Landsat program

The Landsat program is the longest-running enterprise for acquisition of satellite imagery of Earth. On July 23, 1972 the Earth Resources Technology Satellite was launched. This was eventually renamed to Landsat. The most recent, Landsat 8, was launched on February 11, 2013. The instruments on the Landsat satellites have acquired millions of images. The images, archived in the United States and at Landsat receiving stations around the world, are a unique resource for global change research and applications in agriculture, cartography, geology, forestry, regional planning, surveillance and education, and can be viewed through the U.S. Geological Survey (USGS) 'Earth Explorer' website. Landsat 7 data has eight spectral bands with spatial resolutions ranging from 15 to 60 meters; the temporal resolution is 16 days. Landsat images are usually divided into scenes for easy downloading. Each Landsat scene is about 115 miles long and 115 miles wide (or 100 nautical miles long and 100 nautical miles wide, or 185 kilometers long and 185 kilometers wide).

History

Hughes Santa Barbara Research Center initiated, designed, and fabricated the first three Multispectral Scanners (MSS) in 1969. The first prototype MSS was completed within nine months, in the fall of 1970. It was tested by scanning Half Dome at Yosemite National Park.

The program was initially called the Earth Resources Technology Satellites Program, which was used from 1966 to 1975. In 1975, the name was changed to Landsat. In 1979, President of the United States Jimmy Carter's Presidential Directive 54 transferred Landsat operations from NASA to NOAA, recommended development of a long term operational system with four additional satellites beyond Landsat 3, and recommended transition to private sector operation of Landsat. This occurred in 1985 when the Earth Observation Satellite Company (EOSAT), a partnership of Hughes Aircraft and RCA, was selected by NOAA to operate the Landsat system with a ten-year contract. EOSAT operated Landsat 4 and Landsat 5, had exclusive rights to market Landsat data, and was to build Landsat's 6 and 7.

In 1989, this transition had not been fully completed when NOAA's funding for the Landsat program was due to run out (NOAA had not requested any funding, and Congress had appropriated only six months of funding for the fiscal year)[5] and NOAA directed that Landsat's 4 and 5 be shut down. The head of the newly formed National Space Council, Vice President Dan Quayle, noted the situation and arranged emergency funding that allowed the program to continue with the data archives intact.

Again in 1990 and 1991, Congress provided only half of the year's funding to NOAA, requesting that agencies that used Landsat data provide the funding for the other six months of the upcoming year. In 1992, various efforts were made to procure funding for follow on Landsat and continued operations, but by the end of the year EOSAT ceased processing Landsat data. Landsat 6 was finally launched on October 5, 1993, but was lost in a launch failure. Processing of Landsat 4 and 5 data was resumed by EOSAT in 1994. NASA finally launched Landsat 7 on April 15, 1999.

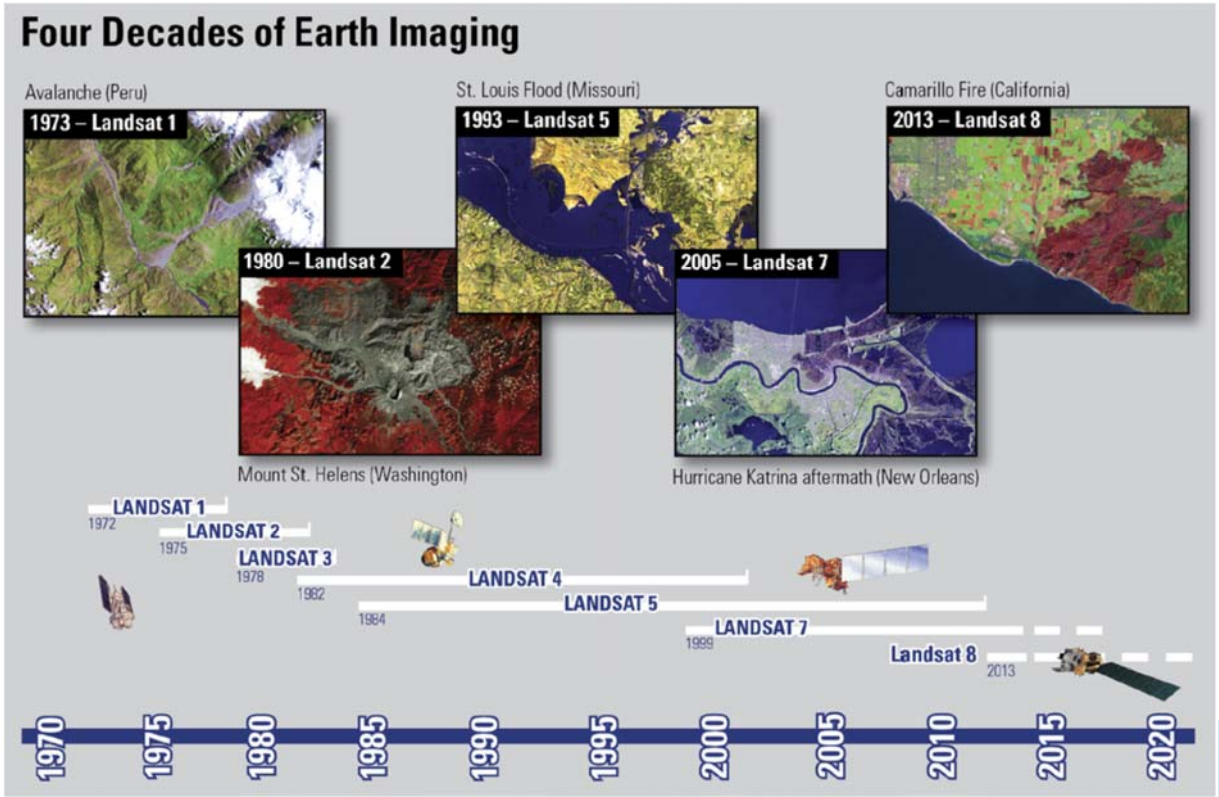
The value of the Landsat program was recognized by Congress in October 1992 when it passed the Land Remote Sensing Policy Act (Public Law 102-555) authorizing the procurement of Landsat 7 and assuring the continued availability of Landsat digital data and images, at the lowest possible cost, to traditional and new users of the data.

Satellite chronology

Instrument	Picture	Launched	Terminated	Duration	Notes
Landsat1		July 23, 1972	January 6, 1978	5 years, 6 months and 14 days	**Originally named Earth Resources Technology Satellite 1. Landsat 1 carried two vital instruments; a camera built by the Radio Corporation of America (RCA) known as the Return Beam Vidicon (RVB). As well as a Multi spectral Scanner (MSS) built by the Hughes Aircraft Company.**

Landsat2		January 22, 1975	February 25, 1982	7 years, 1 month and 3 days	**Nearly identical copy of Landsat 1. Payload consisting of a Return Beam Vidicon (RBV) and a Multi spectral Scanner (MSS). The specifications of these instruments were identical to Landsat 1.**
Landsat3		March 5, 1978	March 31, 1983	5 years and 26 days	**Nearly identical copy of Landsat 1 and Landsat 2. Payload consisting of a Return Beam Vidicon (RBV) as well as a Multi spectral Scanner (MSS). Included with the MSS was a short-lived thermal band. MSS data was considered more scientifically applicable than the RBV which was rarely used for engineering evaluation purposes.**
Landsat4		July 16, 1982	December 14, 1993	11 years, 4 months and 28 days	**Landsat 4 carried an updated Multi Spectral Scanner (MSS) used on previous Landsat missions, as well as a Thematic Mapper.**
Landsat5		March 1, 1984	June 5, 2013	29 years, 3 months and 4 days	**Nearly identical copy of Landsat 4. Longest Earth observing satellite mission in history. Designed and built at the same time as Landsat 4, this satellite carried the same payload consisting of a Multi Spectral Scanner (MSS) as well as a Thematic Mapper.**
Landsat6		October 5, 1993	October 5, 1993	0 days	**Failed to reach orbit. Landsat 6 was an upgraded version of its predecessors. Carrying the same Multi spectral Scanner (MSS) but also carrying an Enhanced Thematic Mapper, which added a 15m-resolution panchromatic band.**

Landsat7		April 15, 1999	Still active	19 years, 5 months and 21 days	**Operating with scan line corrector disabled since May 2003. The main component on Landsat 7 was the Enhanced Thematic Mapper Plus (ETM+). Still consisting of the 15m-resolution panchromatic band, but also includes a full aperture calibration. This allows for 5% absolute radiometric calibration.**
Landsat8		February 11, 2013	Still active	5 years, 7 months and 25 days	**Originally named Landsat Data Continuity Mission from launch until May 30, 2013, when NASA operations were turned over to USGS. Landsat 8 has two sensors with its payload, the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS).**



Characteristics of the Landsat System

Landsat satellites image 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.

Landsat 7 and Landsat 8 orbit the Earth at 705 kilometers (438 miles) altitude. They each make a complete orbit every 99 minutes, complete about 14 full orbits each day, and cross every point on Earth once every 16 days. Although 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 4 and 5 also followed this orbit. Landsat's 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.

The primary sensor onboard Landsat's 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 .

MSS band designations table

Landsat's 1, 2, and 3 spectral bands	Landsat's 4 and 5 spectral bands	Wavelength (micrometer)	Resolution (meters)	Use
Band 4–green	Band 1–green	0.50-0.60	80	Emphasizes sediment-laden water and delineates areas of shallow water
Band 5–red	Band 2–red	0.60-0.70	80	Emphasizes cultural features.
Band 6-NIR	Band 3-NIR	0.70-0.80	80	Emphasizes vegetation boundary between land and water, and landforms.
Band 7-NIR	Band 4-NIR	0.80-1.10	80	Penetrates atmosphere haze best; emphasizes vegetation, boundary between land and water, and landforms.

The improved Thematic Mapper (TM) sensors onboard Landsat's 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 SWIR bands, a 60-meter thermal band, and a 15-meter panchromatic band.

TM and ETM+ band designations table

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	0.52–0.61	30	Emphasizes peak vegetation, which is useful for assessing plant vigor.
Band 3–red	0.63–0.69	30	Emphasizes vegetation slopes.
Band 4–reflected IR	0.76–0.90	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)	0.52–0.90	15	Useful in 'sharpening' multispectral images.

Improved Data from Landsat 8

Landsat 8 ensures the continued acquisition and availability of Landsat data, which will be consistent with current standard Landsat data products. About 400 scenes will be acquired each day. All scenes are processed to data products and are available for download within 24 hours of reception and archiving.

Landsat 8 carries two push-broom sensors: the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), both of which provide improved signal to noise ratio and 12-bit radiometric quantization of the data.

The OLI collects 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, creates data products with improved radiometric performance. OLI data products have a 16-bit range. A new quality assurance band provides information on the presence of features such as clouds and terrain occlusion.

The TIRS captures data in two long wave thermal bands with 100-meter resolution, and is registered to and delivered with the OLI data as a single product. TIRS data products have a 30-meter resolution and a 16-bit range.

Applications of Landsat Data

Landsat data are 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 coastal studies.

Landsat 8 continues the legacy of Landsat missions, while Landsat 7 continues to provide important observations of the Earth, even with the failure of the Scan Line Corrector (SLC) in May 2003.

By March 2013, the network of USGS ground receiving stations had collected nearly 3.7 million Landsat scenes for the U.S. archive. This network, combined with the capabilities of Landsat 7 and Landsat 8 to record and downlink data to foreign sites, enables full coverage of the Earth's landmasses, 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 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.

OLI and TIRS band designations table

Spectral bands	Wavelength (micrometers)	Resolution (meters)	Use
Band 1–coastal/aerosol	0.43–0.45	30	Increased coastal zone observations.
Band 2–blue	0.45–0.51	30	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation.
Band 3–green	0.53–0.59	30	Emphasizes peak vegetation, which is useful for assessing plant vigor.
Band 4–red	0.64–0.67	30	Emphasizes vegetation slopes.
Band 5–near IR	0.85–0.88	30	Emphasizes vegetation boundary between land and water, and landforms.
Band 6–SWIR 1	1.57–1.65	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; can be used to detect active fires, especially during nighttime when the background interference from SWIR in reflected sunlight is absent.
Band 7–SWIR-1	2.11–2.29	30	Used in detecting drought stress, burnt and fire-affected areas, and can be used to detect active fires, especially at nighttime.
Band 8–panchromatic	0.50–0.68	15	Useful in 'sharpening' multispectral images.
Band 9–cirrus	1.36–1.38	30	Useful in detecting cirrus clouds.
Band 10–TIRS 1	10.60–11.19	100	Useful for mapping thermal differences in water currents, monitoring fires and other night studies, and estimating soil moisture.
Band 11–TIRS 2	11.50–12.51	100	Same as band 10.

Open Landsat 8 OLI with ENVI as training