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Landsat: Overview and Issues for Congress

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October 27, 2014

Congressional Research Service
7-5700
www.crs.gov
R40594

CRS REPORT
Prepared for Members and
Committees of Congress

Summary

On February 11, 2013, NASA launched Landsat 8, a remote sensing satellite jointly operated by the U.S. Geological Survey and NASA. Landsat 8 is the latest in a series of Earth-observing satellites that began on July 23, 1972, with the launch of Landsat 1. Landsat has been used in a wide variety of applications, including land use planning, agriculture, forestry, natural resources management, public safety, homeland security, climate research, and natural disaster management, among others. A question for Congress is, should there be a Landsat 9? More generally, should Congress support the development of another moderate resolution land-imaging satellite, and what are the alternatives?

Landsat 8's 30-meter resolution—its ability to capture images at the scale of about a baseball diamond—renders it a valuable tool for characterizing human-scale processes such as urban growth, agricultural irrigation, and deforestation. Landsat supporters also would contend that the consistent and continuous collection of imagery from the succession of Landsat satellites since 1972 makes it possible to document land changes, because images are comparable over that 42-year time period. In congressional deliberations about the future of Landsat, it is likely that the topics of privatization and commercialization will be revisited as one alternative to the current arrangement. Landsat's 30-meter resolution, the continuous and comparable 42-year record of data, and the current policy of making all Landsat data available for no cost would factor into a discussion about commercialization. Efforts to commercialize Landsat in the 1980s and early 1990s culminated with passage of the Land Remote Sensing Policy Act of 1992, which reversed the privatization track for Landsat and restored management of the satellite system back to the federal government.

Although a congressional debate over the next phase of the Landsat legacy is in its early stages, there are potentially divergent opinions among the Administration and Congress. The Administration is examining a future land imaging program that may depart from what might be considered the current Landsat "model"—namely, a dedicated satellite pair, each with the same or similar instruments as those aboard Landsats 7 and 8, the two currently orbiting satellites. For example, the Administration is directing NASA to explore options like a hosted payload and international partnerships, as opposed to a stand-alone payload and launch vehicle and an entirely U.S. project.

The Administration, through NASA and the U.S. Geological Survey, is crafting a post-Landsat 8 strategy via the Sustainable Land Imaging Architecture Study Team, which broadly follows guidelines laid out in the White House *National Plan for Civil Earth Observations*. Senate appropriators have been critical of the Administration's current approach to continuing a Landsat-type moderate-resolution Earth-observing system, namely one that may depart from the current Landsat model. In addition, the committee has emphasized its concerns over a potential data gap should Landsat 7 fail before a successor satellite was launched, leaving just one satellite—Landsat 8—operational. Some members of the House Appropriations Committee have recently questioned if the multiagency Landsat program aligns within the fundamental mission of NASA.

A common theme likely to be expressed by both the House and Senate will be the need to keep costs under control and at least below the amount appropriated for Landsat 8. In addition, Congress will also likely exert pressure on the Administration to move forward on the next land imaging mission and reduce the chances of a data gap if Landsat 7 or 8 fails before the next satellite is placed in orbit. What a data gap actually means, however, may be in question,

depending on the results of the Sustainable Land Imaging Architecture Study Team study and the resulting implementation strategy for the next land remote sensing satellite.

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Introduction

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Landsat satellites have collected remotely sensed imagery of the Earth's surface at moderate resolution[2] for over 40 years.[3] (**Table 1** shows a comparison of the spatial resolution for high, moderate, and low resolution land imaging satellites.) At present two satellites, Landsat 7 (launched in 1999) and Landsat 8, are in orbit and supplying images and data for many users. Landsat 5—launched in 1984—was also operating until late 2011; however, in November 2011 USGS announced that it had stopped acquiring data from Landsat 5 because of deteriorating electronic components.[4] The Landsat Data Continuity Mission (LDCM, now called Landsat 8) was initially planned for launch in July 2011 and would have filled the data gap in Landsat coverage after USGS stopped collecting data from Landsat 5, but because of schedule delays it was not placed in orbit until February 2013, when it was renamed Landsat 8. On May 30, 2013, data from Landsat 8 became available.[5]

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: Future of Land Imaging Interagency Working Group, 2007, "A Plan for a U.S. National Land Imaging Program," Office of Science and Technology Policy and National Science and Technology Council, p. 1, available at http://www.landimaging.gov/fli_iwg_report_print_ready_low_res.pdf.

[1] USGS, *Landsat—A Global Land Imaging Mission*, Fact Sheet 2012-3072, May 30, 2013, http://pubs.usgs.gov/fs/2012/3072/fs2012-3072.pdf.

[2] Moderate resolution land imaging satellites have a resolution between 5 meters and 120 meters. Landsat 7 and 8—the two currently operating Landsat satellites—have resolution in the optical range of 30 meters, and in the thermal infrared range of 100 meters. These features are discussed more fully later in the report.

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

[4] Landsat 5 was decommissioned on June 5, 2013, over 29 years after the satellite was launched. See http://landsat.usgs.gov/L5_Decommission.php.

[5] USGS Fact Sheet, *Landsat 8*, http://pubs.usgs.gov/fs/2013/3060/pdf/fs2013-3060.pdf.

Users of Landsat imagery and data cover a broad spectrum. A 2011 survey and analysis determined that the predominant sector using Landsat was academia (33%), followed by private business (18%), federal government (17%), state government (16%), local government (10%), nonprofit institutions (4%), and tribes or nations (less than 1%).[6] Within this user community as determined by the study, the majority of survey respondents used Landsat imagery to answer questions and solve problems (91%), processed the imagery for themselves or others (62%), and made decisions based on the imagery (57%). Of the respondents, 19% used Landsat imagery to develop algorithms, 12% provided or sold imagery or value-added products, and 2% developed commercial software.

Landsat Satellites and Instruments[7]

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 to huge radio waves. The human eye is sensitive to the visible wavelengths of this spectrum; we can see color ranging from violet to red.

Landsats 7 and 8 "see" and record blue, green, and red light in the visible spectrum as well as near-infrared, shortwave-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 transmits it to ground stations, where it is processed and stored in a data archive.

Since 1972, Landsat satellites have continuously gathered land imagery from space using several instruments mounted on the satellite. The instruments have generally improved in capability with the launch of each successive mission,[8] and the resulting imagery data provide a long-term record of natural and human-caused changes to the Earth's land surface. Landsats 7 and 8 orbit the Earth at an altitude of 438 miles and complete 14 full orbits each day. Each satellite crosses every point on Earth once every 16 days. With Landsats 7 and 8 both operating, each point on Earth gets complete coverage every 8 days, although clouds obscure the imagery over parts of the Earth at any given time.

Landsat 7 carries an instrument called the enhanced thematic mapper, which captures visible, near-infrared, shortwave-infrared, and thermal radiation reflected back from the Earth's surface. These observations allow users to distinguish soil from vegetation, and deciduous from coniferous trees; and to estimate peak vegetation, discriminate soil moisture content, and gather other information about the land surface. Landsat 8 carries two instruments: an operational land imager, which observes many of the same bands of radiation as Landsat 7 but with improvements, and a thermal infrared sensor that can measure land surface temperature in two different thermal infrared bands. The thermal infrared bands on Landsat 8 provide improved temperature estimates and estimates of soil moisture of the land surface.

With the 2013 launch of Landsat 8, a question that arises for Congress is whether there should be a Landsat 9. More generally, should Congress support the development of another moderate resolution land-imaging satellite, and what are the alternatives? This report describes aspects of Landsat's history and discusses potential alternatives to a fully federally supported satellite system, such as commercialization, privatization, and other possible arrangements that would provide continuity beyond the 42-year record of Landsat remote imaging. These other

[6] Holly M. Miller et al., *The Users, Uses, and Value of Landsat and Other Moderate-Resolution Satellite Imagery in the United States-Executive Report*, U.S. Geological Survey, Open-File Report 2011-1031, Reston, VA, 2011, http://pubs.usgs.gov/of/2011/1031/pdf/OF11-1031.pdf.

[7] Parts of this description are excerpted from NASA, The Landsat Program, Landsat News, "The Numbers Behind Landsat," which is available at http://landsat.gsfc.nasa.gov/data/.

[8] The Landsat program has met with some failures in its 40+ year history. For example, Landsat 6 failed to achieve orbit, and an instrument aboard Landsat 7 stopped functioning properly—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. More detailed information is available from USGS in Fact Sheet 2012-3072.

arrangements could include alternative sources of multispectral and thermal imaging, such as partnerships, or procurement of data from other, foreign, moderate resolution satellite systems. A key part of any future congressional debate on Landsat is the satellite's use and value. These issues are discussed below in the context of the 2014 White House *National Plan for Civil Earth Observations*[9] and an ongoing NASA/USGS Sustainable Land Imaging Architecture Study Team project. Some congressional views on a future U.S. land imaging program are also explored.

Landsat After Landsat 8

Most proponents agree that Landsat 8's 30-meter resolution—its ability to capture images with its Operational Land Imager (OLI) instrument at the scale of about a baseball diamond—renders it a valuable tool for characterizing human-scale processes such as urban growth, agricultural irrigation, and deforestation.[10] They also note that the consistent and continuous collection of imagery from the succession of Landsat satellites since 1972 makes it possible to document land changes because images are comparable. This comparability is possible despite changes in the satellites and the onboard instruments over 42 years. Some also argue that the current policy of making all Landsat imagery available at no cost is a prime value of the program. The current no-cost policy, however, does not reflect the varied history of the program and earlier attempts to commercialize Landsat.

During previous deliberations, Congress considered commercializing the Landsat system until passage of Land Remote Sensing Policy Act of 1992 (P.L. 102-555). The attributes just discussed—imagery at a 30-meter scale, continuous and comparable imagery and data of the Earth's surface for 42 years, and the no-cost policy for Landsat data—all could factor in a future discussion about whether Landsat would be amenable to commercialization now, over 20 years since Congress last debated a commercialization option. The following discussion traces earlier efforts to commercialize Landsat and may provide some context for congressional discussion about Landsat's future.

Privatizing Landsat: A Brief History

Almost since the beginning of satellite launches, including both land imaging and weather satellites, privatization of satellite systems has been discussed. Efforts to privatize Landsat began during the Carter Administration and accelerated during the Reagan Administration. The Carter Administration decided that Landsat was mature enough to move from a research land remote sensing system under NASA to an operational system under the National Oceanic and Atmospheric Administration (NOAA), which had successfully managed geostationary and polar orbiting weather satellites. The Carter Administration also asserted that under NOAA management, the user base for Landsat data would eventually grow. Private companies would

[9] National Science and Technology Council, Executive Office of the President, *National Plan for Civil Earth Observations*, July 2014, http://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/national_plan_for_civil_earth_observations_-_july_2014.pdf.

[10] U.S. Geological Survey, NASA, *Landsat Data Continuity Mission: Continuously Observing Your World*, NP-2012-10-346-GSFC, brochure from the NASA Landsat Program and Landsat Data Continuity Mission, 2012, http://landsat.gsfc.nasa.gov/wp-content/uploads/2012/12/LDCM_Brochure_Dec20121.pdf.

assume responsibility for their own remote sensing systems, and would provide data for government and private customers.[11]

In a policy shift to more rapid privatization of operational satellite systems, the Reagan Administration in March 1983 proposed to shift both Landsat and weather satellite system operations, as well as future ocean-observing satellite systems, from the federal government to the private sector.[12] Congress raised concerns that the Reagan Administration was moving too quickly toward privatizing weather satellites without congressional involvement. The opposition from Congress and other stakeholders to privatizing NOAA weather satellites led to Congress enacting language prohibiting their sale in the FY1984 appropriations act funding the Department of Commerce (P.L. 98-166).[13] In deliberations leading up to that prohibition, the House Science and Technology Committee suggested that pursuing the sale of the weather satellites distracted from the more important issue—maintaining global leadership in land remote sensing (i.e., Landsat). In fact, the committee urged that the debate shift back to its original track—namely, how to best accomplish a transfer of land remote sensing capability to the U.S. private sector.[14]

Outcome and Lessons Learned

Ultimately, the issues of whether and how to privatize the system, which federal agency should be responsible, and how public and private funding and operations should be combined were resolved in the Land Remote Sensing Policy Act of 1992 (P.L. 102-555). The act transferred Landsat program management from Commerce to NASA and the Department of the Interior (DOI).

Differing views of the Landsat program's nature—namely, whether the satellites served public or private interests—shaped the outcome of the privatization effort.[15] Evolving views over the public or private nature of the program were influenced by factors other than funding. One observer identified four factors:[16]

1. Landsat data proved important in planning U.S. military operations in the 1992 Gulf War.
2. Other countries had launched similar land remote sensing satellites, and these spacecraft—particularly the French SPOT satellite—were perceived as possible challenges to the U.S. stake in the international market for remote sensing data.[17]

[11] Ray A. Williamson, "The Landsat Legacy: Remote Sensing Policy and the Development of Commercial Remote Sensing," *Photogrammetric Engineering and Remote Sensing*, vol. 63, no. 7 (July 1997), p. 879.

[12] U.S. Congress, House Committee on Science and Technology, Subcommittee on Space Science Applications, *Commercialization of Land and Weather Satellites*, committee print, prepared by the Congressional Research Service, 98th Cong., 1st sess., June 1983 (Washington: GPO, 1983), p. 8.

[13] "No funds made available by this act, or any other act, may be used ... by the National Oceanic and Atmospheric Administration to transfer the ownership of any meteorological satellite (METSAT) or associated ground system to any private entity." P.L. 98-166.

[14] U.S. Congress, House Committee on Science and Technology, *Transfer of Civil Meteorological Satellites*, *Report to Accompany H. Con. Res. 168*, 98th Cong., 1st sess., November 8, 1983, Report No. 98-509, p. 3.

[15] Williamson, p. 880.

[16] Ibid.

[17] However, images from SPOT were also deemed extremely important for Coalition forces during the Gulf War.

3. Growing interest in global climate change and its effects on the Earth's surface led scientists to increasingly value time-series data from a consistent platform in space for identifying environmental changes.
4. The difficulties of commercializing the Landsat system became clear, and federal agencies perceived that private companies might not be able to provide equivalent data at the scale the agencies required.

These and other factors led Congress to accept the idea of Landsat as a public good and to enact P.L. 102-555. One other factor, for example, was the cost of Landsat images. P.L. 102-555 found that "the cost of Landsat data has impeded the use of such data for scientific purposes, such as for global environmental change research, as well as for other public sector applications." Consequently, the act established, with some restrictions, that unenhanced data from Landsat should be made available "at the cost of fulfilling user requests," or COFUR. USGS extended the COFUR policy to all Landsat data products in its Landsat Data Distribution Policy, which also stated that pricing would not be based on the recovery of capital costs of satellites, ground systems, or other capital assets previously paid for by the U.S. government. The current USGS policy is to make all Landsat imagery and data freely available for downloading.

The **Appendix** provides further details about the efforts to privatize Landsat in the 1980s and early 1990s.

Assessing the Use and Value of Landsat Imagery and Data

Other types of remote sensing imagery and data, both public and commercial, are available from satellites that provide different spatial resolutions as well as different frequencies of coverage over the same location. (See **Table 1**.) High-resolution, narrow-coverage imagery might be considered more marketable than moderate-resolution Landsat imagery. Arguably, data from low-resolution weather satellite images of cloud cover that can show the same location within one or two days might also be more marketable, although Congress decided against privatizing U.S. weather satellite data in the 1980s (see discussion above). Marketability issues aside, it may be useful for policy makers to consider some views of the value of Landsat imagery and data as a context for congressional deliberation on the future of the program.

The White House National Plan for Civil Earth Observations

The *National Plan for Civil Earth Observations* is intended "to provide strategic guidance for a balanced portfolio of Earth observations and observing systems."[18] The plan was developed following enactment of the NASA Authorization Act of 2010 (P.L. 111-267, Section 702), which tasked the Office of Science and Technology Policy (OSTP) with developing a mechanism to ensure greater coordination of research, operations, and activities for civilian Earth observations, including development of a strategic implementation plan. The statute requires that OSTP update the strategic implementation plan every three years.

[18] National Science and Technology Council, Executive Office of the President, *National Plan for Civil Earth Observations*, July 2014, p. 1.

The National Plan stated that President Obama's FY2015 budget request provided support for federal agencies to "maintain a sustained, space-based, land-imaging program while ensuring the continuity of 42 years of multispectral information and 36 years of thermal-infrared land-surface information from space, which are unique sources of terrestrial data for understanding land coverage." Although the Landsat system was not specified by name, this seemed to refer to the Landsat observational record.

The National Plan classified federal programs based on the duration of the federal commitment to making Earth observations. Programs could involve "sustained observations"—generally those measurements requiring a federal commitment of seven years or more—or "experimental observations"—measurements that are time-limited.[19] The report placed a priority on sustained observations, and further subdivided and ranked the supporting action required by the federal government as (1) continuity of sustained observations for public services, and (2) continuity of sustained observations for Earth system research.[20]

The National Plan provided specific direction to the federal agencies to carry out sustained observations. It stated that NASA, together with the Secretary of the Interior, will implement a 25-year program of sustained land imaging for routine monitoring of land-cover characteristics, naturally occurring and human-induced land-cover change, and water resources, among other uses.[21] The National Plan further directed the agencies to "ensure that future land-imaging data will be fully compatible with the 42-year record of Landsat observations." Moreover, the National Plan listed agency responsibilities, which match the currently described shared responsibilities between NASA and USGS. NASA would be responsible for satellite development, launch, and commissioning, and USGS would be responsible for user requirements, development and operation of ground systems, operational control once in orbit, and processing, archiving, and distributing data and products.[22]

It appears that the National Plan ranked the value of Landsat-type observations relatively high, and called for the continuation of similar types of space-based observations. The National Plan included a ranking of high-impact observation systems—based on a study called the Earth-Observation Assessment (EOA)—which placed Landsat as the third-highest-ranked observing system out of 145 ranked systems, behind only global positioning satellites (GPS) and Next Generation Weather Radar (NEXRAD).[23]

In a footnote to its stated requirement for the NASA and USGS to implement a 25-year program of sustained land imaging, the National Plan noted that a robust land-imaging program would also include other types of data to supplement the optical imagery that is collected by Landsat. The other types of data (not collected by Landsat) would include radar, LIDAR,[24] and gravity

[19] National Science and Technology Council, Executive Office of the President, *National Plan for Civil Earth Observations*, July 2014, p. 11.

[20] The three other priorities according to the plan are, in ranked order, (3) continued investment in experimental observations, (4) planned improvements to sustained observation networks and surveys for all observation categories, and (5) continuity of, and improvements to, a rigorous assessment and prioritization process. *National Plan for Civil Earth Observations*, p. 17.

[21] *National Plan for Civil Earth Observations*, p. 34.

[22] Ibid.

[23] Ibid., *Annex I: 2012 EOA Results*, p. 40.

[24] LIDAR stands for Light Detection and Ranging, and is a remote sensing technology that uses light in the form of a pulsed laser to measure distances to the Earth.

measurements, as well as others that would be needed to measure changes in topography, biomass, ecosystem flux, soil moisture, land subsidence, water resources, and glaciers.[25] The footnote suggests that the envisioned 25-year program might include a broader array of observations, from different instruments and platforms both space- and airborne, than the types of instruments currently aboard Landsats 7 and 8.

NASA and USGS: The Sustainable Land Imaging Architecture Study Team

The Administration is examining a future land imaging program that may depart from the current Landsat "model"—namely a dedicated satellite pair each with a moderate-resolution multispectral scanner and a thermal imager. NASA and USGS are crafting a post Landsat-8 strategy via the Sustainable Land Imaging Architecture Study Team (AST), which appears to be following the broad guidelines laid out in the National Plan, discussed above. *Continuity* of the data record is a key theme in the AST, but according to NASA "this does not necessarily mean the imagery per se, but the usable products that define the utility of the data record."[26] *Sustainability* is another key theme, and according to NASA a sustainable program would provide data products for the "long haul, without extraordinary infusions of funds, within the budget guidance provided."[27] NASA identifies *reliability* as a third key theme, and specifies that sustainable land imaging data sets "should be able to draw on equivalent or near equivalent deliverables from data sources to provide the data for the highest priority land imaging data products."[28] Notably, NASA adds that reliability also means that loss of a single satellite or instrument should not "cripple the program or significantly impact users, and the program will exhibit graceful degradation."

Alternative Sources of Moderate Resolution Remote Sensing

In previous discussions about pending gaps in Landsat coverage (when Landsat 5 was anticipated to fail before Landsat 8 could be placed in orbit), some Landsat product users suggested that moderate resolution optical imaging satellites of other nations might supply data to fill the Landsat gap.[29] A 2007 report indicated 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.[30]

In 2005, a Landsat Data Gap Study team formed by USGS and NASA found that no international satellite program, current or planned, has the onboard recording capacity, the direct receiving

[25] Ibid., footnote 31, p. 34.

[26] NASA, *Sustainable Land Imaging Architecture Study*, http://sustainablelandimaging.gsfc.nasa.gov/.

[27] Ibid.

[28] Ibid.

[29] See, for example, Scott L. Powell et al., "Moderate Resolution Remote Sensing Alternatives: a Review of Landsat-Like Sensors and their Applications," *Journal of Applied Remote Sensing*, vol. 1 (November 9, 2007), http://www.montana.edu/spowell/pdffiles/powell_jars.pdf.

[30] Future of Land Imaging Interagency Working Group, 2007, "A Plan for a U.S. National Land Imaging Program," Office of Science and Technology Policy and National Science and Technology Council, http://www.landimaging.gov/fli_iwg_report_print_ready_low_res.pdf. See Appendix B for the options available, including foreign satellite operations.

station network, and the data production systems to routinely perform the full Landsat mission.[31] The Data Gap Study team did conclude, however, that capturing and archiving data from comparable systems could reduce the impact of a data gap. The AST will likely revisit this option and reassess the foreign satellite alternative, given that nearly 10 years has passed and the availability of moderate resolution satellite data from non-U.S. sources has changed.

Federal Agency Budget Requests for FY2015

In the current Landsat partnership, NASA develops the satellite and the instruments, launches the spacecraft, and checks its performance. Then USGS takes over satellite operations, and manages and distributes the data.

USGS

In its FY2015 congressional budget justification, USGS states that Department of the Interior (DOI) bureaus rely on Landsat as a data source on wildfires, consumptive water use, land cover change, rangeland status, and wildlife habitat, as well as other departmental responsibilities.[32] USGS proposes to increase funding for Landsat-related activities under its Climate and Land Use Change organizational division, and would allocate $1 million for land remote sensing and $500,000 for land change science. In addition to creating a set of Landsat-based products that would assist natural resource managers at DOI, the budget request states that funding for Landsat-related activities would help develop essential climate variables (ECVs) and climate data records (CDRs). CDRs are long-term time-series measurements that support a variety of ECVs such as surface temperatures, fire disturbance, snow cover, glaciers, ice caps, permafrost, surface water extent, land cover, and biomass.

In the budget justification, USGS describes its participation in the NASA/USGS Sustainable Land Imaging Architecture Study Team, examining long-term operational alternatives to meet "Congressional and Administration directives to devise an aerospace architecture designed to ensure 20 years of sustained land imaging that will provide data compatible with the past 41 years of Landsat data."[33] The AST architecture plan for agency responsibilities matches that described in the National Plan, namely that NASA would develop Landsat-compatible land-imaging capabilities, and USGS would continue to fund ground system development, post-launch operations, data processing, archiving, and distribution. USGS adds that the AST will consider new instruments and satellites, as well as international partnerships.

Neither the Senate nor the House had acted upon the DOI appropriations legislation for USGS prior to September 30, 2014, the end of the fiscal year. The House Committee on Appropriations reported H.R. 5171, the DOI appropriations bill, on July 23 together with an accompanying report.[34] In the report, the committee supported the requested increases for USGS Landsat science

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

[32] FY2015 USGS Budget Justification, http://www.usgs.gov/budget/2015/greenbook/2015_greenbook.pdf, p. B-44.

[33] FY2015 USGS Budget Justification, p. F-4.

[34] U.S. Congress, House Committee on Appropriations, Subcommittee on Interior, Environment, and Related Agencies, *Department of the Interior, Environment, and Related Agencies Appropriations Bill, 2015*, 113th Cong., 2nd sess., July 23, 2014, H.Rept. 113-551 (Washington: GPO, 2013), p. 37.

products for climate and natural resources assessments, under the Climate and Land Use Change line item, as described above.

NASA

In its FY2015 congressional budget justification, NASA states that Landsat is "the only satellite system that is designed and operated to observe repeatedly the global land surface at moderate resolution. Landsat data are available at no cost to those who work in agriculture, geology, forestry, regional planning, education, mapping, and global climate change research."[35] As with USGS, NASA describes its participation in the AST, and states that its "near-term activities will focus on studies to define the scope, measurement approaches, cost, and risk of a viable long-term land imaging system that will achieve national objectives."[36] According to both NASA and USGS budget justifications, the Administration would use the results of the AST study to craft a proposal for a system to follow Landsat 8. However, NASA is already committing funding for a satellite system to succeed Landsat 8. For FY2015, NASA proposed $64.1 million for Land Imaging, an increase from the FY2014 enacted amount of $30 million. If enacted, these funds would total nearly $100 million for NASA's first steps toward the successor to Landsat 8.[37]

Some of the complexity and challenges to a Landsat 8 follow-on mission were revealed in remarks by the NASA Earth Science Division director at a May 28, 2014, meeting, according to one report.[38] One challenge for policy makers includes providing observational continuity with Landsat 8 and its predecessors, yet keeping costs low—lower than costs for Landsat 8. At the meeting, the NASA Earth Science Division director noted that the Administration wants NASA to explore all options to achieve this goal, including options like a hosted payload and international partnerships, as opposed to a stand-alone payload and launch vehicle and an entirely U.S.-based project.[39] Another challenge is to reconcile the Administration directive with congressional perspectives, one of which is skeptical of both the hosted payload strategy and an international partnership. Congress's perspective is likely in agreement with the Administration about the need to keep costs low (discussed in the next section).

Discussion: Differing Views over the Future of Landsat

Senate

Senate appropriators have been critical of the Administration's current approach to continuing a Landsat-type moderate-resolution Earth observing system. In its report accompanying S. 2437, the Commerce, Justice, Science, and Related Agencies appropriations bill for FY2015,

[35] FY2015 NASA Budget Justification, http://www.nasa.gov/sites/default/files/files/508_2015_Budget_Estimates.pdf, p. ES-38.

[36] Ibid.

[37] In addition, the NASA budget request proposed $2.2 million for Landsat Data Continuity Mission (Landsat 8) ongoing activities.

[38] Dan Leone, "NASA Official: A Landsat 8 Clone Would Cost More than $650 Million," *SPACENEWS*, June 9, 2014.

[39] Ibid. The NASA Earth Science Division director at the meeting was Michael Freilich.

appropriators stated that "the Committee does not concur with various administration efforts to develop alternative 'out of the box' approaches to this data collection—whether they are dependent on commercial or independent partners."[40] In the report, the committee emphasized its concerns over a potential data gap should Landsat 7 fail before a successor satellite was launched: such a failure would mean that instead of 8 days for continuous terrestrial coverage with two satellites, it would take 16 days with just Landsat 8. With these concerns, the committee stated that NASA "should proceed with an acquisition in fiscal year 2015 for a mission to launch a follow on to Landsat 8 by not later than 2020."[41] However, the committee also stressed the need to keep costs low, specifically below $650 million, while at the same time noting that NASA was $100 million below what was needed—in a notional FY2016 budget—for a 2020 launch. In the report, appropriators noted that they expected NASA to present a FY2016 budget "to reflect resources necessary to meet that [2020] launch date."[42] For FY2015, Senate appropriators recommended $68.1 million for Landsat Data Continuity, $4 million above the President's request.

The committee's views in its FY2015 report echo remarks a year earlier in the report accompanying the Commerce, Justice, Science, and Related Agencies appropriations bill for FY2014.[43] In that report, appropriators stated that they were "highly skeptical of either a hosted payload or international partner concept for Landsat 9." The committee noted that these alternate approaches have already been considered on multiple occasions over the past 40 years, and "have only distracted and delayed the inherently governmental role in preserving the continuity of Landsat data."[44] In the FY2014 report language, appropriators chided NASA for unrealistic expectations that a Landsat 9 would cost $1 billion, and capped spending at $650 million, noting that the lower figure was substantially below that required for Landsat 8. Senate appropriators recommended $30 million for Land Imaging activities, matching the Administration's request for FY2014.

House

In their FY2014 report accompanying H.R. 2787, the Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2014, House appropriators (majority) objected to NASA's budget request for new projects "that solely or primarily support the requirements of other agencies, including the United States Geological Survey."[45] The report stated that such projects would have significant and undefined outyear costs and "crowd out long term investments in NASA's own scientific priorities." Accordingly, report language instructed that "no funds should be spent in pursuit of a new land imaging system for USGS." In the "Minority Views" section of the report,

[40] U.S. Congress, Senate Committee on Appropriations, Subcommittee on Commerce, Justice, Science, and Related Agencies, *Departments of Commerce and Justice, and Science, and Related Agencies Appropriations Bill, 2015*, report to accompany S. 2437, 113th Cong., 2nd sess., June 5, 2014, S.Rept. 113-181 (Washington: GPO, 2014), p. 109.

[41] Ibid., p. 110.

[42] Ibid.

[43] U.S. Congress, Senate Committee on Appropriations, Subcommittee on Commerce, Justice, Science, and Related Agencies, *Departments of Commerce and Justice, and Science, and Related Agencies Appropriations Bill, 2014*, report to accompany S. 1329, 113th Cong., 1st sess., July 18, 2013, S.Rept. 113-78 (Washington: GPO, 2013). p. 107.

[44] Ibid.

[45] U.S. Congress, House Committee on Appropriations, Subcommittee on Commerce, Justice, Science, and Related Agencies, *Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2014*, report to accompany H.R. 2787, 113th Cong., 1st sess., July 23, 2013, H.Rept. 113-171 (Washington: GPO, 213), p. 62.

appropriators expressed disappointment in the elimination of "funding for several upcoming climate satellite programs, including: (1) NASA's Landsat, which provides valuable data in support of agriculture, forestry, and regional planning."[46] In the FY2014 Omnibus Appropriations bill, enacted as P.L. 113-76, the Senate view was adopted, and $30 million was provided for Land Imaging at NASA for the next Landsat-like mission after Landsat 8.

House appropriators made no mention of Landsat or Land Imaging spending in the FY2015 appropriations bill (H.R. 4660) that passed the House or in the accompanying report (H.Rept. 113-448). Earlier objections—expressed in the FY2014 House appropriations bill report—to a Landsat-like land imaging satellite as not aligning with the NASA mission were not voiced in the FY2015 appropriations bill. That earlier objection was likely part of a debate regarding the mission focus of NASA, and whether it should be responsible for funding satellites that are turned over to other federal agencies to operate, such as Landsat (operated by USGS) and the nation's civilian weather satellites (operated by NOAA).

Potential Conflict

Senate appropriators had also raised concerns about a joint satellite program—civilian weather satellites—between NASA and NOAA in the FY2013 budget process, but with the opposite recommendation from that of the House. As with the joint-agency Landsat program, NASA acquires the weather satellites and their instruments, launches them into orbit, and then hands over operations to another agency, in this case NOAA. In contrast with Landsat, however, Congress appropriates funds directly to NOAA for procuring the weather satellites; NOAA then transfers funds to NASA for satellite and instrument acquisition.[47] In the report accompanying the FY2013 appropriations bill for Commerce and Justice, Science, and Related Agencies, Senate appropriators chose to transfer funding and responsibility for procuring NOAA's operational satellites to NASA.[48] Their decision was not based on a debate over respective agency missions, which seemed to be the case for House majority appropriators in the FY2014 appropriations process, but was based on the view by Senate appropriators that NOAA was mismanaging the satellite procurement process and NASA could do a better job. The weather satellite procurement issue illustrates the different views held by House versus Senate appropriators over the role of NASA in satellite procurement for joint-agency satellite programs. These different views may be a subject of congressional debate when Administration budget requests for the next Landsat ramp up in the next few years.

Although a congressional debate over the next phase of the Landsat legacy is in its early stages, the discussion above notes potentially divergent opinions among the Administration and Congress. Congress is likely to discuss a range of views regarding the future of satellite-based land imaging. Some in Congress may wish to revisit options of privatization or commercialization, which has a long and well-documented history (see discussion above). Others, such as some members of the Senate Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies, have consistently expressed the view that preserving data continuity from the Landsat satellites is an inherently governmental role. Some members of the

[46] Ibid., p. 120.

[47] With Landsat, Congress appropriates funds directly to NASA for satellite and instrument acquisition.

[48] U.S. Congress, Senate Committee on Appropriations, Subcommittee on Commerce, Justice, Science, and Related Agencies, *Departments of Commerce and Justice, and Science, and Related Agencies Appropriations Bill, 2013*, 112th Cong., 2nd sess., April 19, 2012, S.Rept. 112-158 (Washington: GPO, 2012), p. 10.

House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies have recently questioned if the multiagency Landsat program aligns within the fundamental mission of NASA, since NASA acquires and launches Landsat, but a different agency, USGS, assumes operational responsibility, and manages and distributes Landsat data.

A common theme likely to be expressed by both the House and Senate majorities and minorities will be the need to keep costs under control and at least below the amount appropriated for Landsat 8. In addition to a unified admonition to keep the cost of a Landsat successor low, Congress may also exert pressure on the Administration to move forward on the next land imaging mission and reduce the chances of a data gap if Landsat 7 or 8 fails before the next satellite is placed in orbit. However, what a data gap actually means may be in question depending on the results of the AST study, and the resulting implementation strategy. If, for example, the Administration determines that data from non-U.S. satellites suffice to offset some or most of the data loss from a Landsat 7 or 8 failure, then Congress would likely revisit the needs, capabilities, and timeline for developing the next U.S. land-imaging satellite. The broad themes outlined by the AST of *continuity*, *reliability*, and *sustainability* will likely not face congressional opposition. However, Congress may debate what those themes actually mean in terms of more detailed program requirements, and particularly how much funding should be appropriated to meet those requirements.

Appendix. Landsat: A Decade of Privatization Efforts

In contrast to its opposition to the privatization of NOAA weather satellites, Congress in 1983 did not oppose Reagan Administration efforts to transition Landsat to the private sector. The Carter Administration initiated the move toward privatization when it released Presidential Directive 54 in 1979, which recommended transfer of Landsat operations from NASA to NOAA to convert Landsat from a research to an operational program.[49] The directive also recommended development of a plan for eventual transition of Landsat to a private-sector operation.

It was recognized at the time that the market for Landsat products was small, and the customer base grew smaller each time the price of Landsat data rose. The price of a Landsat image rose 300% in 1981, when the Office of Management and Budget directed that operating costs would be recovered by data sales.[50] Sales shrank again when NOAA took over full responsibility for the program in 1983, and raised prices for Landsat data to cover its costs and to prepare customers for commercial prices.[51] Despite these indicators that the commercial market for Landsat data was not robust, Congress gave its support to privatization by passing the Land Remote Sensing Commercialization Act of 1984 (P.L. 98-365). The law established the broad policy and financial requirements for the transfer, and authorized the Department of Commerce to license private remote sensing space systems that complied with provisions of the act.[52] The law required that operators make unenhanced Landsat data available to all users on a nondiscriminatory basis; no preference could be given to one class of data buyers over another.

Landsat proponents supported the move to privatization, in part because of fears that the Reagan Administration would cancel the program altogether. Proponents were also concerned that uncertainty over the program's future would forestall investment in hardware and software necessary to process Landsat data.[53] Landsat supporters also argued that privatization would ensure continuity of the data—an important feature of time-series observational data from satellites generally, allowing data users to analyze changes over time. Supporters argued that privatization would eventually result in a lower price for Landsat data.[54] The larger context for the future of Landsat was, in part, a dispute over whether the satellite served primarily public or private interests.[55] Landsat provided the government with data for scientific research, managing federal lands, and carrying out other responsibilities. It also provided data with direct economic value for managing private lands, or for exploration for oil, gas, and minerals. The argument over Landsat's future concerned which use was more important.[56]

[49] See out-of-print CRS Issue Brief IB92092, *U.S. Civil Earth Observation Programs: Landsat, Mission to Planet Earth, and the Weather Satellites*, by David P. Radzanowski, available from Peter Folger on request.

[50] Williamson, p. 879.

[51] Ibid.

[52] CRS Report IB92092.

[53] Williamson, p. 879.

[54] Ibid.

[55] Williamson, p. 880.

[56] Williamson, p. 880.

Government Subsidies and Problems on the Path to Privatization

Because the market for remote sensing data was considered underdeveloped in 1984, the federal government decided to provide a $250 million subsidy to the Earth Observation Satellite Company (EOSAT), which was selected by NOAA to operate the Landsat system. The subsidy would be used by EOSAT in addition to its capital to develop two new spacecraft, Landsat 6 and Landsat 7, that would replace the then-operating Landsat 4 and Landsat 5. In addition to the $250 million subsidy, the federal government would also pay launch costs for the two new satellites, and would continue to cover operational costs for the Landsat program through the expected lifetimes of Landsats 4 and 5.[57]

The Reagan Administration decided not to fulfill the original funding obligation to EOSAT, and several years of dispute ensued between the Administration and Congress over Landsat funding. Ultimately, the contract was revised to require the development of only Landsat 6, despite earlier agreement that two satellites would be needed to ensure data continuity.[58] The funding dispute led to further debates over the future of the Landsat program. Complicating the debate were different views about which launch vehicle should carry the next Landsats into orbit. EOSAT proposed that the satellite be designed for the space shuttle. However, the Reagan Administration disagreed, and NOAA instructed EOSAT to prepare the spacecraft for launch on an expendable rocket.[59]

Outcome

The Land Remote Sensing Policy Act of 1992 (P.L. 102-555) transferred Landsat program management from Commerce to NASA and the Department of the Interior (DOI), which effectively ended nearly a decade of debate over privatizing Landsat.

Whereas weather satellites were quickly identified as a public good during the 1983 debate, Landsat proved more difficult to categorize. One distinction is that NOAA has had a clear mandate to provide satellite data for weather services. In contrast, NOAA was selected to manage the Landsat program because of the agency's success with operating the weather satellites, and as an interim step en route to privatizing Landsat. The relatively unclear mandate for collecting land surface remote sensing data at NOAA may also have eroded customer confidence in the Landsat system, and in the agency's commitment to developing infrastructure, training personnel, and making other investments that would have bolstered the market for Landsat products.[60]

Although the Land Remote Sensing Policy Act of 1992 reversed the privatization track for Landsat and returned the satellite system to the federal government, the act also authorized the Secretary of Commerce to license operators of private remote sensing space systems.[61] It allowed the operators to use their data as they wish, including choosing their customers and offering their data at prices that vary by customer. Some analysts regard this licensing provision under Subtitle VI of the act as perhaps the most important provision for fostering commercial remote sensing

[57] CRS Report IB92092.

[58] See out-of-print CRS Report 87-477, *Privatization of the Landsat Remote Sensing Satellite System: Current Issues*, by Marcia S. Smith, available from Peter Folger on request.

[59] In part because of the 1986 Challenger accident, which grounded the space shuttle fleet.

[60] Williamson, p. 880.

[61] P.L. 102-555, Subtitle VI.

prospects in the United States.[62] Further, the development of technology to download, store, and distribute remotely sensed data contributed to the ability of commercial interests to add value to satellite data. The advent and rapid growth of geospatial information systems (GIS) has spurred an explosion of interest in the use of geospatial information, which typically includes land remote sensing data from space (e.g., Google Earth).

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Acknowledgments

The author of this report acknowledges the efforts of Carl Behrens, who retired in May 2014.

[62] Williamson, p. 882.