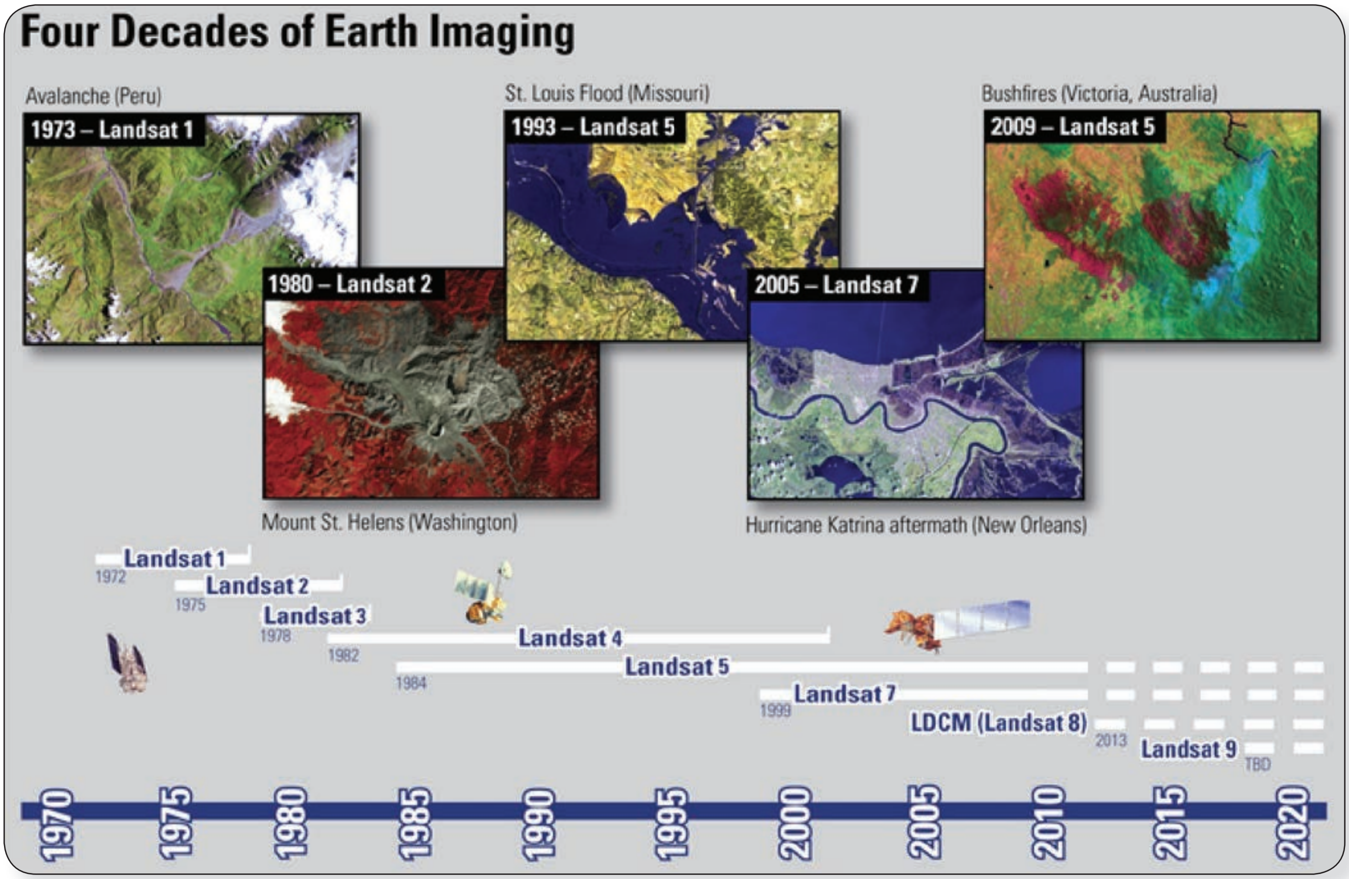

Table 1. Landsat mission dates.

Satellite	Launch(ed)	Decommissioned	Sensors
Landsat 1	July 23, 1972	January 6, 1978	MSS/RBV[1]
Landsat 2	January 22, 1975	July 27, 1983	MSS/RBV[1]
Landsat 3	March 5, 1978	September 7, 1983	MSS/RBV[1]
Landsat 4	July 16, 1982	June 15, 2001	MSS/TM
Landsat 5	March 1, 1984	Operational	MSS/TM
Landsat 6	October 5, 1993	Did not achieve orbit	ETM[2]
Landsat 7	April 15, 1999	Operational	ETM+[2]
LDCM (Landsat 8)	January 24, 2013		OLI/TIRS[3]

[1]Initially, Return Beam Vidicon (RBV) was primary; however MSS became the primary sensor in time.

[2]Landsat 6 carried the Enhanced Thematic Mapper sensor. Landsat 7 carries the Enhanced Thematic Mapper Plus sensor.

[3]LDCM (Landsat 8) will carry the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS).

Today, Landsat 5 (launched in 1984) and Landsat 7 (launched in 1999) continue to capture hundreds of images of the Earth's surface each day. Landsat 6, the only satellite in the series not developed by NASA, failed to achieve orbit in 1993. The next generation land observation system, the Landsat Data Continuity Mission (LDCM—to become Landsat 8 after launch), is intended to ensure continuity of Landsat data well beyond the duration of the Landsat 7 mission.

The USGS also leads a Landsat Science Team that develops and evaluates applications which highlight the historical Landsat record of observations as well as the capabilities of next-generation satellite data, defines a global, long-term data acquisition plan, and advises the USGS on Landsat data requirements of the user community.

Characteristics of the Landsat System

Each Landsat satellite images the Earth's surface along the satellite's ground track in a 185 kilometer-wide (115 mile-wide) swath as the satellite moves in a descending orbit (moving from north to south) over the sunlit side of the Earth. Each satellite crosses every point on the Earth at nearly the same time once every 16 or 18 days, depending on its altitude. Landsats 1, 2, and 3 orbited at an altitude of 920 kilometers (572 miles), circling the Earth every 103 minutes yielding repeat coverage every 18 days. Landsats 4, 5, and 7 were placed in orbit at 705 kilometers (438 miles) altitude, circling the Earth every 99 minutes, for a 16-day repeat cycle.

The primary sensor onboard Landsats 1, 2, and 3 was the Multispectral Scanner (MSS), with an image resolution of approximately 80 meters in four spectral bands ranging from the visible green to the near-infrared (IR) wavelengths (see table 2).

The improved Thematic Mapper (TM) sensors onboard Landsats 4 and 5 were designed with several additional bands in the shortwave infrared (SWIR) part of the spectrum, improved spatial resolution of 30 meters for the visible, near-IR, and SWIR bands, and the addition of a 120 meter thermal-IR band.

Landsat 7 carries the Enhanced Thematic Mapper Plus (ETM+), with 30-meter visible, near-IR, and shortwave infrared bands, a 60-meter spatial-resolution thermal band, and a 15-meter panchromatic band (see table 3). Landsats 5 and 7 each complete approximately 14 full orbits of the Earth each day. While each satellite has a 16-day full-Earth-coverage cycle, their orbits are offset to allow 8-day repeat coverage of any Landsat scene area on the globe.

Landsat Data Continuity Mission (LDCM)

The Landsat Data Continuity Mission (LDCM) is the next-generation Landsat satellite and is expected to be launched in January 2013. This mission will ensure the continued acquisition and availability of Landsat-like data well beyond the duration of the current Landsat 5 and Landsat 7 missions. LDCM data products will be consistent with current standard Landsat data products. Soon after launch, approximately 400 scenes will be acquired each day. All scenes will be processed to Level-1 data products and will be available for download within 24 hours of reception and archiving.

LDCM will carry two pushbroom sensors: the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), both of which will provide improved signal to noise ratio (SNR) and 12-bit radiometric quantization of the data. The OLI will collect data in nine shortwave bands—eight spectral bands at 30-meter resolution, and one panchromatic band at 15 meters. Refined heritage bands and the addition of a new coastal/aerosol band, as well as a new cirrus band, will create data products with improved radiometric performance. The TIRS will capture data

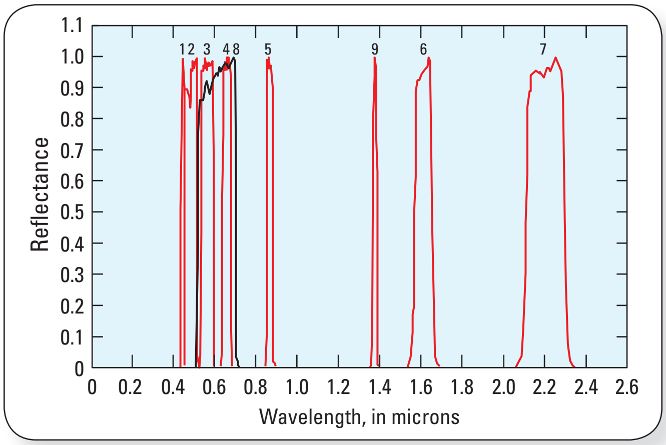

Figure 2. Operational Land Imager Relative Spectral Response.

Table 2. MSS band designations.

Landsats 1,2,3 spectral bands	Landsats 4,5 spectral bands	Wavelength (micrometers)	Resolution (meters)	Use
Band 4–green	Band 1–green	0.5–0.6	80	Emphasizes sediment-laden water and delineates areas of shallow water.
Band 5–red	Band 2–red	.6–.7	80	Emphasizes cultural features.
Band 6–near IR	Band 3–near IR	.7–.8	80	Emphasizes vegetation boundary between land and water, and landforms.
Band 7–near IR	Band 4–near IR	.8–1.1	80	Penetrates atmosphere haze best; emphasizes vegetation, boundary between land and water, and landforms.

Instrument-specific relative spectral response functions may be viewed and compared using the Spectral Viewer tool: *http://landsat.usgs.gov/tools_spectralViewer.php*.

Table 3. TM and ETM+ band designations.

Spectral bands	Wavelength (micrometers)	Resolution (meters)	Use
Band 1–blue-green	0.45–0.52	30	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation.
Band 2–green	.52–.61	30	Emphasizes peak vegetation, which is useful for assessing plant vigor.
Band 3–red	.63–.69	30	Emphasizes vegetation slopes.
Band 4–reflected IR	.76–.90	30	Emphasizes biomass content and shorelines.
Band 5–reflected IR	1.55–1.75	30	Discriminates moisture content of soil and vegetation; penetrates thin clouds.
Band 6–thermal	10.40–12.50	120	Useful for thermal mapping and estimated soil moisture.
Band 7–reflected IR	2.08–2.35	30	Useful for mapping hydrothermally altered rocks associated with mineral deposits.
Band 8–panchromatic (Landsat 7)	.52–.90	15	Useful in 'sharpening' multispectral images.

Instrument-specific relative spectral response functions may be viewed and compared using the Spectral Viewer tool: *http://landsat.usgs.gov/tools_spectralViewer.php*.

in two longwave thermal bands with a minimum of 100 meter resolution. The TIRS data will be registered to and delivered with the OLI data as a single product (see table 4). A new Quality Assurance band will also be included with each data product that will provide information on the presence of features such as clouds, water, and snow.

Applications of Landsat Data

Landsat data have been used by government, commercial, industrial, civilian, military, and educational communities throughout the United States and worldwide. These data support a wide range of applications in such areas as global change research, agriculture, forestry, geology, resource management, geography, mapping, water quality, and coastal studies.

Landsats 5 and 7 continue to provide important observations of the Earth. The design of the Landsat 5 satellite, launched in 1984, included a large fuel supply, which has enabled the satellite to operate longer than anticipated. This satellite has established a tremendous record for reliability throughout 28 years of continuous operation.

By February 2012, the network of USGS ground receiving stations had collected nearly 3.3 million Landsat scenes for the U.S. archive. This network, combined with Landsat 7's capability to record and playback images of foreign sites, enables full coverage of the Earth's land masses, although the satellite's orbit does not include direct over-flight of the North or South Pole.

The consistency of Landsat data acquired through the years allows for direct comparison of current specific site images with those taken months, years, or decades earlier. This comparison process can reveal land-cover changes that occur slowly and subtly, or quickly and devastatingly. The richness of the archive, combined with a no cost data policy, allows users to exploit time series of data over extensive geographic areas to establish long term trends and monitor the rates and characteristics of land surface change. Pre- and post-event Landsat images also are invaluable for emergency response and disaster relief. Within hours of data acquisition, the USGS Earth Resources Observation and Science (EROS) Center in Sioux Falls, South Dakota, provides relief organizations worldwide with satellite images for disaster response, as well as image-derived products that incorporate information on population density, elevation, and other environmental factors.

Table 4. OLI and TIRS band designations.

Spectral bands	Wavelength (micrometers)	Resolution (meters)	Use
Band 1–coastal/aerosol	0.433–0.453	30	Increased coastal zone observations.
Band 2–blue	.450–.515	30	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation.
Band 3–green	.525–.600	30	Emphasizes peak vegetation, which is useful for assessing plant vigor.
Band 4–red	.630–.680	30	Emphasizes vegetation slopes.
Band 5–near IR	.845–.885	30	Emphasizes vegetation boundary between land and water, and landforms.
Band 6–SWIR 1	1.560–1.660	30	Used in detecting plant drought stress and delineating burnt areas and fire-affected vegetation, and is also sensitive to the thermal radiation emitted by intense fires, and can be used to detect active fires, especially during night-time when the background interference from SWIR in reflected sunlight is absent.
Band 7–SWIR-1	2.100–2.300	30	Same as band 6.
Band 8–panchromatic	.500–.680	15	Useful in 'sharpening' multispectral images.
Band 9–cirrus	1.360–1.390	30	Useful in better-detecting cirrus clouds.
Band 10–TIRS 1	10.30–11.30	100	Useful for thermal mapping differences in water currents, to monitor fires and other night studies, and estimated soil moisture.
Band 11–TIRS 2	11.50–12.50	100	Same as band 10.

Instrument-specific relative spectral response functions may be viewed and compared using the Spectral Viewer tool: *http://landsat.usgs.gov/tools_spectralViewer.php*.

Figure 3. Dam construction and progression of deforestation in Rondônia, Brazil. The image on the left was acquired on June 24, 1984; the right image on August 6, 2011.

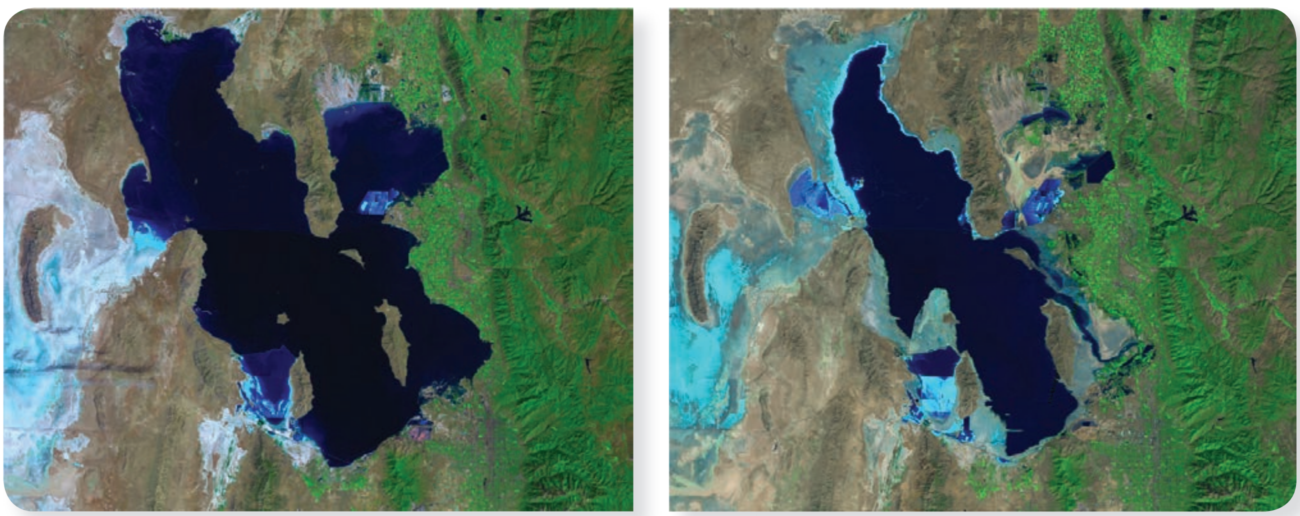

Figure 4. The Great Salt Lake in Utah. Each image was created by mosaicking four Landsat scenes. The left image represents the area in August 1985; the right image in September 2010.

Landsat 7 ETM+ —Scan Line Corrector Failure

On May 31, 2003, unusual artifacts began to appear within the data collected by the ETM+ instrument onboard Landsat 7. The problem was caused by failure of the Scan Line Corrector (SLC), which compensates for the forward motion of the satellite to align forward and reverse scans necessary to create an image. Efforts to recover the SLC were unsuccessful. Without an operating SLC, the line of sight traces a zigzag pattern along the satellite ground track with resulting data gaps that form alternating wedges that increase in width from the center of the image to the edge. Landsat 7 is still capable of acquiring highly geometrically and radiometrically accurate data worldwide, however. The USGS has provided the user community with methods to fill gaps in a Landsat 7 scene. Whether or not they choose to fill the gaps, many users continue to find Landsat 7 data to be useful.

Information

All Landsat data held in the USGS archives are available for download at no charge and with no user restrictions via *http://glovis.usgs.gov* or *http://earthexplorer.usgs.gov*. For information about Landsat operations, technology, and product specifications, visit *http://landsat.usgs.gov*, or contact:

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Landsat Customer Service
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Sioux Falls, SD 57198
Telephone: 605–594–6151
Fax: 605–594–6589
Email: *landsat@usgs.gov*

For more information about Landsat or LDCM, visit *http://landsat.usgs.gov*.

For information about the USGS Land Remote Sensing Program, visit *http://remotesensing.usgs.gov*.

For additional information about the USGS, visit *http://www.usgs.gov or http://ask.usgs.gov*.