NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY
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Springfield, Virginia 22150

Steven Aftergood
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Washington, DC 20036

Sent via **U.S. mail**
November 28, 2012
Re: FOIA Case Number: **20100025F**

Dear Mr. Aftergood:

This letter responds to your **October 29, 2009** Freedom of Information Act (FOIA) request, which we received on **October 29, 2009**. You requested access to documents pertaining to **"*U.S. National Security and Economic Interests in Remote Sensing: The Evolution of Civil and Commercial Policy by James A. Vedda, Aerospace Corp., February 20, 2009, prepared for NGA Sensor Assimilation Division.*"**

A search of NGA's system of records located one document (37 pages) that is responsive to your request. We reviewed the responsive documents and determined they are releasable in full.

If you have any questions about the way we handled your request, or about our FOIA regulations or procedures, please contact Elliott Bellinger, Deputy FOIA Program Manager, at 571-557-2994 or by email at Elliott.E.Bellinger@nga.mil or via postal mail at:

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FOIA Requester Service Center
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Sincerely,

Elliott Belinger
Deputy FOIA Program Manager

AEROSPACE REPORT NO.
TOR-2009(3601)-8539

U.S. National Security and Economic Interests in Remote Sensing: The Evolution of Civil and Commercial Policy

20 February 2009

James A. Vedda
NSS Programs Policy and Oversight
National Space Systems Engineering

Prepared for:

National Geospatial-Intelligence Agency
Sensor Assimilation Division
Sunrise Valley Drive
Reston, VA 20191-3449

Contract No. FA8802-09-C-0001

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AEROSPACE
Assuring Space Mission Success

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14. ABSTRACT
The Aerospace Corporation prepared this report in partial fulfillment of a study for NGA on balancing national security and economic equities in satellite remote sensing. The report chronicles the policy history of civil and commercial remote sensing from 1960 through 2008. It highlights the difficulties in establishing a consistent government role in a field where public good and private profit exist side-by-side, and where business interests have the potential to contribute to and conflict with national security interests.

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Approved by:

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National Space Systems Engineering
Systems Planning and Engineering

Table of Contents

List of Figures

Foreword

The documentation and study of lessons learned is an important tool for guiding policy formulation and implementation, just as it is for technology development and operations. The policy history of civil and commercial remote sensing goes back to the beginning of the space age and is closely intertwined with national security policy. It has been remarkably difficult to establish a consistent government role in a field where public good and private profit exist side-by-side, and where business interests have the potential to both contribute to and conflict with national security interests. Despite a number of important achievements in remote sensing technology and applications, the policy history in this area is riddled with missteps, delays, and indecision. As the nation becomes increasingly dependent on civil and commercial satellite remote sensing capabilities for environmental monitoring, climate studies, resource and land use management, and support to national security needs, the errors of the past must be avoided so that the required capabilities can be provided in an affordable and timely manner.

This report is a component of a larger project begun in fiscal year 2008 by The Aerospace Corporation for the National Geospatial-Intelligence Agency (NGA). The project seeks to define the balance between the national security sector's needs and aspirations for satellite remote sensing and those of the economic and scientific communities. Aerospace's Center for Space Policy & Strategy contributed the civil and commercial analysis, presented here in two parts. The first part begins in the early days of the space age when NASA, NOAA, and other civilian agencies laid the groundwork for the science, technology, and eventual commercialization of remote sensing. The second part begins in 1992, a turning point for commercial remote sensing efforts. At that point, a major course correction in national policy began at the same time that technical advances and industry efforts started to show promise. By late 2008, considerable progress was evident in both commercial enterprise and NASA Earth science research, but difficult challenges remained for both endeavors.

1. Civil Remote Sensing Programs, 1960-1992

Earth observations, in addition to their utility for defense and intelligence purposes, yield important civilian benefits involving a wide range of disciplines. For example, satellite images can be used for weather forecasting, climate studies, map making, land use planning, pollution detection, wildlife conservation, mineral location, crop management, forest conservation, water supply management, and earthquake zone identification. Comprehensive estimates of the national and worldwide societal and economic benefits from applications of satellite remote sensing are impossible to determine. Numerous case studies related to resource exploration, agricultural use, and natural disaster mitigation and recovery have demonstrated that the benefits are real, though difficult to quantify. Weather data alone are responsible for saving untold millions of dollars annually in the U.S. in the transportation, utility, and agricultural sectors.[1]

The potential value of imagery from space was identified long before the dawn of the space age,[2] so it should be no surprise that space systems and applications directed toward realizing this potential were early goals of the U.S. civil space program. A logical start was the development of capabilities to augment existing government activities such as monitoring the weather.

1.1 Weather Satellites

Weather satellites require low spatial resolution since their primary task is tracking weather patterns that can cover vast areas. The less-demanding sensors for this job were addressed early in the space age and yielded immediate, obvious benefits. The first in a series of civilian weather satellites, the Television and Infrared Observation Satellite (TIROS), began service in 1960. In the decades that followed, civilian and military weather satellite programs developed in parallel with each other.

The U.S. government's civilian weather satellites are operated by the National Oceanic and Atmospheric Administration (NOAA), which is in charge of the National Weather Service. Spawned from the Environmental Science Service Administration and other legacy organizations going back to the early 19th century, NOAA was created within the Department of Commerce (DoC) in 1970.[3] In keeping with NOAA's mission, sensors for atmospheric research, such as radiometers, accompany the standard weather imaging hardware to perform additional functions such as tracking of atmospheric ozone concentrations. One of NOAA's polar orbiters documented the seasonal Antarctic ozone hole as early as 1978, though researchers didn't understand what the data meant until it was correlated with British ground observations seven years later.

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1 Ray A. Williamson, et al, "The Socioeconomic Benefits of Earth Science and Applications Research: Reducing the Risks and Costs of Natural Disasters in the United States," report prepared under NASA grant #NAG5-10539, July 23, 2001; Ray A. Williamson, et al, "The Socio-Economic Value of Improved Weather and Climate Information," George Washington University Space Policy Institute, December 2002.

2 For example, see Douglas Aircraft Company (Project RAND), "Preliminary Design of an Experimental World-Circling Spaceship," May 2, 1946, pp 10-14.

3 Eileen L. Shea, "A History of NOAA," http://www.history.noaa.gov/legacy/noaahistory_1.html, accessed November 2007.

As much as we still bemoan the errors made by the "weather guessers" on the local TV news, their seven-day forecasts are substantially more accurate than the two-day forecasts that were developed prior to the birth of weather satellites. In the decades since this capability emerged, countless lives, property, and crops have been saved as a result. We take for granted the nightly weather map shown on newscasts, but we are repeatedly reminded that early warning of a severe turn in the weather, made possible by a long-term commitment to satellite technology for the public good, can prove extremely valuable.

1.2 Human Earth Observation

Unclassified Earth observations from orbit for purposes other than weather started almost as an afterthought in the early 1960s using some fairly standard equipment: hand-held cameras and astronauts' eyeballs. Initially it was believed that the occupants of spacecraft orbiting at altitudes in excess of 100 miles would be incapable of discerning much detail on the Earth's surface. In fact, ground controllers originally did not believe the Mercury astronauts who reported what they saw below, such as Gordon Cooper's description of a train moving crossing the midwestern United States.[4] But after more experience and photographic proof, it was clear that a potentially valuable capability was in the making.

Earth observation in Project Gemini benefited from longer duration flights, an extra pair of eyes on each flight, a variety of orbital altitudes, and remarkably clear atmospheric conditions. The pictures brought back from the Gemini flights pointed the way for civilian applications of high-resolution imaging systems. This was evident even outside of NASA, particularly in the U.S. Departments of Interior and Agriculture. Crews aboard Skylab during 1973-74 followed up with even more extensive Earth observations from orbit, but by that time NASA had already launched the first civil remote sensing satellite.

The space shuttle program continued the tradition of human observations, with each flight bringing back pictures of Earth sometimes numbering more than a thousand. Shuttle astronauts are the most skilled observers the U.S. has sent into space, having been trained by the Space Shuttle Earth Observations Office at the NASA Johnson Space Center. Beyond simply learning how to use the camera equipment, astronauts also are taught how to identify and evaluate interesting phenomena and are briefed on what to look for on their particular flight. As the astronauts' trainers have noted,

> ... astronauts are unexcelled at detecting dynamic phenomena whose existence and location cannot be predicted. Astronauts operate in a discovery mode: detecting, evaluating, and documenting anomalous phenomena. This capability is not matched by any existing or planned satellites.[5]

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4 Pamela E. Mack, *Viewing the Earth: The Social Construction of the Landsat Satellite System* (Cambridge: MIT Press, 1990), pp. 39-40.

5 C.A. Wood, M.R. Helfert, & K.P. Lulla, "Earth Observations During Space Shuttle Flight: STS-26, *Discovery*'s Mission to Earth, September 29-October 3, 1988," *Geocarto International* (2), 1989.

1.3 Landsat: Experimental or Operational System?

Drawing on what had been learned from early human spaceflights, the development of weather satellites, and the agency's work on Lunar Orbiters and other space probes, NASA established its first Earth resources program in 1964. The Departments of Interior and Agriculture quickly took interest, but became frustrated with NASA's approach. Interior and Agriculture wanted a simple, affordable satellite system that could be brought into service quickly to serve immediate needs. However, NASA wanted an experimental system aimed at advancing the state of the art in sensor technologies and favored the use of manned platforms. NASA did not want to become an operator of an orbital imagery service for other agencies, nor did it want to share the planning or control of the system. By 1966, the user agencies, especially Interior, wanted to forge ahead on their own, but budget concerns and eventual interagency compromises would prevent this from happening.[6]

The Bureau of the Budget (later renamed the Office of Management and Budget, OMB) did not want to fund an ongoing operational system unless it could be demonstrated that such a system would pay its way through savings to user agencies and/or fees collected from users outside the U.S. government.[7] With this restriction in mind, an interagency compromise was reached and NASA launched its first land remote sensing satellite in 1972. Initially called the Earth Resources Technology Satellite, it was renamed Landsat, a label that has been applied to seven members of the series to date. NASA originally was responsible for designing, procuring, launching, and operating the spacecraft, including data collection at the Goddard Space Flight Center, while the Department of Interior's U.S. Geological Survey (USGS) was given the task of archiving and distributing the data, to be carried out by the newly established EROS Data Center in Sioux Falls, South Dakota.

The experimental satellite's user community was expected to consist almost exclusively of NASA, Interior, Agriculture, and their associated research communities around the country. But even before the launch of the first satellite, scientific interest in the U.S. and around the world far exceeded NASA's expectations.[8] By the time it completed its first decade of operation, the Landsat system had users throughout the government, including the Defense Department and state and local agencies; corporations, especially oil and mineral companies, as well as private firms offering processing and analytical services for the raw data; environmental groups; and foreign users in over 130 countries, some of which built their own ground stations to receive the data.[9] However, despite the extent and diversity of this community, it was not enough to justify development of an operational system. Users paid only for distribution costs, and it was evident that many would not continue to use the data if they were required to pay a price reflecting the full costs of the system. Also, many potential users did not want to become reliant on a system that could change its specifications or disappear at any time. This limited Landsat's constituency, making it difficult to prove the operational utility of Earth resources satellites using an experimental system.

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6 Mack, pp. 45-65.
7 Mack, pp. 88-93.
8 Mack, p. 126.
9 M. Mitchell Waldrop, "Imaging the Earth: The Troubled First Decade of Landsat," *Science* (March 26, 1982), Vol. 215, p. 1601.

The first three Landsat spacecraft flew in the 1970s with two instruments, the Return Beam Vidicon and the Multi-Spectral Scanner (MSS). When the time came to plan Landsat 4, NASA wanted to replace the Vidicon with a new sensor called the Thematic Mapper (TM), and the OMB proposed eliminating the MSS on the grounds that it was ready for operational use and therefore did not belong on an experimental satellite. Although the TM would improve spatial resolution to 30 meters (compared to 80 meters for the MSS), it would produce data incompatible with the MSS system. The users of MSS data were a large enough group by this time that the proposed change prompted an outcry to save the MSS and a recommendation by an ad hoc council in the White House Office of Science and Technology Policy to continue flying the MSS.[10] Both the MSS and TM sensors flew on Landsats 4 and 5, launched in July 1982 and March 1984, respectively. Both satellites lasted well beyond their expected lifetime, with marginal functionality still available more than 20 years later.

Landsat 6 was lost in a launch failure in October 1993. Landsat 7 made it to orbit safely in April 1999 and continues to function as of this writing, although with degraded capabilities.[11] These launches followed more than a decade of activity aimed at stabilizing the land remote sensing program, but this goal would remain elusive.

1.4 A Failed Attempt at Privatization

The seemingly rapid evolution of Landsat applications led some to believe, in the late 1970s, that land remote sensing was ready to be moved out of the federal government to become a profit-making private sector activity, as had been done with communications satellites several years earlier. Proposals for an operational Landsat system were brought to Congress and the executive branch, some favoring government management, some preferring the private sector, others encouraging the creation of a quasi-private company similar to Comsat.[12] The issue remained unresolved – partially because several congressional committees claimed jurisdiction over at least some part of Landsat's activities – so the White House attempted to settle the matter with a presidential directive in November 1979.[13] NASA would continue remote sensing technology development, but Landsat operational duties would shift to NOAA, which was chosen because of its experience in operating the weather satellites. Also, it was felt that since NOAA was not a user of the higher-resolution remote sensing data, it would not tend to favor the design of future systems that would serve in-house needs at the expense of other user needs. While NASA, Commerce, and Agriculture approved of this arrangement, Interior and the Agency for International Development felt that Interior should have been given responsibility because it had been managing Landsat data processing and distribution since the start of the program.[14]

President Jimmy Carter's directive made NOAA's control of Landsat temporary. One of the agency's assigned duties was to devise a plan for the phased transfer of remote sensing to the private sector. This would assure data continuity while the privatization process was being implemented. Funding was included in Carter's final budget request for two additional spacecraft beyond the ones already

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10 Waldrop, p. 1602.

11 U.S. Geological Survey, "Landsat Project," http://landsat.usgs.gov/, accessed November 2007.

12 John McLucas, *Space Commerce* (Cambridge: Harvard University Press, 1991), p. 122-126.

13 Presidential Directive 54, "Civil Operational Remote Sensing," November 16, 1979.

14 Patricia E. Humphlett & Marcia S. Smith, "Landsat (Earth Resources Satellite System)," Issue Brief Number IB82066, Library of Congress, Congressional Research Service, Washington, D.C., December 27, 1982, p. 7.

being planned. This would guarantee coverage into the 1990s, by which time the transfer should be complete.

Despite this high-level attention, the debate was not settled over who should operate the Landsat system or whether land remote sensing primarily served the public good or private interests. The Carter plan did not have the opportunity to demonstrate whether or not it could have resulted in a smooth, albeit lengthy transition for Landsat operations. Ronald Reagan took over the White House a little over a year later with different ideas about the privatization of government programs.

When the Reagan administration entered office in 1981, the two additional spacecraft were quickly cut from the budget, and OMB director David Stockman declared that when the fifth Landsat expired (then expected to be around 1987), the government would be out of the remote sensing business, and private industry would inherit the responsibility.[15] During 1981-84, OMB downplayed the significance of scientific and foreign relations gains from Landsat, viewing the program as a money sink. The Reagan plan accelerated Carter's privatization timetable: there would be no more government-funded Landsats after number five (which was already being built), so the system would be terminated if no private operator came forward by 1988.

Meanwhile, Comsat Corporation had been keeping its eye on Landsat, and now saw an opportunity to move. Comsat approached OMB with a plan to take over Landsat, provided that the weather satellite system was included in the deal, and that the government would guarantee a minimum annual purchase of data. The OMB saw this as a way to unload Landsat quickly and without direct subsidy. But no one had thought about privatizing the weather satellites, so the Cabinet Council on Commerce and Trade (CCCT), along with its numerous advisory groups, studied the idea for almost two years. They concluded that even with both systems packaged together, subsidy would still be necessary. The CCCT recommended that Commerce solicit bids for the land and weather systems separately, but that joint bids for both would be allowed. To many this appeared to be a setup for Comsat, since no one else had expressed interest in the weather satellites.[16]

Congress had not been consulted as the administration developed its plan, and the Hill had strong objections to the privatization of the weather satellites. The Land Remote Sensing Commercialization Act of 1984 spelled out how Congress felt the transfer should take place, and prohibited the transfer of weather satellites.[17] Federal subsidy would be provided in the early years of the transfer, and the amount that became a guideline in the bidding was $150 million per year, a figure that had been mentioned in a March 8, 1983 administration statement on privatization of Landsat.[18]

The Landsat debate is an illustration of the classic tug-of-war between Congress and the executive branch. Neither branch wanted the other to seize the initiative in setting the nation's remote sensing

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15 M. Mitchell Waldrop, "Imaging the Earth: The Politics of Landsat," *Science* (April 2, 1982), Vol. 216, p. 41.

16 M. Mitchell Waldrop, "What Price Privatizing Landsat?" *Science* (February 11, 1983), Vol. 219, p. 753-754.

17 Public Law 98-365, "Land Remote Sensing Commercialization Act of 1984," July 17, 1984.

18 Statement by Dr. John V. Byrne, Administrator, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, March 8, 1983.

policy. The Reagan administration, promoting reductions in government programs, took office and found the Congress still indecisive on the Landsat issue. The White House moved quickly to speed up Landsat privatization, causing Congress to respond hastily, passing ill-conceived legislation that hindered rather than helped the new industry and its user community.

Notably, neither the White House nor the Congress took heed of the finding of the Office of Technology Assessment, reported to Congress two months before the legislation passed: "Until the market expands substantially, and more efficient spacecraft are developed and deployed, it could cost the Federal Government as much to subsidize a private owner as to continue operating the system itself."[19]

The office of Commerce Secretary Malcolm Baldrige, which was handling the bidding process for Landsat, received seven bids, each requesting a total subsidy of approximately $500 million. The field was narrowed to two bidders: Earth Observing Satellite Company (EOSAT), a joint venture of RCA and Hughes Aircraft; and the team of Kodak, Fairchild, and TRW. When OMB Director Stockman heard of the subsidy commitment that was about to be made, he intervened to insist that there should be no subsidy at all. When the issue was finally settled at the White House level, a ceiling of $250 million was placed on the total subsidy. As a result, the Kodak team quietly withdrew its bid, and EOSAT became the winner by default.[20]

The Department of Commerce negotiated an agreement with EOSAT that became effective in September 1985 under which the company would operate Landsats 4 and 5 and market their data. The existing ground and space segments would continue to be owned by the U.S. government, but new hardware – including two follow-on satellites, for which the government would provide $250 million over five years plus launch costs – would belong to EOSAT. As specified in the 1984 Landsat legislation, the company would be required to maintain a non-discriminatory data access policy and abide by international treaties and agreements that affected its activities.[21]

Policies and agreements are only as good as their implementation, and this is where the Landsat arrangement faltered, immediately and repeatedly. A month after the agreement went into effect, DoC submitted its FY87 budget request but neglected to include funding for EOSAT. Meanwhile, a $90 million supplemental had been obtained to carry EOSAT through 1986, allowing development of the next satellite to begin. However, in mid-1986, OMB Director Stockman refused to release funds from the supplemental, prompting a reaction from industry lobbyists and the Senate Commerce Committee. When a compromise was reached, the subsidy was approved, but EOSAT had to provide additional assurances that it would produce two satellites and forego an escalation clause in its agreement that could have allowed the subsidy to increase. Additionally, it was specified that there would be no guarantee of data purchases by the government. These added risks forced a financial restructuring at EOSAT.[22]

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19 U.S. Congress, Office of Technology Assessment, "Remote Sensing and the Private Sector: Issues for Discussion" (Washington: Government Printing Office, March 1984), p. 3.

20 M. Mitchell Waldrop, "White House Slashes Landsat Subsidy," *Science* (September 21, 1984), Vol. 225, p. 1373.

21 Brendan M. Greeley, "Commercial Marketing of Landsat Data Begins," *Commercial Space*, Fall 1985.

22 "EOSAT struggles for money and market," *Space Business News*, June 16, 1986.

The House approved $75 million for Landsat in July 1986, but none of this amount was earmarked for EOSAT.[23] Subsequently, Congress appropriated only $27.5 million for the transition of Landsat operations to the private sector. As a result, the hardware development subsidy dried up in September 1986 and EOSAT kept the work going with internal funds until December.[24] Around that time, DoC once again failed to include EOSAT in its annual (FY88) budget request, and a squabble ensued between the two organizations as to whether the company should be expected to produce two satellites as originally promised. The next release of hardware funding did not occur until October 1987, and the amount was just $5 million.

Something had to give if the program was to move ahead, so in April 1988 the DoC awarded a $220 million hardware development contract to EOSAT and reduced the company's requirement to one satellite instead of two. A small portion of this award was actually a loan – $2.5 million per year was to be returned, up to a total of $10.8 million.[25]

The Reagan administration did not request funding to sustain Landsat operations for FY89. With the Landsats expected to expire in a short time, Congress appropriated $9.4 million, enough to continue operations for about six months.[26] NOAA temporarily shut down data collection operations at U.S. ground stations in November 1988 to cut costs, although satellite control and data downlinks to foreign stations were maintained. To the surprise of EOSAT, NOAA announced that it had entered negotiations with the French space agency CNES on a possible merger of the Landsat and SPOT programs to share costs and the customer base.[27]

By March 1989, the situation had gotten so bad that NOAA announced the imminent shutdown of Landsats 4 and 5, prompting the White House National Space Council, newly formed by the George H.W. Bush administration, to intervene. The Space Council brokered a deal in which NASA, DoD, Interior, and Agriculture contributed a few million dollars to keep Landsat alive. A similar arrangement kept Landsat going through 1990 using contributions from DoD ($5.6 million), Agriculture ($3 million), and USGS ($900,000). In the process, the Space Council acknowledged the government's continuing role in satellite remote sensing, recognizing that Landsat could never be fully commercial.[28]

EOSAT was unable to get on its feet financially despite the fact that data prices soared from the early 1980s to the beginning of the 1990s. The price per scene jumped from a few hundred dollars to $4400, and redistribution of the imagery was restricted. This priced many data users out of the market, driving some to switch to the free low-resolution data being captured by meteorological satellites. According to Rep. George Brown, who was chairman of the House Science, Space, and Technology Committee in 1991, the scientific community purchased up to 70,000 Landsat images per year in the late 1970s, but this number shrank to around 300 per year a decade later.[29] Furthermore,

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23 "House reinstates EOSAT budget," *Space Business News*, July 28, 1986.
24 "EOSAT, Congress await NOAA plan," *Space Business News*, November 3, 1986.
25 "Congress okays Landsat plan – reluctantly," *Space Business News*, April 4, 1988.
26 Landsat Program Chronology, http://geo.arc.nasa.gov/sge/landsat/lpchron.html, accessed December 2007.
27 McLucas, p. 124.
28 White House Office of the Press Secretary, Statement by the Press Secretary on continued operation of Landsat, June 1, 1989.
29 Andrew Lawler, "Brown Offers Solution for LANDSAT Fiasco," *Space News*, Vol. 2, No. 37, p. 1, 28 October - 3 November, 1991.

Landsat was no longer the only game in town. The French SPOT satellite had broken the U.S. monopoly in 1986.

During the period from the mid-1980s through the 1990s, Landsat system calibration suffered and coverage was far less thorough because data typically was collected only when there was an established customer. As a result, many observations that could have contributed to scientific study were missed. For government agencies, this was a disincentive to making hefty investments in computer hardware and software for a system with unreliable performance and an uncertain future.[30]

The failure of Landsat privatization since the 1984 legislation prompted the Bush administration in 1992 to put forth a new strategy calling for completion of Landsat 6, continued operation of Landsats 4 and 5 until Landsat 6 was operational, development of a government-owned Landsat 7, and the crafting of a plan for management, funding, operation, dissemination, and archiving for the Landsat program, including options for the system beyond Landsat 7.[31] The Land Remote Sensing Policy Act of 1992, which repealed the 1984 statute, became law later that year (discussed further in Part 2).

The Landsat experience from the 1970s through the 1990s was an example of inefficient and ineffective policy-making. For several years prior to its legislative action in 1984, the Congress had discussed many scenarios for Landsat operations (e.g., a weather satellite model or a Comsat/Intelsat model). Then, goaded by the administration, it joined the executive branch in supporting an approach that was unlikely to succeed given the lack of technical and market maturity of civil remote sensing. For its part, the White House failed to achieve its goal of removing Landsat from dependence on taxpayer dollars. Unreasonable expectations, faulty implementation, and a roller-coaster relationship between the contractor and the government sealed the fate of the privatization plan. The ultimate losers were the Landsat data users and the value-added entrepreneurs who were attempting to create a new industry. It should not be surprising that no other companies applied for licenses to operate commercial remote sensing satellites until after the passage of the 1992 Act.

1.5 Factors Affecting the Viability of Commercial Remote Sensing

Several factors stand in the way of rapid, widespread acceptance of remote sensing services. Ironically, the fact that remote sensing has such a wide variety of applications can be a hindrance to building a user community. Non-technical users, and even potential professional users who are unfamiliar with the technology and the multitude of data interpretation techniques, have difficulty comprehending its value. Productive use of remote sensing imagery requires special training, unlike satellite communications and navigation services that can deliver benefits through simple-to-use devices.

In its early years, civil remote sensing did not share the advantages that sparked rapid acceptance of satellite communications at around the same time. While demand for satellite imagery is substantial, it does not have the universal appeal of communications. The basic product, raw digital imagery, is ill-defined, in sharp contrast to homogeneous services like telephone calls or television programming. Consumers around the world will use communications routinely, for entertainment and personal

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30 NASA, "The Landsat Program," http://landsat.gsfc.nasa.gov/about/landsat5.html, accessed November 2007.

31 National Space Policy Directive 5, "Landsat Remote Sensing Strategy," February 5, 1992.

needs as well as for revenue-generating activities. Not so with remote sensing – potential users require considerable convincing that the imagery provides them with added value worth the price.

Satellite communications also had the advantage that the necessary physical and regulatory infrastructure was already in place around much of the globe when it emerged on the scene. Once the ground stations were plugged into the grid, they merged into the network in much the same way as relay towers or undersea cables. Such a network did not exist for satellite remote sensing, and is still in the formative stages.

Although President John F. Kennedy attached great importance to weather satellites as the space age began,[32] no presidential fanfare heralded the appearance of other types of civil remote sensing. Only rarely were decisions regarding this activity raised to the highest levels, and no long-term funding commitment was made. Federal support for U.S. civil remote sensing R&D over the years has been a small and irregular part of NASA's budget.

Communications satellite systems revolutionized an important industry sector, making it clear to all that they needed to quickly become operational systems. This won them early acceptance into the mainstream of daily activities. In contrast, perhaps the biggest factor holding back the evolution of civil remote sensing in the U.S. was insistence that Landsat remain an experimental system. NASA is partly responsible for this situation. The space agency wanted to keep pushing the state of the art in space-based sensors rather than serve operational users, and also wanted to retain control of the system for as long as possible. OMB drove planning in this direction well before the first Landsat flew by insisting that once a remote sensing system moved from experimental to operational it should no longer be funded by the government.

The resulting program was planned and implemented across several agencies that split the responsibilities and was overseen by numerous congressional committees. Landsat was assigned experimental frequencies, and no provision was made for rapid processing and distribution of large volumes of data (at the insistence of OMB), guaranteeing its inability to function adequately in an operational environment.[33]

Sorting out the appropriate roles of the government and the private sector has been complicated by the fact that remote sensing is a public good – an appropriate undertaking for the government – as well as a revenue-generating activity. Sometimes both of these characteristics are present in a single image. So far, private operators have found that the majority of their sales are to government entities, both domestic and foreign, and the public good/private profit debate continues.

1.6 Foreign Interest Leads to a Proliferation of Orbital Observers

In addition to delivering domestic benefits, the U.S. government's non-discriminatory ("open skies") data policy that was established early in the Landsat program helped civil remote sensing become a successful soft-power tool that contributed to American foreign policy. Within five years after the launch of the first Landsat in 1972, over 130 countries enjoyed access to satellite imagery, and several

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32 President John F. Kennedy, speech to a joint session of the U.S. Congress titled "Urgent National Needs," May 25, 1961.

33 McLucas, p. 118.

countries purchased their own ground stations to allow direct downlink of the satellite data.[34] For many developing countries, the benefits were quick and significant. For example, countries with large undeveloped regions were able to make their first accurate maps. Brazil was able to correct the recorded positions of Amazon River tributaries, some of which were off by as much as 20 kilometers. U.S. embassies around the world reported that substantial good will was gained by the sharing of Landsat images.[35]

Some foreign governments raised objections to the sensing of their countries without explicit permission. In their view, open availability of satellite imagery could undermine their national security or economic competitiveness as commercial interests and other governments exploited the data, possibly without the sensed nations even realizing that the data existed.[36] These objections were largely alleviated by the non-discriminatory access policy. All data collected by Landsat was available to all interested parties at the same price. This practice was in keeping with the spirit of the Outer Space Treaty, which states that "The exploration and use of outer space... shall be carried out for the benefit and in the interests of all countries..." (Article I) and "States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space... with due regard to the corresponding interests of all other States Parties to the Treaty" (Article IX).[37]

Foreign concerns about Landsat predated the launch of the first satellite, as did efforts by the United Nations to defuse the problem. The U.N. General Assembly asked the Committee on the Peaceful Uses of Outer Space to address international cooperation in remote sensing in December 1969, but the Committee's legal subcommittee did not begin work on the issue until 1974. By that time, non-discriminatory access was standard practice, easing the urgency for action.[38] However, many nations still wished to establish international norms, especially with operational civil and commercial imaging satellites on the horizon. Agreement was finally reached on remote sensing principles in 1986. In general, these principles reiterate Outer Space Treaty concepts in a manner specific to remote sensing, and encourage international cooperation "taking into particular consideration the needs of developing countries."[39]

While the U.S. struggled with how to make Landsat operational, other countries around the world sought their own indigenous satellite imaging capabilities. The United States' 14-year head start in civil remote sensing eroded quickly after the February 1986 launch of the French SPOT satellite. Developed by the European Space Agency and then handed over to a newly formed commercial organization, SPOT offered better spatial resolution than Landsat (10 meters as opposed to the thematic mapper's 30 meters) but inferior spectral resolution (four bands rather than seven). More significant than the technical specifications was the worldwide marketing effort that started three

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34 American Institute of Aeronautics and Astronautics, *Space: A Resource for Earth* (New York: AIAA Publications, April 1977), p. 28.

35 Mack, p. 189.

36 Charles K. Paul & Adolfo C. Mascarenhas, "Remote Sensing in Development," *Science* (October 9, 1981), Vol. 214, pp. 139-145.

37 United Nations General Assembly, "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies" (Outer Space Treaty), 1967.

38 Mack, p. 187.

39 United Nations General Assembly, "Principles Relating to Remote Sensing of the Earth from Space," 1986.

years before SPOT-1 was launched. The Europeans had planned from the beginning that SPOT would be an operational system serving a global customer base, not an experimental one with limited distribution channels like Landsat.

The operating company, Spot Image Corp., currently operates the fifth in the series of SPOT satellites. It has maintained an appearance of stability that is unmatched by the Landsat system, an important factor to customers who want an ongoing flow of compatible data products. Spot Image managed to outsell its U.S. competitor by its fourth year of operation.

Soon after the arrival of SPOT, it became clear that other nations would enter the global remote sensing market. Soviet prowess in civil and military applications of space imagery emerged in a diverse assortment of offerings that eventually included photographic, digital, and radar images. The organization Soyuzcarta began by marketing photographic imagery with spatial resolution as good as five meters, although only archival images were for sale and none were made available from areas within Eastern Bloc countries.[40] Radar imagery with 15-meter resolution from the Almaz satellite became available in 1991, making the Soviet Union the first nation to launch an operational radar satellite serving commercial users.

Around the world, satellite remote sensing has long been acknowledged to have great value, even though no space imaging system so far has been able to turn a profit without help from a substantial government subsidy. Other nations have followed the lead of the United States, France, and the Soviet Union by investing in their own Earth observing satellites in order to join the world market for satellite imagery. Sometimes this has meant pursuing a niche area that is important to particular national needs. For example, Japan, home to the world's largest fishing fleet, began operating its Marine Observation Satellite in 1987.

In general, the pretension that remote sensing satellites are profit-making ventures has been disproven so far, as some level of government support has continued to be necessary. Fully equipped spacecraft like Landsat and SPOT have required up to five years and well over $200 million to build, plus launch and ongoing operations costs. Enhancing, interpreting, and integrating the data as a service to end users is the profitable segment of the business, involving hundreds of "value added" companies that have appeared globally since the late 1970s.

[40] Jay Lowndes, "Soviets Selling Sharpest Satellite Imagery," *Aerospace America*, March 1988; James Harford, "Soyuzcarta's Hard Sell," *Aerospace America*, November 1989.

2. Civil and Commercial Remote Sensing, 1992-2008

Renewed interest in environmental monitoring and the high priority assigned to the new U.S. Global Change Research Program prompted both Congress and the administration of George H.W. Bush to adjust remote sensing policy in general, and Landsat policy in particular, to better serve the needs of users inside and outside the U.S. government. Executive branch and legislative policy-makers recognized that Landsat privatization had failed, and that the 1984 Act's goals of maintaining leadership in civil remote sensing and preserving national security were not being served.

2.1 Corrective Action on Remote Sensing Policy

In the early 1980s, the Reagan administration treated civil remote sensing as a drain on the federal budget, an activity that should be handed off to the private sector to thrive or perish. By the early 1990s, when it was recognized that full privatization of Landsat was not possible, even the promoters of the previous decade's remote sensing commercialization plan who were still in office had to admit that it wasn't working.

A February 1992 White House directive sought to correct this situation and maintain continuity of Landsat-type data by directing U.S. government agencies to:

- Provide data which are sufficiently consistent in terms of acquisition geometry, coverage characteristics, and spectral characteristics with previous Landsat data to allow comparisons for change detection and characterization;
- Make Landsat data available to meet the needs of national security, global change research, and other federal users; and,
- Promote and not preclude private sector commercial opportunities in Landsat-type remote sensing.[41]

(The Clinton administration's Landsat strategy reiterated these policy goals in 1994 and made adjustments to the Bush strategy to compensate for the launch failure of Landsat 6.[42])

Congress followed in October of that year with the Land Remote Sensing Policy Act of 1992[43] which repealed the Land Remote Sensing Commercialization Act of 1984. The 1992 Act encompassed the strategic elements outlined in the Bush directive, and more. It brought the Landsat program back under government control starting with Landsat 7. The legislation called for a Landsat advisory committee and a management plan under which NASA and DoD would have responsibility for procurement, launch, and operation of that satellite. These duties eventually were assigned to NASA alone.[44]

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41 George H.W. Bush, National Space Policy Directive 5, "Landsat Remote Sensing Strategy," February 5, 1992.

42 William J. Clinton, Presidential Decision Directive 3, "Landsat Remote Sensing Strategy," May 5, 1994.

43 Public Law 102-555, "Land Remote Sensing Policy Act of 1992," signed October 28, 1992.

44 NASA and the Department of Defense, "Landsat 7 Transition Plan," February 7, 1994.

During the eight years that the 1984 Act's provisions were in effect, no U.S. company applied for a license to operate a private remote sensing space system. In stark contrast, just four months after passage of the 1992 Act, the first license was issued by the Department of Commerce to WorldView Imaging Corp., and license applications from Lockheed and Orbital Sciences Corp. quickly followed. Changes to pricing restrictions and data access policies made the difference that turned around the business environment for prospective satellite operators.

The 1984 Act required continuation of the non-discriminatory access ("open skies") policy that had been in place since the earliest days of Landsat. In order to address the concerns of foreign governments regarding possible exploitive use of data on their countries by other governments or corporations outside their borders, raw data was made available to all potential users on the same terms. With the U.S. government as the operator, and the price set at the cost of duplication and distribution, this was a workable system. For the commercial operator, however, this eliminated the ability to offer different terms to different customers, such as bulk discounts, priority service, or exclusive imagery sets. Additionally, as prices jumped enormously in an attempt to approximate the product's true market value,[45] a large swath of the academic and developing country customer base could no longer afford the imagery. In effect, the non-discriminatory policy had become discriminatory due to high prices. At the same time, the strict interpretation of non-discriminatory access hindered development of a competitive market, thus preventing the product and service innovations that might have brought prices down and driven capabilities up.

The 1992 Act recognized that commercial systems need to operate by different rules than Landsat or other government systems. For commercial operators, non-discriminatory access was redefined to require only that companies make raw data available to the governments of sensed states. Imagery sellers could now price and package their products more flexibly for their civil and commercial customers (within limits, as discussed below). While this does not guarantee a successful business plan, it removes a major obstacle.

As the door opened for commercial operators to propose their own remote sensing systems, the door closed for privatization of Landsat. Under the new law, the U.S. government would retain ownership of the system and any follow-on satellites. More importantly for research and other non-profit users, the government would hold title to all unenhanced data and would continue its traditional non-discriminatory access policy, making the imagery available to all users at the cost of fulfilling data requests. Value-added services would continue to be a private-sector function.

Despite the legislation, the future of the Landsat series continued to be in doubt due to budget shortfalls and ideological resistance from some members of Congress, who believed it was neither necessary nor appropriate for the federal government to be in the civil remote sensing business. Before discussing the most recent developments in the Landsat story, we now turn to the commercial remote sensing activities enabled by the changed policy environment.

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45 Landsat imagery was priced as low as $200 per scene in the 1970s and rose to $4000 per scene by the mid-1980s.

2.2 Commercial Remote Sensing Policy Takes Shape

Prior to the 1992 Act, EOSAT had been the only player in the U.S. commercial remote sensing field. Through the rest of the 1990s, the picture changed dramatically. As mentioned earlier, Lockheed was an early applicant for a license, which was granted in April 1994 for its proposed Ikonos satellite. Six months later, Lockheed created a subsidiary called Space Imaging to take over the remote sensing business. Space Imaging grew in 1996 by acquiring EOSAT, which still held the license to operate Landsats 4 and 5 and market their data.[46] This gave the company a presence on the imagery market well in advance of the launch of its first satellite. After the first Ikonos was lost in a launch failure in April 1999, the backup spacecraft was successfully orbited that September, becoming the first high-resolution commercial satellite. It featured spatial resolution of one meter for panchromatic imagery and four meters for multispectral.

On July 1, 2001, about two years after the successful launches of Ikonos and Landsat 7, Space Imaging returned operational responsibility for Landsats 4 and 5 back to the U.S. government and relinquished its right to commercially market Landsat data. This cleared the way for the U.S. Geological Survey to sell all Landsat 4 and 5 data, and for Space Imaging to focus on developing the high-resolution imagery market.

With the 1999 launch of Ikonos, commercial remote sensing attained the capability to widely distribute current, militarily useful imagery at a resolution previously available only to the national security components of a few governments. This had been anticipated and addressed by the Clinton administration.

Imagery collection from space is a dual-use technology that can contribute to both economic pursuits and national security. Landsats 4 & 5 (30-meter resolution) and the early SPOT satellites (10-meter resolution) did not prompt significant security fears because the military usefulness of their images was limited. But new capabilities in the 1-meter range like Ikonos – able to distinguish, for example, individual vehicles and specific types of airplanes – did raise security concerns if the imagery could be purchased by anyone in the world who could afford it. Presidential direction to head off these concerns came in 1994 with Presidential Decision Directive (PDD) 23.[47]

PDD-23 wisely did not impose a specific resolution limit on commercial sensors. The interagency team that drafted the directive recognized that the technology, both domestic and foreign, would always be a moving target. Instead, PDD-23 specified case-by-case review of remote sensing license applications, with favorable consideration of systems "whose performance capabilities and imagery quality characteristics are available or are planned for availability in the world marketplace."

At first glance, this language would seem to force U.S. businesses to always be followers, never leaders on the world market. In practice, licenses have been issued by the Department of Commerce that keep U.S. operators ahead of their foreign competition, at least for optical imaging systems.

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46 Space Imaging press release, "Space Imaging and EOSAT Agree on Acquisition," November 5, 1996 (http://www.geoeye.com/newsroom/releases/si_Archive/1996_EOSAT_aquisition.htm, accessed November 2007).

47 William J. Clinton, Presidential Decision Directive 23, "Foreign Access to Remote Sensing Space Capabilities," March 10, 1994.

DigitalGlobe and GeoEye today hold licenses that allow them to operate imaging satellites in the sub-meter range.

The conditions attached to the licenses were developed in the regulatory process in the years after PDD-23, which assigned the regulatory duties to the Commerce Department (with advice from the interagency process). The Secretary of Commerce, in consultation with the Secretaries of State and Defense, has the authority to "require the licensee to limit data collection and/or distribution by the system to the extent necessitated by the given situation."[48] This authority is known as shutter control, and has caused controversy due to its implications for operators' business plans and marketability as well as the questions it raises on freedom of speech issues.

Government officials have said that they would prefer never to use shutter control, but such statements provide no guarantees and leave some outside observers doubtful. To date, shuttler control authority has not been exercised, although in the months following the 2001 invasion of Afghanistan a contractual arrangement was implemented that was labeled "checkbook" shutter control. The U.S. government simply purchased exclusive rights to all high-resolution (1-meter) commercial satellite imagery of Afghanistan that was on the market at the time. This was easy to do because all such imagery came from one satellite (Ikonos) licensed by the U.S. government. Since then, the opportunity has passed for checkbook shutter control to be a viable option. As high-resolution satellite systems proliferate, there is a decreasing likelihood that the U.S. government would be able to buy exclusive rights to all imagery over a particular area for an extended period of time, especially since many capable systems will not be licensed in the U.S.

Commercial remote sensing licenses have contained other restrictive elements in addition to the shutter control provision. For example, commercial systems with foreign ground stations have been required to place limits on the satellite tasking capabilities and distribution rights of those stations, and companies offering imagery with sub-meter resolution have been required to delay distribution for at least 24 hours after it is collected.

Other U.S. laws in addition to the 1992 Act are relevant to remote sensing companies. The most prominent of these, due to its specific applicability to satellite imagery providers, is the Kyl-Bingaman Amendment, passed in 1996 as part of the 1997 defense authorization act. It allows collection and dissemination of satellite imagery of Israel "only if such imagery is no more detailed or precise than satellite imagery of Israel that is available from commercial sources."[49] To date, this has meant that commercially available imagery of Israel has been limited to about two-meter resolution.

Israel is the only nation to receive U.S. statutory protection from high-resolution observation. It has been justified as a concession to an important U.S. ally that is surrounded by unfriendly neighbors. In the wake of this legislation, other allies, including France and India, sought similar accommodation but did not receive it.[50] However, the value of this arrangement to Israel will be short-lived. As

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48 Ibid.

49 Kyl-Bingaman Amendment, National Defense Authorization Act for Fiscal Year 1997, §1064, "Prohibition on Collection and Release of Detailed Satellite Imagery Relating to Israel," House Report 104-724, July 30, 1996.

50 Scott Pace, "The Future of Space Commerce" in W. Henry Lambright (ed.), *Space Policy in the Twenty-First Century* (Baltimore: Johns Hopkins University Press, 2003), p. 77.

foreign systems join U.S. providers at the one-meter or sub-meter level, the limit on imagery of Israel will change as well, and at some point will become moot.

PDD-23 was superseded by an updated presidential directive (NSPD-27) in April 2003.[51] In addition to dealing with the provision of imagery and related technologies to foreign interests, which was the subject matter of PDD-23, the new directive addressed more broadly the interaction between the U.S. government and the U.S. satellite remote sensing industry. Its stated goal is to "advance and protect U.S. national security and foreign policy interests by maintaining the nation's leadership in remote sensing space activities, and by sustaining and enhancing the U.S. remote sensing industry." The principal strategy for achieving this goal directs national security and civil federal agencies to "rely to the maximum practical extent on U.S. commercial remote sensing space capabilities" and to develop their own remote sensing space systems only to meet "needs that can not be effectively, affordably, and reliably satisfied by commercial providers because of economic factors, civil mission needs, national security concerns, or foreign policy concerns."

Conceptually, this is a straightforward approach. Routine government needs, such as updating maps, would use commercial imagery, freeing government assets to perform more specialized or sensitive duties. Ideally, this would ease tasking bottlenecks and workloads of expensive government systems, possibly reducing the number of satellites needed. As commercial systems improve in product quality and service, no utility would be lost, and some new functionality would be gained as the government received a steady stream of unclassified imagery that could be easily shared with uncleared personnel such as domestic first responders or foreign allies.

Implementation of NSPD-27 has required that entrenched practices and cultural perspectives be addressed, such as:

- Reluctance of agency personnel to change habits or procedures.
- Agency accounting practices that make government imagery appear "free" while commercial imagery drains the budget.[52]
- Persistent belief among government users that inferior quality and slow delivery will always plague commercial imagery as compared to government sources.
- Inadequate budgets to cover the routine tasks that are most appropriate for commercial suppliers.
- Complications caused by the handling and distribution of an external, unclassified information source.

There has been substantial progress in interagency cooperation and government-industry interaction since NSPD-27 was issued.[53] The policy clarified interagency relationships and procedures to

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[51] George W. Bush, National Security Presidential Directive (NSPD) 27, "U.S. Commercial Remote Sensing Policy," April 25, 2003.

[52] The same situation affects DoD use of commercial satellite communications: military satellites are perceived as "free" but commercial bandwidth costs money. Richard DalBello, "Required Summer Reading," *Space News*, June 16, 2008, p. 19.

[53] Industrial College of the Armed Forces, "Spring 2007 Industry Study Final Report: The Space Industry," National Defense University, 2007, p. 9.

facilitate U.S. government purchase and use of commercial imagery. Since the policy went into effect, some licensing restrictions have been adjusted, allowing greater spatial resolution and removing the requirement for a 24-hour hold on the distribution of imagery with resolution no better than 0.5-meter. Also during this time, commercial remote sensing moved more into the social and economic mainstream as Internet mapping sites featuring satellite imagery quickly became commonly used tools.

By directing the U.S. government to use commercial imagery "to the maximum practical extent," NSPD-27 boosted agencies' ability to help cultivate the remote sensing industry. This is best exemplified in the ClearView and NextView programs, which support U.S. companies by contracting for large data purchases and helping to fund a new generation of commercial satellites. DigitalGlobe and GeoEye have been the benefactors of these programs.

Both of these companies had their origins in the early 1990s, immediately after passage of the 1992 Act. DigitalGlobe, based in Longmont, Colorado, was founded in 1992 as WorldView, changed its name to EarthWatch in March 1995, and changed to its current name in September 2001. The company obtained licenses for EarlyBird-1 (January 1993) and QuickBird-1 (September 1994), but would suffer failures of both satellites before finally achieving success with QuickBird-2, launched in October 2001. The National Geospatial-Intelligence Agency (NGA) awarded a ClearView contract for Quickbird imagery (.6-meter resolution) in January 2003, worth between $72-$500 million over five years. That was followed eight months later by a NextView contract worth over $500 million to support development of the WorldView-1 satellite featuring half-meter resolution.[54] WorldView-1 was launched successfully in September 2007, and DigitalGlobe plans to follow up with WorldView-2, funded by company resources, in mid-2009.[55] DigitalGlobe reported earnings of $152 million in 2007.[56]

GeoEye of Dulles, Virginia has roots that go back even farther, accompanied by a complicated gestation resulting in the corporate entity that appeared in January 2006. It started with OrbImage in 1991, which obtained licenses for the OrbView-1 through 4 satellites in 1994. OrbView-4 was lost in a launch failure in September 2001; the other three were orbited successfully in April 1995, August 1997, and June 2003, respectively. The last of this series, OrbView-3, is capable of 1-meter resolution.

In addition to marketing the data from its own satellites, OrbImage began selling imagery from other platforms, including SPOT and Radarsat, and providing imagery processing services. In March 2004, NGA awarded OrbImage a ClearView contract for at least $27.5 million of imagery purchases over

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54 DigitalGlobe press release, "DigitalGlobe Awarded in Excess of $500 Million NextView Contract," September 30, 2003 (http://media.digitalglobe.com/index.php?s=43&item=98).

55 DigitalGlobe press release, "DigitalGlobe Taps Boeing Launch Services to Launch WorldView-2," April 16, 2008 (http://media.digitalglobe.com/index.php?s=43&item=137).

56 Becky Iannotta, "Lockheed Martin Begins to Pull Away," *Space News*, July 28, 2008, p. 13.

two years.[57] This was followed in September 2004 with a NextView contract worth $500 million over four years for next-generation satellite development.[58]

The parallel development of Space Imaging of Thornton, Colorado, its Ikonos satellite, and its acquisition of EOSAT already have been discussed. Space Imaging also sold imagery from the Landsat, Indian Remote Sensing, and Canadian Radarsat satellites, as well as aerial-derived products collected by its Digital Airborne Imaging System (DAIS-1). NGA awarded the company a five-year ClearView contract in January 2003 worth between $120-$500 million.[59] However, its failure to win a NextView contract was a serious blow, putting it at a disadvantage compared to its competitors and setting it up for the acquisition by OrbImage that would follow. Announcement of the acquisition came in September 2005,[60] and the merger that created GeoEye became official in January 2006.[61] GeoEye reported earnings of $184 million in 2007,[62] and launched its new high-resolution satellite GeoEye-1 on September 6, 2008.[63]

The discussion of the commercial remote sensing industry so far has focused only on electro-optical (EO) imagery in the visible and near-infrared parts of the spectrum. There is a noteworthy absence of U.S. companies in the commercial radar and hyperspectral imagery markets. This is not due to a lack of policy or procedural mechanisms to accommodate the licensing needs of potential operators. Rather, it is the result of U.S. companies' inability to craft viable business plans without a commitment from the U.S. government similar to ClearView or NextView. Radar and hyperspectral are at earlier stages of development than EO imagery: many potential users are not familiar with these data types; value-added resellers are not fully prepared to handle the data; new processing techniques and applications for the data need to be developed; and the space segment is costly to build and operate (and in the case of radar, requires higher power levels for its active sensor). In other words, both technical and market risk are high. Meanwhile, the competition that U.S. companies would face consists of radar satellite programs that are state-supported (at least in part, through public-private partnerships) such as Canada's Radarsat, Italy's COSMO/Skymed, and Germany's TerraSAR, and hyperspectral imaging systems aboard aircraft that have a head start of about two decades.

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57 OrbImage press release, "ORBIMAGE Receives Clearview Contract Award From NGA," March 29, 2004 (http://geoeye.mediaroom.com/index.php?s=43&item=84).

58 OrbImage press release, "ORBIMAGE Selected as NGA's Second NextView Provider," September 30, 2004 (http://geoeye.mediaroom.com/index.php?s=43&item=76).

59 Space Imaging press release, "Space Imaging Receives Multi-Million Dollar Pentagon Contract for Commercial Satellite Imagery," January 17, 2003 (http://geoeye.mediaroom.com/index.php?s=43&item=129).

60 OrbImage press release, "ORBIMAGE Announces Agreement to Purchase Assets of Space Imaging," September 16, 2005 (http://geoeye.mediaroom.com/index.php?s=43&item=53).

61 OrbImage press release, "ORBIMAGE Completes Acquisition of Space Imaging; Changes Brand Name to GeoEye," January 12, 2006 (http://geoeye.mediaroom.com/index.php?s=43&item=36).

62 Becky Iannotta, "Lockheed Martin Begins to Pull Away," *Space News*, July 28, 2008, p. 13.

63 Becky Iannotta, "GeoEye Launches Satellite; Restates 3 Years of Earnings," *Space News*, September 15, 2008, p. 4.

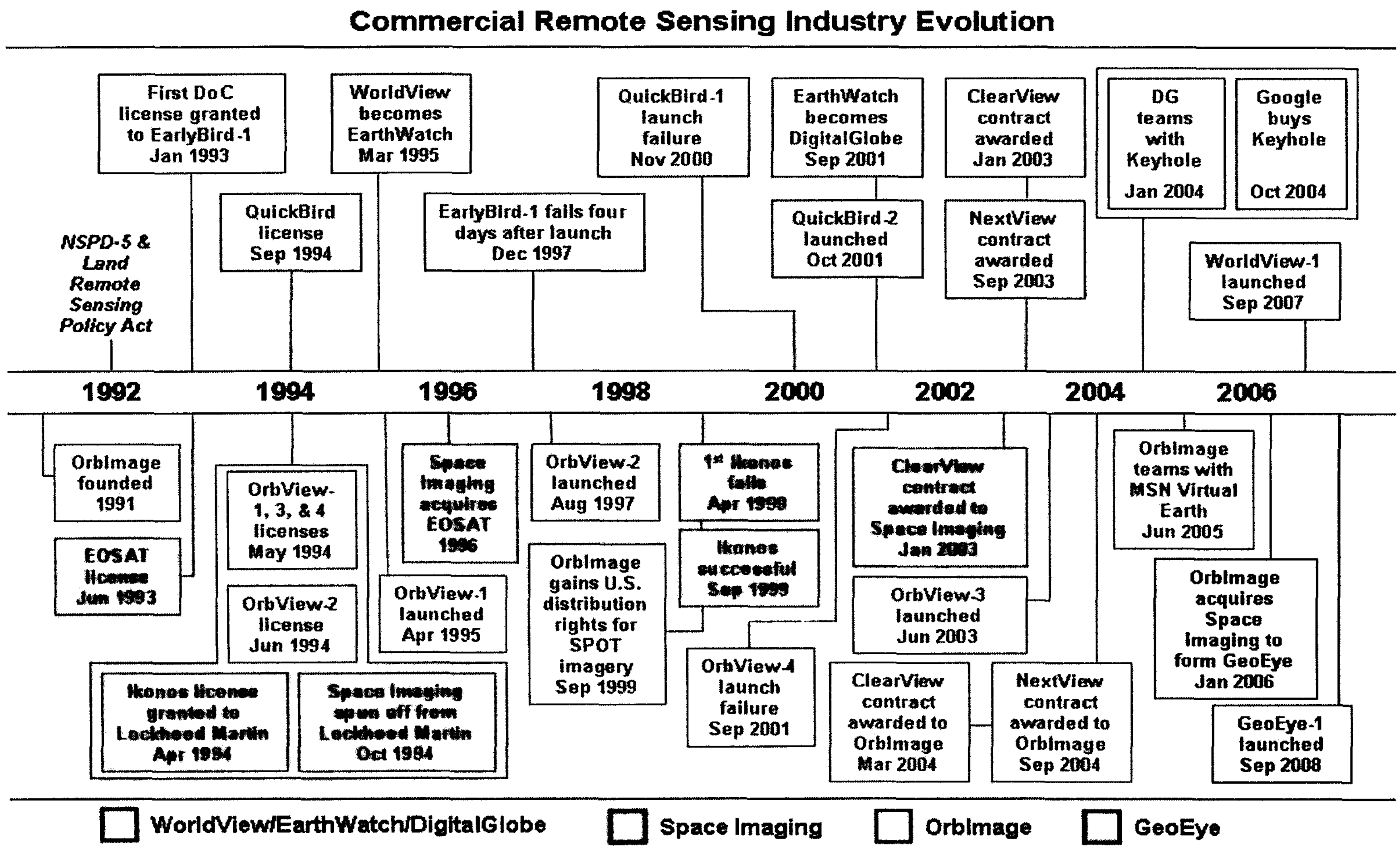

Figure 1. Commercial Remote Sensing Industry Evolution

From 1988 through 1999, NASA's Stennis Space Center ran a program called the Earth Observations Commercial Applications Program (EOCAP) designed to provide technical and financial support for a limited time to help develop marketable applications for satellite imagery. This was done through partnerships between government, industry, academic, and non-profit organizations in which industry generally held the leadership role and success was measured by achievements in the marketplace. The initial focus was on EO imagery, for which a series of competitions was held through the early 1990s. Not all selected projects achieved their goals, and some that did achieve them took longer than expected, but overall the NASA investment in this effort yielded a net gain.[64]

EOCAP branched out into hyperspectral imagery by granting 10 awards in 1998. The intention was to do the same for synthetic aperture radar (SAR) imagery in 1999. However, like the EO projects, the hyperspectral and SAR efforts hinged on data to be provided by government-supported satellite systems. In both cases, this resulted in failure of the projects because some of the satellites never made it to orbit (e.g., OrbView-4 suffered a launch failure, LightSAR was canceled) and the science requirements of the government systems were at odds with commercial requirements (e.g., orbital inclination, resolution, single vs. dual frequency radar). In the earlier EOCAP experiences, the most frequent reason that projects failed the market test was unavailability of data, usually because sensors were not deployed in a timely manner by the government.[65] For the hyperspectral and SAR efforts, this was a fatal flaw for all projects. EOCAP ended before commercially available hyperspectral and SAR data could become a factor in any proposed projects. As of this writing, hyperspectral data still is not provided by any operational space system in the global market. SAR data is available from several sources, but none based in the United States.

2.3 Recent Developments in Civil Remote Sensing

In addition to the economic benefits and regional public good aspects of remote sensing, interdisciplinary studies of the Earth system have received more attention in recent years, both in the scientific community and in public policy circles. Researchers have known for a long time that global climate change occurs routinely, having documented cyclic appearances of large-scale events such as ice ages and mass extinctions. Some of the questions that challenge our knowledge and theories include: Are we now experiencing a global climate fluctuation, and if so, where is it going? What combination of factors is affecting regional changes that are evident to us, and how can these be extrapolated to a global scale? How quickly are the regional and global environments changing? How much of the change is due to human activities? And possibly most important of all, given the potential danger to our species, what can we do about it?

For a study of this scope, scientific disciplines that have been isolated from each other throughout most of their existence must be united to facilitate understanding of complex interactions on a variety of scales – an approach known as Earth System Science. Geology, oceanography, atmospheric sciences, chemistry, and biology, along with their sub-disciplines, must interact in unprecedented ways and across national boundaries. All must have access to large databases established to support integrated study. A substantial portion of the content of those databases will come from orbiting observation platforms. Due to the extraordinary data handling and dissemination requirements, the

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64 Molly K. Macauley, "NASA's Earth Observations Commercialization Applications Program," *Space Policy*, February 1995.

65 Ibid.

ground segment for NASA's Earth Observing System (EOS) got more than the usual share of attention. Most of NASA's spaceflight projects devote about three-fourths of their resources to the space segment, with the rest going toward ground support. EOS was unusual in that an estimated 60% of the program's budget went to ground support. This is mostly due to the demands of the EOS Data and Information System (EOSDIS), which stretched the limits of capabilities in data storage, retrieval, and dissemination. The expected onslaught of incoming data was so huge that new measures were created to describe it. Some data-processing documents refer to terabits of data (trillions of bits), while other sources have used a measure called LOC – the equivalent of all the information contained in the Library of Congress. The program's managers projected that when fully operational, the input to EOSDIS would be on the order of one LOC every few days.

In cooperation with other countries, the U.S. Global Change Research Program has been pursuing this gargantuan task, led by a NASA program originally called Mission to Planet Earth and more recently labeled the Earth Science Enterprise in the agency's Science Mission Directorate. The Goddard Space Flight Center in Greenbelt, Maryland, is the primary field center for this activity, which involves several satellite programs including Landsat, NOAA's polar orbiters, and the EOS program,[66] which emerged in the late 1980s and became a "new start" in FY 1991.

As originally envisioned, EOS would have been a 15-year project using two very large polar-orbiting platforms with about a dozen instruments on each, having a total program cost of around $30 billion. The rationale behind this approach was to permit an assortment of data to be collected over the same target from the same physical perspective at the same time. This would simplify calibration of data sets from different instruments and avoid data integration errors that tend to creep in when using different platforms (variations in altitude, sun angle, cloud cover, season, etc.). The problems with this approach, at least from the policy-makers' perspective, were that it would take too long, cost too much, and involve too much risk.

EOS plans endured a series of major adjustments throughout the 1990s, all linked to budget cuts. This was partially a result of the fact that funding for the space station program was ramping up at the same time, affecting program budgets throughout NASA. Almost immediately, EOS faced a reduction of $6 billion from the amount originally envisioned over the next decade, requiring a major restructuring of the program. In 1992, budget projections declined by another $3 billion, prompting more re-scoping, including a shift to the use of a common spacecraft bus for some missions. The budget cuts and restructuring continued in 1994, 1995, and at a "biennial review" in 1997 that addressed the program's implementation strategy. The large EOS-A and EOS-B platforms were transformed into six smaller platforms with more focused missions. These would eventually evolve into Terra, Aqua, Aura, and other spacecraft collectively referred to as Earth Probes.[67] These changes served to reduce program risk in the event of a launch failure as well as lower the cost of each launch because the smaller platforms could fit on less costly boosters rather than the expensive Titan 4 as originally planned.

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66 NASA's Earth Observing System (http://eospso.gsfc.nasa.gov/eos_homepage/description.php, accessed June 2008).

67 Alan B. Ward, "The Earth Observer: 20 Years Chronicling the History of the EOS Program," *The Earth Observer*, NASA Goddard Space Flight Center, March-April 2008, pp. 4-8.

The first phase of the Earth Science Enterprise, starting in the early 1990s, was comprised of a variety of free-flying satellites, space shuttle observations, and airborne and ground-based studies. The second phase began with the launch of Terra, the first EOS satellite, in December 1999 and continued with the launch and operations of the other EOS spacecraft during the next decade. Additional space systems providing multispectral and radar imaging of landmasses complement the program because EOS (other than Terra) heavily favors instrumentation to study the oceans and atmosphere and has lower spatial resolution than many existing imaging systems. Setting public policy with regard to global environmental concerns is highly contentious both domestically and internationally, and must be done with the most complete and accurate information available. EOS and related spacecraft are making substantial and timely contributions to the policy debate over climate change and natural vs. human-induced effects on the Earth's ecosystem.

While EOS and related programs have been a boon to Earth System Science and have led to more informed public debates on environmental and climate issues, their sustainability has been questioned. The Space Studies Board and the Engineering and Physical Sciences division of the National Research Council, in their 2007 report commonly referred to as the Earth Science Decadal Survey, stated that:

> Between 2006 and the end of the decade, the number of operating missions will decrease dramatically, and the number of operating sensors and instruments on NASA spacecraft, most of which are well past their nominal lifetimes, will decrease by some 40 percent.[68]

According to NASA's website there are 19 Earth science missions currently active, including the aging and partially disabled Landsat 7 for the USGS and three weather satellite systems for NOAA.[69] Twelve of the 15 NASA satellites will be out of service or beyond their design lifetime by the beginning of 2009, and two more will expire during the presidential term beginning in that year. (The remaining mission consists of the long-lived LAGEOS 1 & 2 satellites, which are simply laser reflectors.) Six new missions are in development and scheduled for launch from 2008-2012, including two weather satellite projects for NOAA. The four NASA research missions will reach the end of their design lifetime by 2012-2013.

Under current planning, NASA will replace its Earth science missions at a slower rate than they are expiring, meaning that the robustness enjoyed by the Earth science enterprise since the mid-1990s will not last beyond the early part of the next decade – a time when concerns about global climate change and environmental degradation are likely to increase. The Obama administration will be faced with an urgent need to set the course for future Earth science, and can be expected to pursue a subset of the missions recommended by the Decadal Survey, constrained by the funding available.

Meanwhile, a number of European and Asian nations, as well as Canada and Brazil, are increasing their activities in scientific and operational Earth sensing missions. Within a few years, these efforts will surpass U.S. Earth science work as new U.S. systems are deployed at less than the attrition rate. A prime example of growing international activity is the Global Monitoring for Environment and Security (GMES) program, led by the European Commission and the European Space Agency (ESA).

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68 National Research Council, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (Washington: National Academies Press, January 2007), p. ES-3.

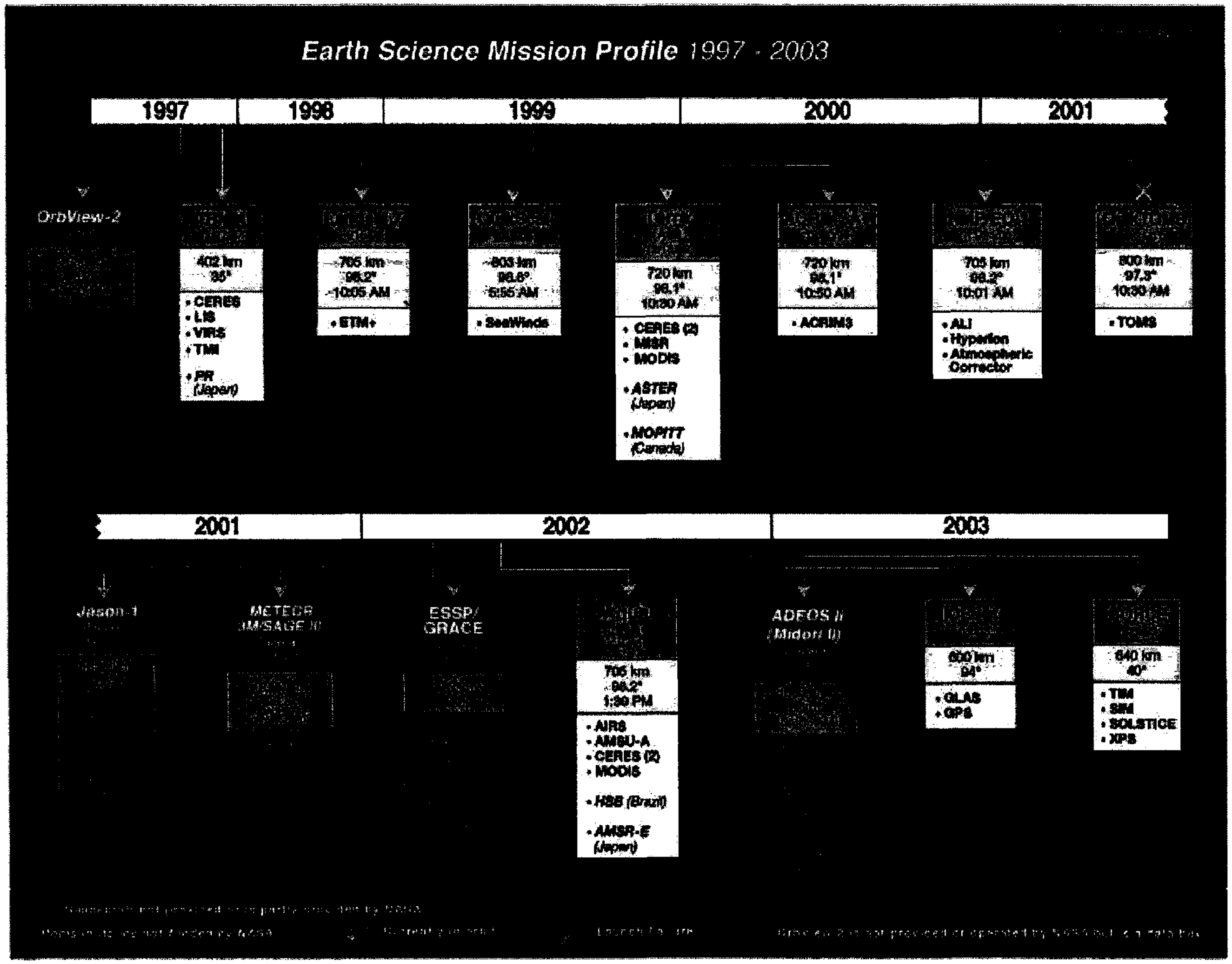
69 http://nasascience.nasa.gov/earth-science/mission_list, accessed June 2008.

Over a 10-year period starting in 2008, the GMES program plans to launch 15 EO and radar satellites to study the land, oceans, and atmosphere for both scientific investigations and ongoing operations.[70,71] Collectively, Europe is seeking to be the uncontested world leader in Earth observations from space.

The strong push by many foreign interests in civil remote sensing seems to contrast with the challenges faced in U.S. civil remote sensing efforts. Proposed programs to advance the state of the art, or to simply maintain data continuity for existing programs, often must endure a lengthy process to overcome organizational, programmatic, and budgetary hurdles. Recent developments in the Landsat program provide a telling example.

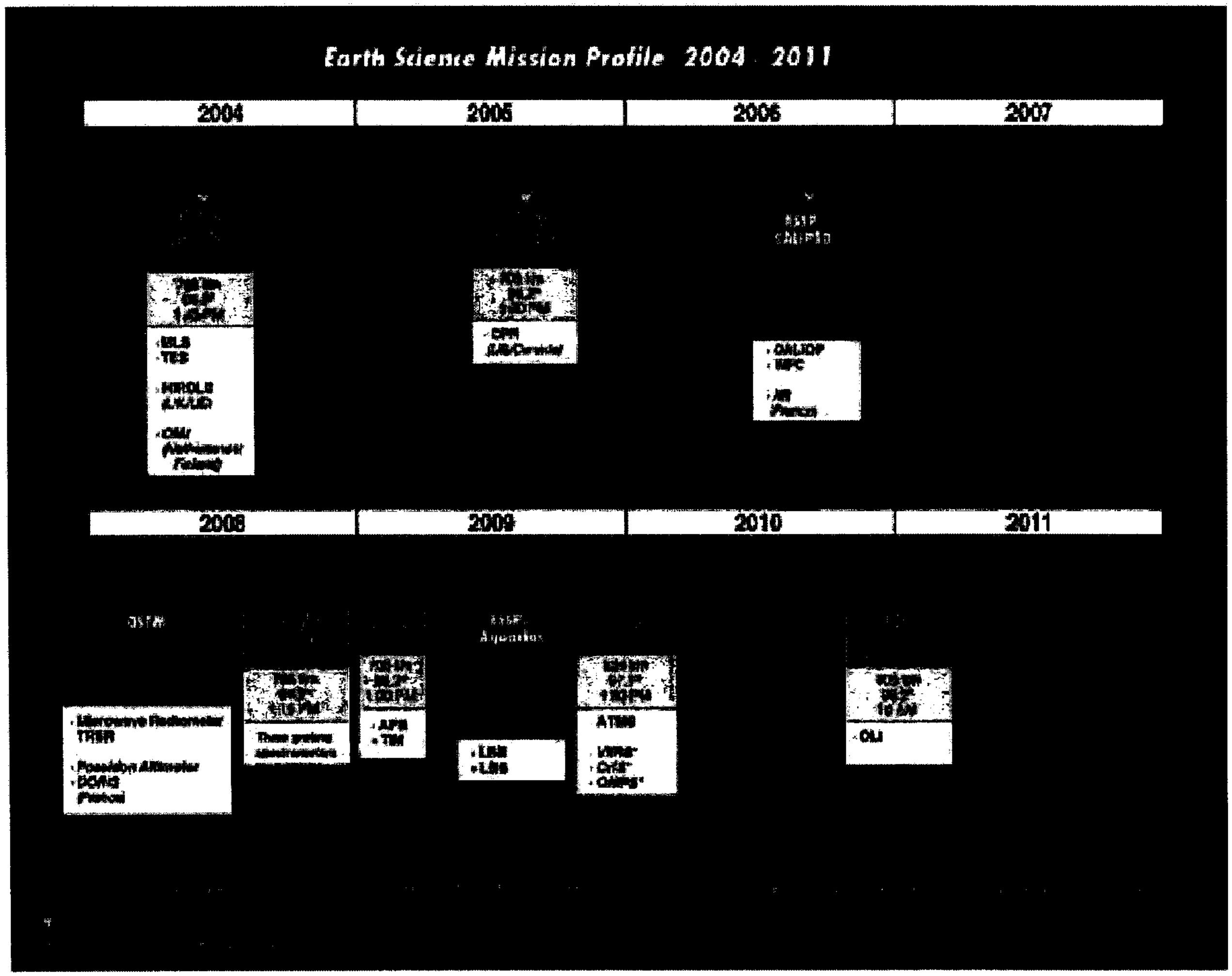
70 Peter B. deSelding, "Europe Makes Earth Observation a Priority," *Space News*, April 7, 2008, p. 20.

71 Michael A. Taverna, "Stepping In: European Earth-observation proposals could shift oceanography responsibility to ESA and the EC," *Aviation Week & Space Technology*, April 21, 2008, p. 51.



Source: NASA (http://eospso.gsfc.nasa.gov/eos_homepage/mission_profiles/docs/mission.gif)

Figure 2. Earth Science Mission Profile 1997 – 2003.



Source: NASA (http://eospso.gsfc.nasa.gov/eos_homepage/mission_profiles/docs/mission2.gif)

Figure 3. Earth Science Mission Profile 2004-2011.

After the April 1999 launch of Landsat 7, the questions of what would come next in the series, who would operate it, and how it would be paid for needed to be answered. These questions were thought to be settled more than five years later (August 2004) by a White House memorandum directing that a Landsat-type sensor be placed on board the National Polar-orbiting Operational Environmental Satellite System (NPOESS).[72] Technical, schedule, and budgetary problems prompted the removal of the Landsat sensor from the NPOESS spacecraft. Sixteen months passed before Dr. John Marburger, Director of the Office of Science and Technology Policy (OSTP), signed a new memorandum in December 2005 that directed NASA to acquire a single free-flyer spacecraft for the Landsat Data Continuity Mission (LDCM).[73] NASA selected Ball Aerospace to be the builder of the LDCM instrument, the Operational Land Imager (OLI), on July 16, 2007.[74] General Dynamics Advanced Information Systems was chosen on April 22, 2008 to build the spacecraft.[75]

The December 2005 memo also created the Future of Land Imaging Interagency Working Group, which included representatives from fifteen federal agencies convened under the National Science and Technology Council. The Working Group was charged with developing a sustainable plan to continue the collection of moderate resolution multispectral remote sensing data, a task it completed 20 months later. The Working Group's report offered three recommendations:

- The U.S. must commit to continue the collection of moderate-resolution land imagery.
- The United States should establish and maintain a core operational capability to collect moderate-resolution land imagery through the procurement and launch of a series of U.S.-owned satellites.
- The United States should establish the National Land Imaging Program (NLIP), hosted and managed by the Department of the Interior, to meet U.S. civil land imaging needs.[76]

According to the report, the NLIP should lead, coordinate, and plan for future U.S. civil operational moderate-resolution land imaging, and promote wide public and private use of land imagery in the United States. The NLIP should acquire global, moderate-resolution land imagery data; manage all U.S. civil moderate-resolution land imaging technologies, satellites, and systems; ensure archival preservation of U.S.-acquired moderate-resolution land imagery; and perform research, development, and training. The program should accommodate private, nonprofit, academic, commercial, and international users, state and local government, and the satellite and land imaging data industries. Implementation of the plan will be a challenging new task for the Interior Department, and it remains to be seen if future administrations and Congresses will provide sufficient resources. As of this writing, the plan already has hit a funding snag: the House Appropriations subcommittee responsible for the Interior Department's budget has denied a $2 million request to fund the NLIP in FY09 because of a reluctance to initiate new space operations responsibilities at Interior.[77]

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72 John H. Marburger III, "Landsat Data Continuity Strategy," Office of Science & Technology Policy, August 13, 2004.

73 John H. Marburger III, "Landsat Data Continuity Strategy Adjustment," Office of Science & Technology Policy, December 23, 2005.

74 NASA contract release C07-031, "NASA Awards Contract for Land Imaging Instrument," July 16, 2007 (http://ldcm.nasa.gov/07-16-2007.html, accessed July 2008).

75 NASA contract release C08-021, "NASA Awards Contract for Landsat Data Continuity Mission Spacecraft," April 22, 2008 (http://www.nasa.gov/home/hqnews/2008/apr/HQ_C08021_Landsat_Data.html, accessed July 2008).

76 National Science & Technology Council, Future of Land Imaging Interagency Working Group, *A Plan for a U.S. National Land Imaging Program*, Office of Science & Technology Policy, August 2007.

77 Brian Berger, "House Panel Wary of Plan for Future Land Imaging," *Space News*, July 28, 2008, p. 17.

Thirty-five years elapsed between the first Landsat launch and the official recognition that the collection of moderate-resolution satellite imagery is an operational function that fulfills national needs and is worthy of being sustained. Unlike weather monitoring from space, it has been treated as an experimental function supporting scientific research with no guarantee of continuous data flow. Under these circumstances, it took more than eight years after the launch of Landsat 7 to come to a decision on what to do next – and the decision would not result in a spacecraft being launched for at least another four years. This and other examples have taught observers that civil remote sensing programs, and the policy guiding both civil and commercial remote sensing, develop at a far slower pace than the relevant technologies and user communities.

Acronyms

CCCT	Cabinet Council on Commerce and Trade
CNES	Centre National d'Etudes Spatiales (French space agency)
DAIS	Digital Airborne Imaging System
DoC	Department of Commerce
DoD	Department of Defense
EO	Electro-optical
EOCAP	Earth Observations Commercial Applications Program
EOS	Earth Observing System
EOSAT	Earth Observing Satellite Company
EOSDIS	Earth Observing System Data and Information System
EROS	Earth Resources Observations Systems
ESA	European Space Agency
FY	Fiscal year
GMES	Global Monitoring for Environment and Security
LAGEOS	Laser Geodynamics Satellite
LDCM	Landsat Data Continuity Mission
LOC	Library of Congress
MSS	Multi-Spectral Scanner
NASA	National Aeronautics and Space Administration
NGA	National Geospatial-Intelligence Agency
NLIP	National Land Imaging Program
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NSPD	National Security Presidential Directive
OLI	Operational Land Imager
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
PDD	Presidential Decision Directive
R&D	Research and development
SAR	Synthetic aperture radar
TIROS	Television and Infrared Observation Satellite
TM	Thematic Mapper
U.N.	United Nations
U.S.	United States
USGS	United States Geological Survey