Historical Record of Landsat Global Coverage: Mission Operations, NSLRSDA, and International Cooperator Stations

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Abstract

The long-term, 34+ year record of global Landsat remote sensing data is a critical resource to study the Earth system and human impacts on this system. The National Satellite Land Remote Sensing Data Archive (NSLRSDA) is charged by public law to: "maintain a permanent, comprehensive Government archive of global Landsat and other land remote sensing data for long-term monitoring and study of the changing global environment" (U.S. Congress, 1992). The advisory committee for NSLRSDA requested a detailed analysis of observation coverage within the U.S. Landsat holdings, as well as that acquired and held by International Cooperator (IC) stations. Our analyses, to date, have found gaps of varying magnitude in U.S. holdings of Landsat global coverage data, which appear to reflect technical or administrative variations in mission operations. In many cases it may be possible to partially fill these gaps in U.S. holdings through observations that were acquired and are now being held at International Cooperator stations.

Introduction

While in the Department of the Interior, William Pecora envisioned a series of land-observing satellites serving the Earth science community (Pecora, 1966). His persistence prevailed upon a reluctant bureaucracy to initiate the Earth Resources Technology Satellite (ERTS) series of observatories, later renamed Landsat (Lauer *et al.*, 1997). In 1973, the U.S. Geological Survey (USGS) constructed a facility outside of Sioux Falls, South Dakota dedicated to receiving, processing, distributing, and archiving the Landsat imagery, known as the USGS Center for Earth Resources Observation and Science (EROS).

The Landsat observation series continues today, currently being served by Landsat-7 and, remarkably, Landsat-5, which was launched in 1984 with a three-year planned lifetime. This 34+ year record of the Earth's land dynamics is unique to this generation and in recent years has been complemented with observations collected by other countries including France, India, and China/Brazil. As this global land observation record increases in length, its value to science, commerce, and international affairs increases as well.

The actual dimensions of the historical land satellite data record held in the U.S. and other countries are not well understood. The ill-founded but frequently-held assumption that Landsat-type sensors are operated continuously as they orbit the Earth is not true. There are many variables that intervene to produce less than comprehensive, systematic coverage, including system technical capabilities, mission operation decisions, and clouds (Arvidson *et al.*, 2006). Until recently, we had little insight into the quantities and qualities of Landsat holdings in the U.S. and international archives (Drager *et al.*, 1997). This study, undertaken at the behest of the Advisory Committee to the USGS National Satellite Land Remote Sensing Data Archive, provides a first intensive look at the historical global Landsat data record.

This paper reports progress to date on two aspects of this study: (a) determining the status of the U.S. held archive and generating a means to visualize this status; and (b) building a chronology of events that shaped this archive, explaining why there are gaps and shifts in regional coverage. The third element of this activity, determining the status of the International Cooperator (IC)-held archives and identifying sources of data that might help fill the gaps is still underway, but our initial findings are reported here.

Background

National Satellite Land Remote Sensing Data Archive (NSLRSDA)

In 1992, the U.S. Congress, recognizing the importance of this long-term Landsat data record, directed the Department of the Interior (DOI) to establish a permanent Government archive containing satellite remote sensing data of the Earth's land surface, and to make these data easily accessible and readily available for study. The DOI established the National Satellite Land Remote Sensing Data Archive (NSLRSDA) at the USGS/EROS. NSLRSDA comprises the U.S. collection of Landsat and related observations (e.g., declassified CORONA imagery and selected Système Probatoire d'Observation de la Terre (SPOT) coverage of the U.S.), providing a comprehensive, permanent record of the planet's land surface derived from 45+ years of satellite remote sensing.

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TABLE 1. LANDSAT SATELLITE CAPABILITIES

	Launch Date	Deactivation Date	Sensor Payload	On-board Data Storage	TDRSS Science Data Transmission
Landsat-1	23 July 1972	6 January 1978	MSS, RBV	Yes	No
Landsat-2	22 January 1975	25 February 1982	MSS, RBV	Yes	No
Landsat-3	05 March 1978	31 March 1983	MSS, RBV	Yes	No
Landsat-4	16 July 1982	1 June 2001	MSS, TM	No	Yes
Landsat-5	01 March 1984		MSS, TM	No	Yes
Landsat-7	15 April 1999		ETM+	Yes	No

In 1996, in accordance with the Land Remote Sensing Policy Act of 1992[1] (U.S. Congress, 1992) and with the encouragement of Dr. Joanne Gabrynowicz, then at the University of North Dakota, the Secretary of the Interior convened the NSLRSDA **A**dvisory **C**ommittee (AAC) to provide recommendations related to data selection, inclusion, maintenance, and preservation in the NSLRSDA, as well as to consider access management policies and procedures.

The AAC requested an assessment of the NSLRSDA content. Committee members expressed concerns about possible time and space gaps in the U.S. Landsat holdings. They further noted that images that had not been captured in the U.S. archive but which might fill gaps in the U.S. archive may have been transmitted to the IC stations. However, IC archives are aging and many of the acquired images may not be retrievable. The AAC tasked a subcommittee, including Williams, Goward, and Faundeen, to perform an analysis of NSLRSDA Landsat holdings that would determine where spatial and temporal gaps exist in the U.S.-held archive. The Committee further requested that, as much as possible, this subcommittee assess and review IC-reported archives as a potential means to fill some of the identified gaps in the U.S.-held archive. Here, we summarize our current findings.

Landsat Mission

The concept of a U.S. satellite system dedicated to observing the Earth's land areas at a resolution where one could detect human activities was first proposed in the early days of the U.S. space program, when productive uses of this new technology were being sought in the late 1950s (National Research Council, 1969; Mack, 1990; Lauer *et al.*, 1997). The ERTS (later re-named Landsat) concept struggled to be born in the presence of competition from the defense intelligence community, severe questioning from the U.S. Bureau of the Budget (now Office of Management and Budget) and civilian interagency competition. Finally, with a strong push from William Pecora, the ERTS concept was implemented in the early 1970s (Pecora, 1966).

Capabilities

In the first phase of the Landsat mission, a series of two Earth Resources Technology Satellites was planned to test the Landsat concept (Table 1). Somewhat later, a third satellite was added to the series. Landsat-1 sensors consisted of a Return Beam Vidicon (RBV) and the experimental Multispectral Scanner (MSS) (Mika, 1997). The RBV system was viewed originally as the primary mission instrument. Unfortunately (or perhaps fortunately), the Landsat-1 RBV failed shortly after launch, leaving the MSS as the primary instrument. In any case, the MSS turned out to be the far better sensor. On Landsats 2 and 3 the MSS was considered the primary instrument. Little use was made of the three-band RBV sensor on Landsat-2. On Landsat-3 the RBV was converted to a panchromatic 40 m sensor, but again little use was made of the imagery, primarily because the images were quite noisy due to issues with the analog telemetry from the satellite.

By the late 1970s, work on the more advanced, 30 m, seven spectral bands, Thematic Mapper (TM) instrument was well underway. Landsat-4 was launched in 1982, soon to be followed by Landsat-5, launched in 1984. Landsat-4 and Landsat-5 carried both TM and MSS instruments. This two-instrument configuration was done primarily because the emerging Landsat user community had become accustomed to handling and analyzing the MSS digital imagery but feared the additional complexity and volume of data produced by the TM instrument (recall that this was well before the days of high-capacity desktop PCs).

Following the loss of Landsat-6 during launch in 1993[2], Landsat-7 was placed on a fast track for launch in 1998, but was ultimately launched on 15 April 1999 (a one-year delay resulted from having to replace some faulty electronics inside the ETM+ sensor). Both Landsats 6 and 7 carried Enhanced Thematic Mapper (ETM) sensors, enhanced because of the addition of a 15 m panchromatic band and two selectable gain states for all bands. The plus designation (ETM+) for the Landsat-7 instrument occurred because the spatial resolution of the thermal infrared band was improved to 60 m from 120 m.

Summary and Conclusions

This first look at the composition and character of the historical global Landsat observation record has made us realize how little we know about this historical record, both within the U.S. and internationally. With each passing day, we move further away from the visionaries, experts, and technicians who originally developed and implemented this innovative global observing system.

Through conduct of this analysis, we are now aware of how quickly we need to take steps to embrace and document all possible collections of these data, particularly from the International Cooperator holdings. Further, we now also understand that we still do not know enough about the U.S. and international archives to accurately characterize and describe the holdings, as well as address such issues as data calibration and observation interoperability.

We have made a start, as described in this paper, but we have a long way to go. We need the support of all members of the Landsat community, past and present, to help us fill in the blanks. If you feel that you have important information about historical aspects of the Landsat program, we ask that you contact us as soon as possible to share your knowledge. We are already moving into further analyses of the U.S. and IC holdings to refine our assessment and can use all the help we can get in clarifying our current initial understanding of the Landsat legacy.

[1]The Land Remote Sensing Policy Act of 1992 (15 USC 5652. SEC.502. Archiving of Data. c.3): "In determining the initial content of, or in upgrading, the basic data set, the Secretary of Interior shall – . . . (3) consult with and seek the advice of users and producers of remote sensing data and data products."

[2]Landsat-6 was not a NASA-managed activity. Its build occurred during the commercialization phase of Landsat, and it failed to reach orbit immediately following launch.