Landsat: A Global Land-Observation Project

Landsat represents the world's longest continuously acquired collection of space-based land remote sensing data. The Landsat Project is a joint initiative of the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA) designed to gather Earth resource data from space. NASA developed and launched the spacecrafts, while the USGS handles the operations, maintenance, and management of all ground data reception, processing, archiving, product generation, and distribution.

Landsat satellites have been collecting images of the Earth's surface for more than thirty years. Landsat's Global Survey Mission is to repeatedly capture images of the Earth's land mass, coastal boundaries, and coral reefs, and to ensure that sufficient data are acquired to support the observation of changes on the Earth's land surface and surrounding environment. NASA launched the first Landsat satellite in 1972, and the most recent one, Landsat 7, in 1999. Landsats 5 and 7 continue to capture hundreds of additional images of the Earth's surface each day. These images provide a valuable resource for people who work in agriculture, geology, forestry, education, regional planning, mapping, and global change research.

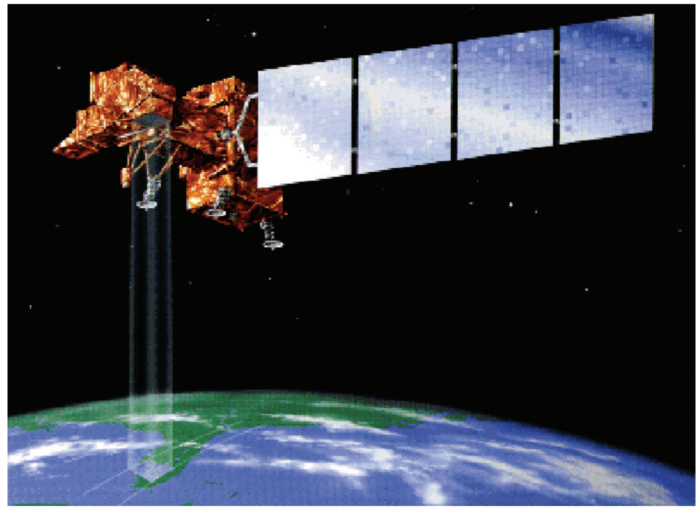
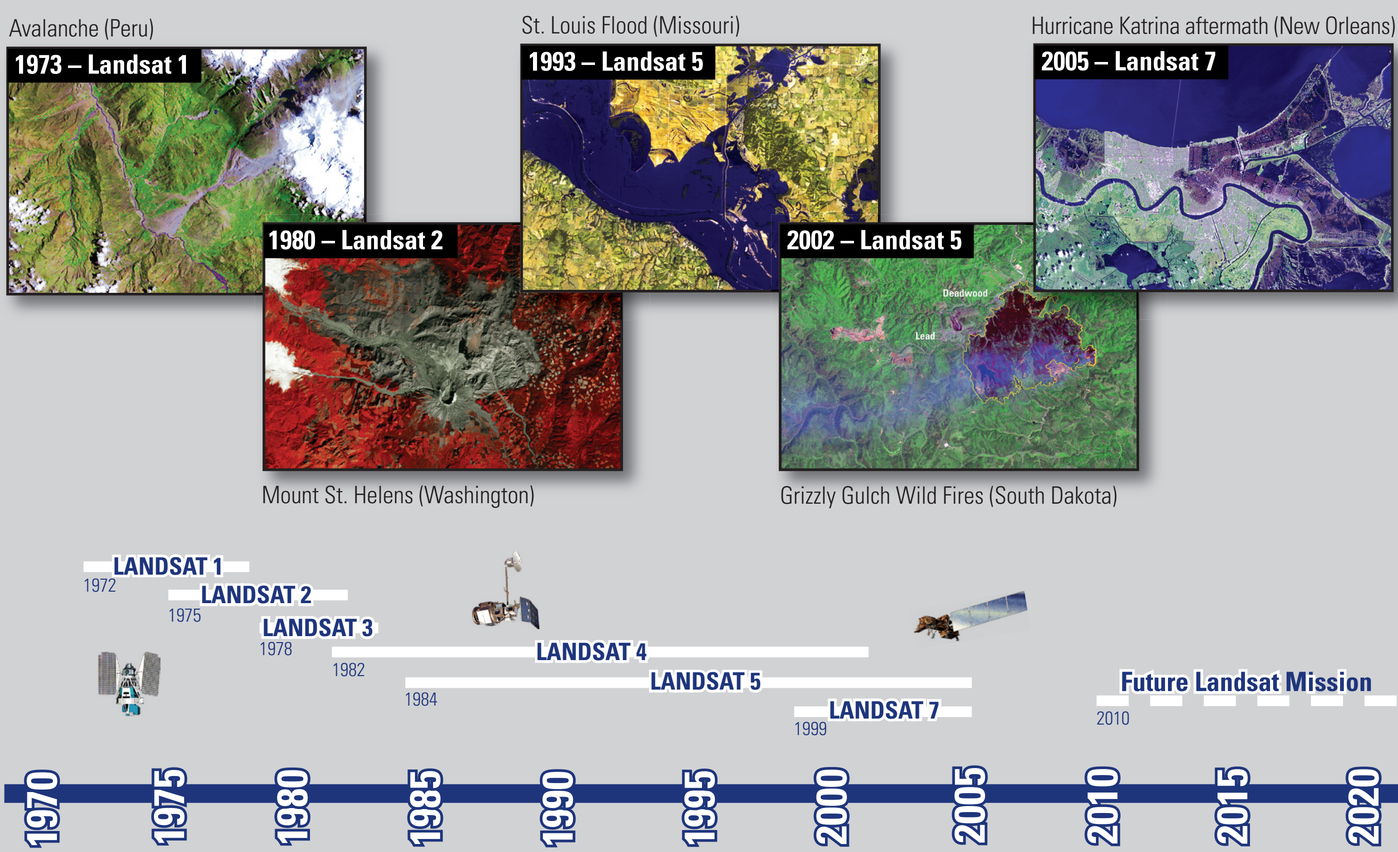


Figure 1. Landsat 7 Satellite.

Continuing Three Decades of Earth Imaging



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A Brief History of the Landsat Project

In the mid-1960s, stimulated by success in planetary exploration using unmanned remote sensing satellites, the Department of the Interior, NASA, the Department of Agriculture, and others embarked on an ambitious initiative to develop and launch the first civilian Earth observation satellite program. On July 23, 1972, NASA launched the first in a series of Landsat satellites designed to provide repetitive global coverage of the Earth's land masses.

Landsat, originally named "ERTS" for Earth Resources Technology Satellite, has continued to provide high-quality, moderate-resolution data depicting land and coastal regions of the planet. As a result of subsequent satellites launched throughout the 1980s and 1990s, there is a continuous set of Landsat data from mid-1972 until the present (Table 1).

Table 1. Mission Dates and Sensors

Satellite	Launched	Decommissioned	Sensors
Landsat 1	July 23, 1972	January 6, 1978	MSS/RBV*
Landsat 2	January 22, 1975	February 25, 1982	MSS/RBV*
Landsat 3	March 5, 1978	March 31, 1983	MSS/TM
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**
Landsat 7	April 15, 1999	Operational	ETM+**

*The return beam vidicon (RBV) was essentially a television camera and did not achieve the popularity of the MultiSpectral Scanner (MSS) sensor.

**The sensor onboard Landsat 6 was the Enhanced Thematic Mapper (ETM). Landsat 7 carries the ETM+.

Landsat Data Continuity Mission

For more than three decades, Landsat has provided the science community with an important archive of space-based land remote sensing data. The next generation of land-observation systems, the Landsat Data Continuity Mission (LDCM), is an effort to ensure continuity of Landsat-like data well beyond the duration of the Landsat 7 mission.

The USGS has formed, and will lead, a Landsat Continuity Science Team. This team will evaluate applications of the next-generation satellite, define a global, long-term data acquisition plan, and provide guidance on Landsat data requirements. The science team effort and LDCM implementation will ensure the continuation of quality data for users worldwide. The planned future launch of the LDCM will continue to contribute to the long-term data archive, further enhancing the value of all past Landsat missions.

Characteristics of the Landsat System

Landsat satellites scan the Earth's surface across the satellites' track as the satellites move in their descending orbit (moving from north to south) over the sunlit side of the Earth, so that they cross every point on the Earth about the same time once every few weeks. Landsat satellites cross the equator in the morning, anytime from 8:30 to10:00 a.m. (local time).

Landsats 1, 2, and 3 orbited at an altitude of 920 kilometers (km). These satellites circled the Earth every 103 minutes, completing 14 orbits a day.

It took 18 days to provide nearly complete coverage of the Earth's surface with 185-km image swaths. The primary sensor aboard Landsats 1, 2, and 3 was the Multispectral Scanner (MSS). The resolution of the MSS sensor was approximately 80 meters, with four bands of spectral coverage ranging from the visible green to the near-infrared (IR) wavelengths. The MSS sensor on Landsat 3 included a fifth band in the thermal-IR wavelength (Table 2).

Table 2. MSS Band Designation (Landsats 1, 2, and 3)

Landsats 1, 2, & 3 Spectral Bands	Landsats 4 & 5 Spectral Bands	Use
Band 4 - green	Band 1 - green	Emphasizes sediment-laden water and delineates areas of shallow water
Band 5 – red	Band 2 – red	Emphasizes cultural features
Band 6 – near IR	Band 3 – near IR	Emphasizes vegetation boundary between land and water, and landforms
Band 7 – near IR	Band 4 – near IR	Penetrates atmosphere haze best; emphasizes vegetation, boundary between land and water, and landforms

Landsats 4 and 5 orbited at an altitude of 705 km and carried both the MSS and the newly developed Thematic Mapper (TM)

Table 3. TM and ETM+ Sensor Band Designations

	Spectral Bands	Use
1	Blue-green	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation
2	Green	Emphasizes peak vegetation, which is useful for assessing plant vigor
3	Red	Emphasizes vegetation slopes
4	Reflected IR	Emphasizes biomass content and shorelines
5	Reflected IR	Discriminates moisture content of soil and vegetation; penetrates thin clouds
6	Thermal IR	Useful for thermal mapping and estimated soil moisture
7	Reflected IR	Useful for mapping hydrothermally altered rocks associated with mineral deposits
8	Panchromatic	Landsat 7 carries a panchromatic band (visible through near infrared) with 15 m resolution for "sharpening" of multispectral images

sensor. The MSS sensors onboard Landsats 4 and 5 were identical to those carried on Landsat 3.

The TM sensors onboard Landsats 4 and 5 included several additional bands in the shortwave infrared (SWIR) and an improved spatial resolution of 120m for the thermal-IR band and 30m for the other six bands (Table 3).

The currently operating Landsats 5 and 7 orbit at an altitude of 705 km. Each of the satellites has a 16-day orbit cycle, but the two orbits are offset by eight days, thus allowing 8-day repeat coverage. Landsats 5 and 7 are also designed to collect data over a 185km swath. Landsat 7 carries the Enhanced Thematic Mapper Plus (ETM+), with 30m visible and IR bands, a 60m spatial resolution thermal band, and a 15m panchromatic band (Table 3).

Applications of Landsat Data

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

Both Landsats 5 and 7 continue to provide important observations of the Earth. The design of the Landsat 5 satellite, which was launched in 1984, has lasted longer than anticipated and has established a tremendous record for reliability. Landsat 7 continues to provide the global science community with a wealth of data.

As of August 2005, USGS ground stations have collected more than 1.5 million scenes for the U.S. archive. This network of ground stations, along with the ability to record data to an onboard solid state recorder, allows virtually complete global coverage.

The consistency of Landsat data over three decades of acquisition offers opportunities to compare land cover changes over time. Landsat images are also invaluable for emergency response and disaster relief. Advances made in data reception and processing permit rapid access to imagery in times of natural or human-made disaster.

Within hours of data acquisition, the USGS Center for Earth Resources Observation and Science (EROS) 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 relevant topics.

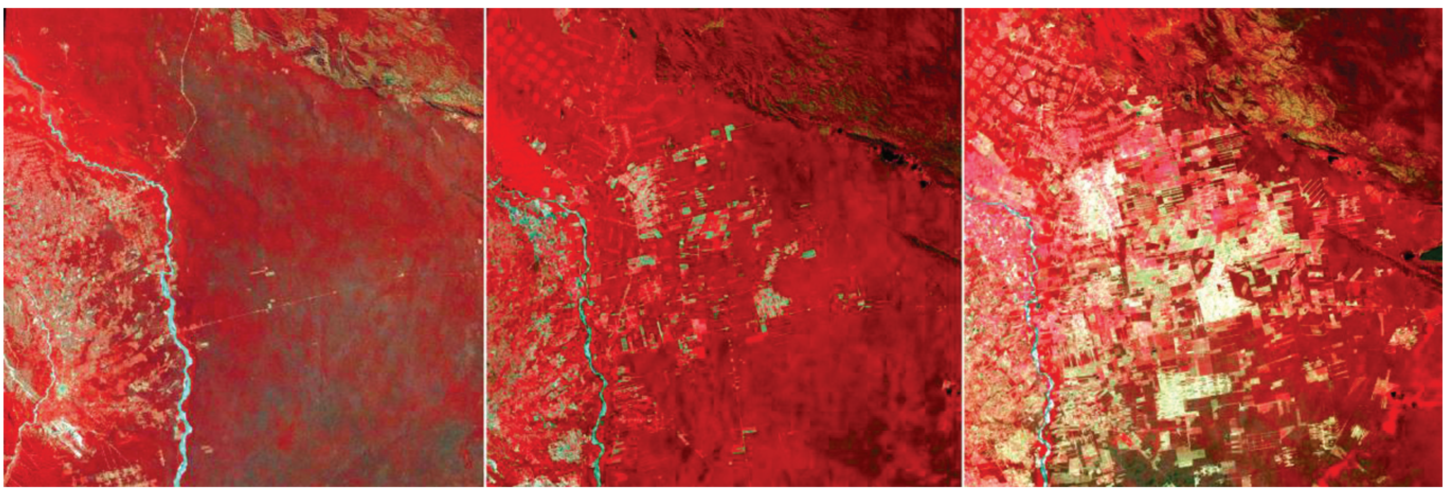

Figure 2. Progression of deforestation in Bolivia from 1975 to 2000. The image on the left was acquired on June 17, 1975; the middle image on July 10, 1992; and the right image on August 1, 2000.

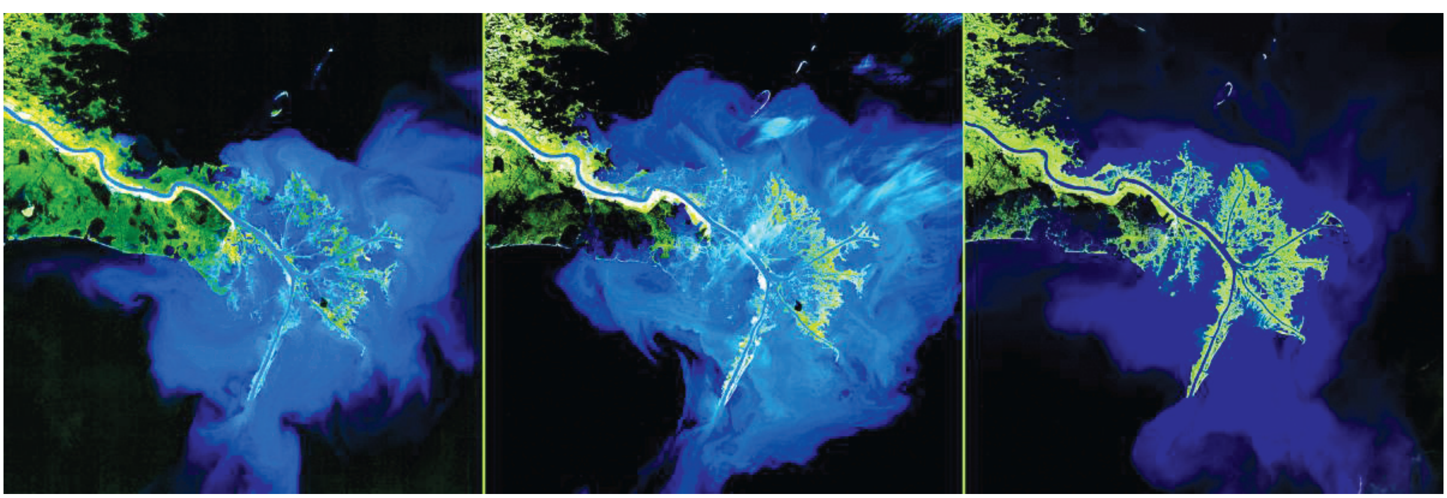

Figure 3. Three decades of Mississippi Delta sediment deposition from the Mississippi-Missouri River system eroded debris. The left image was acquired on January 16, 1973; the middle image on March 12, 1989; and the right image on January 6, 2003.

Landsat 7 ETM+ – Scan Line Corrector Failure

On May 31, 2003, unusual artifacts began to appear within image 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. Subsequent efforts to recover the SLC were not successful. Without an operating SLC, the line of sight traces a zig-zag 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. However, Landsat 7 is still capable of acquiring useful imagery with the SLC turned off, particularly within the central portion of any given scene.

In response to the SLC anomaly, the USGS has developed several new products to improve the utility of Landsat 7 data captured with the non-functioning SLC. Among the new options, gap-filled products now allow the data merge of one or more SLC-off scenes from separate dates for generation of a final gap-free image.

In addition, the gaps may also be filled using an image segmentation approach that allows for same-scene spectral data to be used to fill the gaps. The segment is generated from a complete satellite image with no missing spectral data, which is overlaid and then used to fill the Landsat SLC-off image based on identical features.

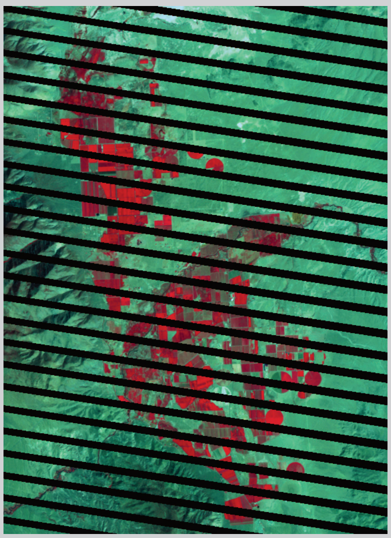

Figure 4. Agriculture in Nevada. Scan Line Corrector anomaly creates a zig-zag pattern along satellite ground track. Image aquired August 28, 2003.

Figure 5. Agriculture in Nevada. An image collected at the same location, but on a different date, is used to fill the scan lines from the image in Figure 4. Scene acquired August 12, 2003.

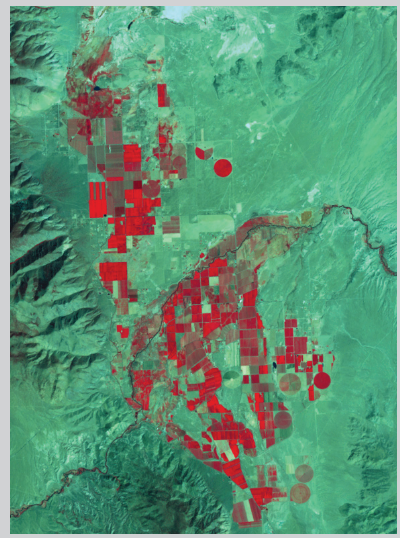

Figure 6. Agriculture in Nevada. Scenes from Figures 4 and 5 are combined to form this final gap-filled image.

Information

For information about the Landsat Project and Landsat holdings in the U.S. archive, visit the Landsat Web site at landsat.usgs.gov, or contact:

USGS/EROS
Customer Service
Mundt Federal Building
Sioux Falls, SD 57198
Telephone: 605-594-6151
Fax: 605-594-6589
Email: custserv@usgs.gov

For information about the Land Remote Sensing Program, please visit remotesensing.usgs.gov.

For information about LDCM, please visit ldcm.usgs.gov.

For information on other USGS products and services, call 1-888-ASK-USGS or visit the USGS Geography Products Web site at erg.usgs.gov/isb/pubs/pubslists/.

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